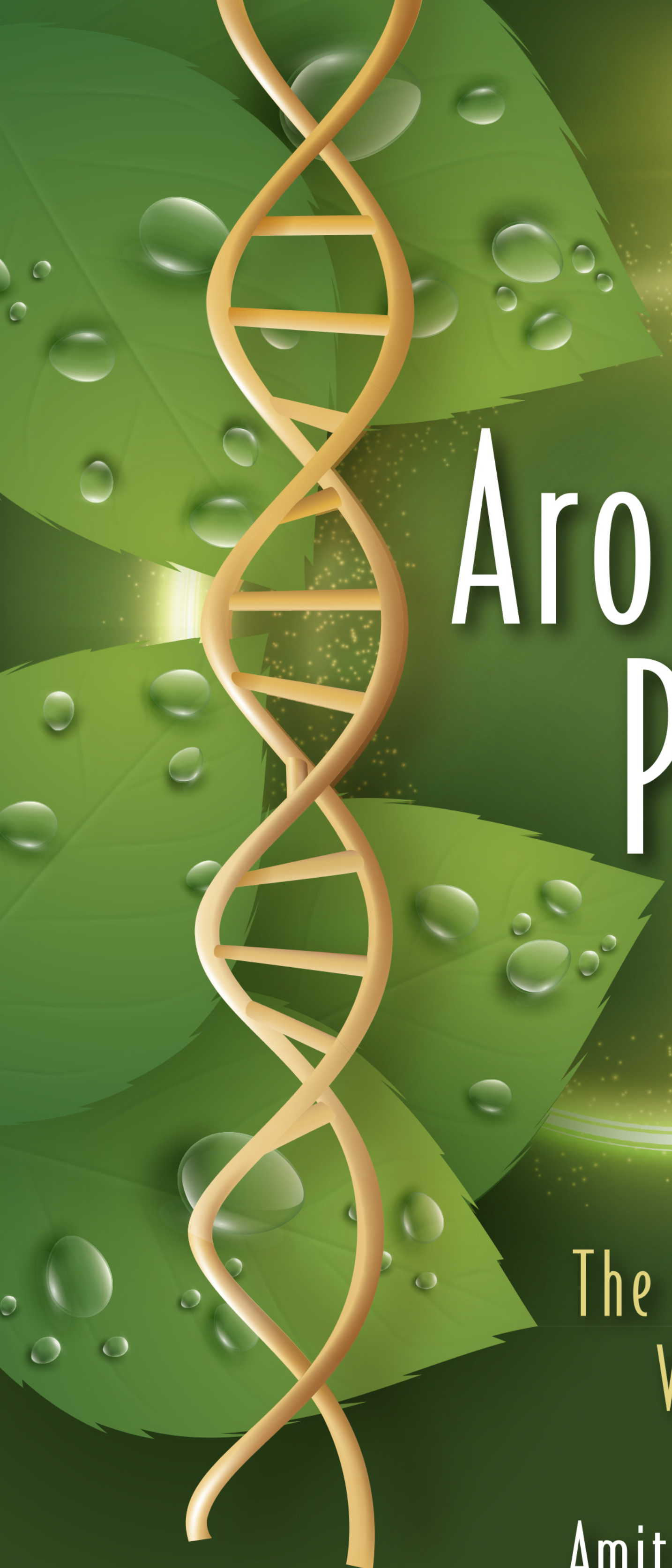

Aromatic Plants

The Technology, Human Welfare and Beyond

Amit Baran Sharangi, PhD
Editor

Plant Science Research and Practices

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AROMATIC PLANTS

THE TECHNOLOGY, HUMAN WELFARE AND BEYOND

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AMIT BARAN SHARANGI
EDITOR

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FOREWORD

K. V. Peter, PhD, FNAAS, FNASc FNABS.FISVeg, FISGen., FHSI, H.FCHAI FISNS

Former Vice-Chancellor, Kerala Agricultural University and Director ICAR IISR Calicut, India

"Earth provides enough to satisfy every man's need, but not every man's greed"
– Gandhiji.

"Mother Earth's medicine chest is full of healing herbs of incomparable worth"
– Robin RoseBannet.

"Nature gives to every time and season some beauty of its own"
– Charles Dickens.

"A pro-poor, pro-nature and pro-women orientation to technology development and dissemination is essential for achieving the goals of food and health for all"
– M. S. Swaminathan.

The present book, *Aromatic Plants: The Technology, Human Welfare and Beyond* derives inspiration from the above quotes and inspiring thoughts by Rabindranath Tagore. Fragrances and perfumes are used by man since time immemorial to incense body and mind. Moghul Emperors provided patronage to the art of extraction of fragrant and perfumery principles from plants. Scents and attars from sandal wood, agarwood and roses carried India's name and fame far and beyond. Perfumery herbs, oils and aroma chemicals are extensively used in flavorings, cosmetics and drug industries. Aromatherapy attracts tourists from worldover to India. India is probably the only country which grows all the major essential oil yielding plants. Of about 18,000 plant species in India, about 1500 are aromatic producing essential oil in one or another plant origin, may be roots, leaves, flowers and sometimes bark or wood. India's bio-diversity is unmatched with the presence of 16 different agro-climatic zones, 10 vegetation zones, 25 biotic provinces and 426 biomes. Deforestation and indiscriminate collection are dwindling natural resources. Unless large scale scientific cultivation is taken up to augment supply of raw materials, the flavor, fragrance, cosmetic and pharmaceutical industries will be in doldrums in near future. Cheaper synthetics may overtake naturals in nature can no way be matched. More than a hundred aromatic oils are in global trade. Their uses in health and beauty care can be traced back to 1500 years before Christ. Late Prof. Dr. Baby P. Skaria, Aromatic and Medicinal Plants Research Station, Odakkali, authored the book *Aromatic Plants* and the present book by Prof. Dr. A. B. Sharangi is an updated treasure house of knowledge, well-conceived and well thought out covering the whole gamut from cultivation to utilization of aromatic plants. The book is an excellent practical and theoretical manual and reference treatise for students, researchers, entrepreneurs, extension personnels and farmers. Being a celebrated and decorated Professor, Dr. Sharangi's book will be much read and made use of by all concerned.

K. V. Peter

PREFACE

The history of aroma and fragrance dates back through several ages and civilizations. The sagacity of smell plays a remarkable role for human being to recognize right food. Best fruits can be judged when they are ripe and fit for consumption emitting lovely smell or aroma. The same attribute from flowers attract insects leading to cross-pollination. India has enjoyed a paramount place in the fabrication of quality perfumes and aromatics since prehistoric era. The celebrated Chinese voyager Fa-Hien described India as the land of aromatic plants. Visitors, at Nawabi banquets, were welcomed essentially with attar. Indian cities like Delhi, Agra, Kannauj, Lucknow, Jaunpur, Ghazipur, Aligarh, Bharatpur, Mysore, and Hyderabad, emerged as centers of the national and international trade in perfumery and other aromatic compounds, and were known for their quality across Asia, Europe and Africa. Aromatic plants precisely possess odorous volatile substances in root, wood, bark, stem, foliage, flower and fruit. The typical aroma is due to an assortment of composite chemical compounds. At present, information on the chemistry and properties of essential oils of only about 500 aromatic plants species is known in some detail out of a total of about 1500. Of these, about 50 species find use as commercial source of essential oils and aroma chemicals. It is realized now that perfumes are not the essentials of sumptuousness as they were in the past. It has given birth to new streams of medicinal therapy, aromatherapy, involving the use of essential oils and aromatics derived from plants to treat diseases. Essential oils are also reported to be better than antibiotics due to their safety and broad spectrum activity. Natural essential oils are also potentially safe insecticides. The essential oil obtained from *Acorus calamus* having ß-asarone as an active principle, produces sterility among a variety of insects of either sex. It has, therefore, been found very useful and secure for the storage of food grains. However, there is still very inadequate research for the cultivation of aromatic crops and extraction of essential oils across the globe.

This book has been designed to highlight the associated issues of aromatic plants including the aspects of their classification, importance, uses and applications for human wellbeing, botany, agrotechniques, major bioactive constituents, post harvest extraction, chemistry and biochemistry of aroma compounds alongwith an informative modern global research on these plants throughout the world. Hope this book will cater the scholastic services and rewards to diverse professionals and stakeholders and serve as an informative handbook for theoretical as well as practical purposes.

Amit Baran Sharangi
Editor

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Chapter 1

AROMATIC PLANTS AND AROMA: HISTORICAL PERSPECTIVES

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ABSTRACT

Essentials oils were prized more than gold in ancient era. The mention of Myrrh, frankincense, balsam oil, lavender oil made in ancient literature evident the importance of essential oils. Construction of the temple using essential oil to prevent plague is also mentioned in Bible. Essential oils were used in customary, religious and spiritual rites and rituals, adornment and aromatherapy, appeasing local deities etc. Historical perspective of essential oils dating back to ancient Egyptian, Arabic, Greek, Roman, Persian, Hebrew, Chinese, French, Indian, and Tibetan are mentioned in this chapter.

Keywords: aromatherapy, aroma, essential oil, Egypt, Roman

Plants have long been the source of medicines and drugs for a multitude of diseases. Ancient civilizations used plant extracts in therapies to enhance one's senses. The

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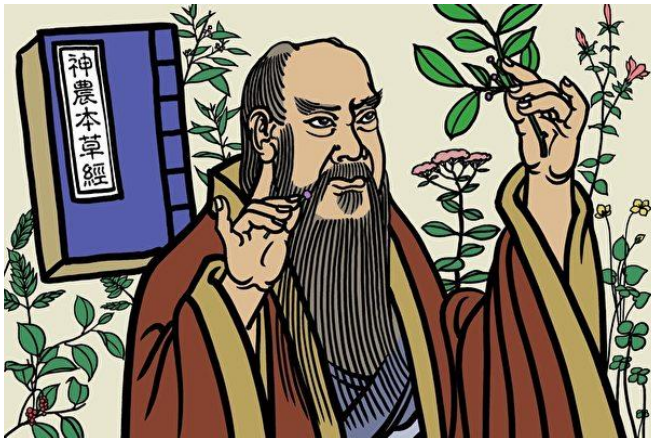
extracts were believed to greatly elevate one's physical and mental health and were frequently used in traditional medicine to treat ailments. Utilization of such extracts as cosmetics, perfumes and incense is also well-documented. Plants are known to naturally produce and store secretions containing volatile compounds in specialized tissues that are localized within different plant parts. When these parts (which may be the fruit, seed, flower, root, leaves, bark, peel or the entire plant) are subjected to distillation, the excessive steam penetrates through the layers of the raw materials and the volatile compounds present in the tissues gets vaporized. The vapors are allowed to pass through a cooling coil and condense back into liquid form in a collecting vessel. Such biological extracts containing volatile compounds from various plant parts are collectively called essential oils. According to the European Pharmacopoeia (7th edition), essential oils are defined as: "Odorant product, generally of a complex composition, obtained from a botanically defined plant raw material, either by driving by steam of water, either by dry distillation or by a suitable mechanical method without heating. An essential oil is usually separated from the aqueous phase by a physical method that does not lead to significant change in its chemical composition." Essential oils are characterized by their unique smell and the different therapeutic effects they produce on human body. The distinctive smell is attributed to the volatile compounds present in the extract. Swiss philosopher and physician Paracelsus von Hohenheimis credited for coining the term 'essential oil'. The word itself is derived from a Latin expression *"Quinta essential"* which literally translates into "the fifth essence." The use of the word "essential" here does not imply that the oil in itself is very crucial for sustenance of plant. Essential in this context implies that the oil contains the essence (or the very soul) of the plant (Wikipedia 2020). The ancients believed soul or spirit of life as the fifth element along with air, fire, water and earth (Duarte et al., 2018). And the soul (or in present context-essential oils) of the plants could be separated by distillation and evaporation. But far from being soul, essential oils are volatile oils with complex compositions.

There is ample archaeological substantiation indicating the significance of plant extracts, understood by mankind as far back as the Neolithic age that came to an end 4000 years ago. By far, the most persuasive and decisive evidence in favour of this statement is the discovery of medicinal herbs in mass graves that may have been as old as 8000 years (Anonymous, 2017). These ancient buried remains offer subtle clues that aromatic plants were possibly used as condiments in cooking as well as in healing. Civilizations around the world have documented the use of essential oils in therapies. The practice of using essential oils as remedies for diseases and infection can be traced back as far as Ancient Egypt. Ancient Egyptians cultivated those plants extensively whose parts could be used in production of essential oils. These oil extracts were commonly used in adornment and aromatherapy (Anonymous, 2020a). Moreover, these oils also found customary use in religious and spiritual rites and rituals, in the preservation of dead bodies and as offerings to appease the local deities. For Egyptians, the sense of smell was regarded as the most important among all the other senses, even more so than sight and they strongly believed that spiritual or psychological transformation could be evoked within an individual through inhalation of different fragrances (Anonymous, 2020b). The excavation of King Tutankhamen's tomb in the year 1922 revealed the presence of over 50 alabaster mason jars that were meant for storage of aromatic oil. However, the contents of the jars were later revealed to be empty as the tomb was likely invaded and the oil present in the containers seized by thieves who greatly prized the oil more so than the gold. Egyptian scrolls (dated 1500 BC) which documents hundreds of ancient treatment procedures that involved using aroma oils have also been unearthed (Anonymous 2020b). There is no known record of distillation ever being used for the production of essential oils in ancient Egyptian culture. Rather, the essential oils during that period were produced by using a primitive extraction technique that involved crushing the plant tissues in warm fat. The therapeutic ideas from the Egyptian culture were later borrowed and improved upon by the Greeks. Outstanding historical Greek physicians like Hippocrates (460-377 BC) have been known to stress the significance of using essential oil in therapies and baths for maintaining good health. The use of aromatic plants has also been mentioned in Dioscorides' (100 AD) revered book *Materia Medica* (Anonymous, 2017). The concept of healing baths was originally perceived, introduced and popularized by the Greeks. The use of aroma oils in Ancient Rome to promote health and hygiene is a well-established reality. Much of the Arabic world had also adopted the knowledge of the aromatic herbs from the Greeks and the Romans. The works of Dioscorides, Hippocrates and other historical physicians were translated by scholars into many languages including Persian and Arabic and thus information about essential oil also expanded to the Arabic world (Anonymous, 2017). Around 500 BC, the frankincense trade gained huge traction in Arabia and became so eminent among Arabian traders that the trade route came to be popularly known as "the Frankincense trail." The trade market during this time period flourished greatly owing to the huge demand and supply of aromatic herbs and spices. The traders would transport these items with enormous effort in caravans pulled by camels and protected by heavy security because they were often under the risk of being raided by thieves and bandits. Today, the aromatic herbs make up an integral part of the Arabian culture and are used in the same way as it was centuries before, especially in cuisine and medicine. Many forms of aromatherapy have originated in ancient Arabia and the techniques to this day are preserved among Arabian families, passed down from generation to generation (Anonymous, 2020b). Around the same time when Ancient Egyptians started using aroma oils, other civilizations such as India and China had also begun to realize the importance of aromatic oil and sought to implement it in the field of medicine. The use of aromatic herbs in traditional Chinese medicine can be traced back as far as 3000 BC. One of the oldest Chinese literatures that has been preserved unscathed to this day is an herbal book written by Shennong (2700 BC) who is widely regarded as the father of agriculture in China. The herbal book contains sets of different monographs of around 350 medicinal herbs along with its benefits. Some of the monographs also document the use of essential oils and its medicinal benefit (Anonymous, 2020b). In a similar fashion, aromatic herbs were also an integral part of the Ayurvedic system of medicine, said to be originated almost 5000 years ago in the Indian sub-continent (Anonymous, 2020a). Ancient scriptures like the Bible mention the word “anointing" over 150 times. The word anoint here is derived from a Latin word *inunctus* which when roughly translated means to “cover with” or “rub in.” In this context, anoint implies making oneself sacred, committing oneself to cater to a higher purpose or being and choosing the correct path to attain spiritual liberation. Interestingly enough, the words Messiah and Christ when converted to their Hebrew and Greek form respectively, literally translates into “the anointed.” The scriptures also have records of a plague being prevented by constructing a temple with aromatic oils. It also tells the story of how the infant Christ received gifts from the three wise men in the form of gold, myrrh and frankincense. Many historians argue that the gold in the story is not actual gold but rather a cleverly disguised reference to liquid gold in the form of balsam oil, which was a much sought out item in Middle Eastern culture. In the story of Mary anointing Jesus’ feet, the oil she used for this purpose is believed to be equal to a year’s worth of wage (Anonymous, 2020b). The term aromatherapy was popularized in the 20th century by a French perfumer and chemist, Rene Maurice Gattefosse, who is also the person responsible for coining the term. In 1910, while working on the potential use of essential oils in cosmetics, a minor explosion in his laboratory caused a ruthless burn on his hands and arms. He began to apply undiluted lavender oil on his burns as this was the only liquid accessible to him during that time. Surprisingly enough, the lavender oil worked wonders on his skin, and he began to discover that the burn began to heal rapidly without any infection or leaving any signs of scar (Anonymous, 2020b). In the course of his experiments on essential oil, he found that the aromatic compounds he was testing were being absorbed by the body and these compounds could interact with the biomolecules, producing some sort of therapeutic effect in the process (Anonymous, 2020c). In the book “*Aromatherapie*” that he published based on his research findings, a plethora of medicinal uses of aromatic herbs as well as the usage of the term “aromatherapy” is well documented (Anonymous, 2017). Jean Valet, a French doctor and a researcher, was successful in treating the infected wounds of soldiers as well as wounded civilians during the Second World War. Widely regarded as the father of modern-day aromatherapy, he went on to author *“Practice of aromatherapy,”* a book that details the current as well as the potential use of aromatic oils in treating infections and psychological disorders (Anonymous, 2017). After their experiments, aromatic oil was the focus of research for many physicians. Marguerite Mary, an English nurse and surgical assistant during the 1950s, began extracting essential oils using vegetable oil as an extraction solvent and started using the extracted oil to massage patients using a technique called Tibetan massage; the oil was directly smeared onto the bare skin of the patient and pressure was applied on the body parts wherever nerve endings were present presumably so that the essential oil could be absorbed by the skin. She was the first individual to prescribe essential oil or a combination of essential oils as a form of therapy, the suggestions depending on the person's needs. Aromatherapy has become largely mainstream today thanks to the many research findings on health benefits of essential oils, and its market is expected to grow even more as growing concerns over the use of chemicals and inorganic drugs will push people to try out more healthy, organic alternatives.

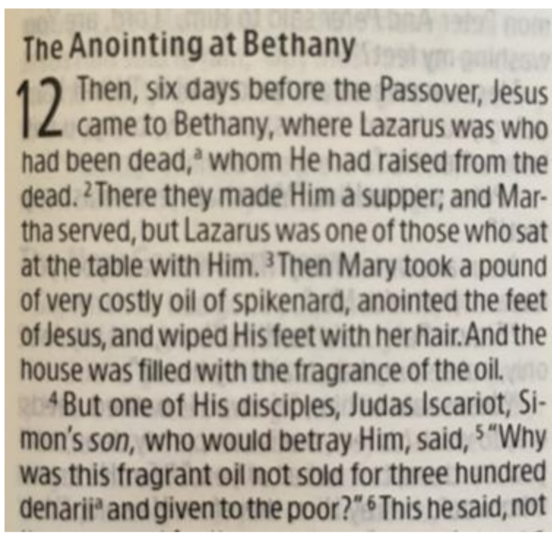
Figure 1. Alabaster mason jars found in King Tutankhamen's tomb.

Figure 2. Use of essential oil in Roman bath houses to promote health and hygiene.



Source: www.teasenz.com.

Figure 3. Shennong was the first Chinese herbal doctor. It is said that he tasted all kinds of herbals, even poison, to make herbal medicines. Shennong's herbal classic was the first book on Chinese herbal medicine.



The Anointing at Bethany

12 Then, six days before the Passover, Jesus came to Bethany, where Lazarus was who had been dead,[a] whom He had raised from the dead. [2] There they made Him a supper; and Martha served, but Lazarus was one of those who sat at the table with Him. [3] Then Mary took a pound of very costly oil of spikenard, anointed the feet of Jesus, and wiped His feet with her hair. And the house was filled with the fragrance of the oil.

[4] But one of His disciples, Judas Iscariot, Simon's *son*, who would betray Him, said, [5] "Why was this fragrant oil not sold for three hundred denarii[a] and given to the poor?" [6] This he said, not

Figure 4. Citing of essential oil in ancient scripture; Bible.

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Chapter 2

CLASSIFICATION OF AROMATIC PLANTS

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ABSTRACT

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 dozen. The important aromatic plants of the world are listed below, classified according to the botanical family, genus and species.

BOTANICAL CLASSIFICATION OF AROMATIC PLANTS

Division: Embryophyta

Subdivision: I. Gymnospermae

Class: **Coniferae**

Cupressaceae:

- *Callitropsis araucarioides*

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- *Thujopsis dolabrata*
- *Thuja plicata*
- *Cupressus fastigiata, C. glauca, C. japonica, C. lambertiana, C. lawsoniana C. lusitanica, C. macrocarpa, C. pendula, C. sempervirens, C. sinensis, C. torulosa*
- *Chamaecyparis lawsoniana, C. obtusa, C. taiwanensis, C. thyoides*
- *Juniperus communis, J. mexicana, J. oxycedrus, J. phoenicea, J. procera, J. sabina, J. thurifera, J. virginiana*

Pinaceae:

- *Picea abies, P. alba, P. canadensis, P. excelsa, P. glauca, P. jezoensis, P. mariana, P. nigra, P. obovata, P. vulgaris*
- *Tsuga canadensis, T. douglasii, T. heterophylla*
- *Pseudotsuga douglasii, P. glauca, P. mucronata, P. taxifolia*
- *Abies alba, A. balsamea, A. balsamifera, A. douglasii, A. excelsa, A. mayriana, A. mucronata, A. pectinata, A. picea, A. sachalinensis, A. sibirica*
- *Cedrus atlantica, C. deodara, C. libani, C. libanotica)*
- *Pinus albicaulis, P. aristata, P. attenuata, P. ayacahuite, P. balfouriana, P. balsamea, P. banksiana, P. caribaea, P. cembra, P. clausa, P. contorta, P. coulteri, P. echinata, P. edulis, P. flexilis, P. glabra, P. jeffreyi, P. lambertiana, P. longifolia, P. monophylla, P. montana, P. monticola, P. mugo.*

Podocarpaceae: *Dacrydium franklini*

Taxodiaceae:

- *Sciadopitys verticillata*
- *Cryptomeria ja*ponica

Subdivision: II. Angiospermae

Class 1. **Monocotyledonae**

Amaryllidaceae:

- *Narcissus jonquilla, N. poeticus, N. tagetta*
- *Polyanthes tuberosa*

Araceae:

- *Acorus calamus*

Cyperaceae:

- *Cyperus rotundus*

Graminae(Poaceae):

- *Elyonurus latiflorus, E. tripsacoides*
- *Vetiveria zizanioides*
- *Cymbopogon afronardus, C. caesius, C. citratus, C. clandestinus, C. coloratus, C. confertiflorus, C. densiflorus, C. exaltatus, C. flexuosus, C. georingii, C. giganteus, C. jwarancusa, C. rectus, C. martinii, C. nardus, C. nervatus, C. polyneuros, C. procerus, C. proximus, C. schoenanthus, C. senaarensis, C. stipulatus, C. virgatus, C. winterianus*
  - *Andropogon aciculatus, A. connatus, A. fragrans, A. intermedius, A. kuntzeanus, A. muricatus, A. nardoides, A. odoratus, A. versicolor*

Liliaceae:

- *Allium cepa, A. sativum*
- *Lilium candidum*
- *Hyacinthus non-scriptus, H. orientalis*
- *Convallaria majalis*

Palmae (Palmaceae):

- *Cocos nucifera*

Zingiberaceae:

- *Hedychium flavum*
- *Kaempferia galanga, K. rotunda*
- *Curcuma amada, C. aromatica, C. caesia, C. domestica, C. longa, C. xanthorrhiza, C. zedoaria, C. zerumbet*
- *Alpinia alleghas, A. galanga, A. officinarum, A. calcarata, A. khulanjan, A. malaccensis, A. nutans*
- *Zingiber mioga, Z. nigrum, Z. officinale*

- *Amomum angustifolium, A. aromaticum, A. cardamom, A. globosum, A. hirsutum, A. korarima, A. melegueta*
- *Elettaria cardamomum*

Class 2. Dicotyledonae

Anacardiaceae:

- *Pistacia lentiscus*
- *Schinus molle*

Anonaceae:

- *Cananga odorata*

Aristolochiaceae:

- *Asarum canadense, A. europaeum*

Betulaceae:

- *Betula alba, B. brea, B. dulce, B. lenta, B. papyrifera, B. pendula, B. pubescens*

Burseraceae:

- *Boswellia carterii*
- *Bursera aloexylon, B. delpechiana, B. fragroides, B. glabrifolia*
- *Commiphora abyssinica, C. erythraea, C. myrrha, C. schimperi*
- *Canarium luzonicum*

Caprifoliaceae:

- *Lonicera caprifolium, L. gigantea, L. japonica*

Caryophyllaceae:

- *Dianthus caryophyllus*

Chenopodiaceae:

- *Chenopodium ambrosioides*

Cistaceae:

- *Cistus ladaniferus*

Compositae(Asteraceae):

- *Solidago odora*
- *Erigeron canadensis*
- *Blumea balsamifera, B. lacera, B. ampletectens, B. densiflora, B. aurita, B. glabra*
- *Helichrysum angustifolium, H. arenarium, H. italicum, H. stoechas*
- *Inula helenium*
- *Tagetes glandulifera, T. minuta, T. erecta, T. patula*
- *Santolina chamaecyparissus*
- *Anthemis nobilis*
- *Achillea millefolium, A. moschata*
- *Matricaria chamomilla, M. inodora*
    - *Artemisia absinthium, A. cina, A. dracuculus, A. maritima, A. pallens, A. pontica, A. tridentata, A. vulgaris, A. vestita, A. scoparia, A. parviflora*
- *Arnica montana*
- *Saussurea lappa*
- *Tanacetum vulgare*

Cruciferae:

- *Cochlearia armoracia*
- *Brassica alba, B. juncea, B. napus, B. nigra*
- *Raphanus sativus*

Dipterocarpaceae:

- *Dryobalanops aromatica, D. camphora*
- *Dipterocarpus tuberculatus, D. turbinatus*

Ericaceae:

- *Gaultheria procumbens*

Euphorbiaceae:

- *Croton eluteria*

Geraniaceae:

- *Geranium lugubre, G. macrorrhizum*
- *Pelargonium capitatum, P. fragrans, P. graveolens, P. odoratissimum, P. radula, P. roseum, P. terebinthinaceum*

Hamamelidaceae:

- *Hamamelis virginiana*
- *Liquidambar orientalis, L. styraciflua*

Labiatae (Lamiaceae):

- *Rosmarinus flexuosus, R. lavandulaceus, R. laxiflorus, R. officinalis, R. tournefortii*
- *Lavandula barmanni, L. dentata, L. hybrida, L. intermedia, L. latifolia, L. officinalis, L. pedunculata, L. spica, L. stoechas, L. vera, L. viridis*
- *Nepeta cataria, N. liniaris, N. spicata*
- *Salvia carnosa, S. espanola, S. hiemalis, S. hispanorum, S. lavandulaefolia, S. leucophylla, S. moscatel, S. officinalis, S. sclarea, S. triloba, S. verbenaea*
- *Monarda citriodora, M. fistulosa, M. menthaefolia, M. pectinata, M. punctata*
- *Melissa officinalis*
- *Hedeoma pulegioides*
- *Satureia hortensis, S. montana*
- *Hyssopus officinalis*
- *Origanum compactum, O. elongatum, O. fort-queri, O. grossi, O. majorana, O. virens, O. vulgare*
- *Marjorana silvestre, M. hortensis*
- *Thymus capitatus, T. cephalotus, T. hiemalis, T. hirtus, T. loscossi, T. mastichina, T. serpyllum, T. virginicus, T. vulgaris, T. zygis*
- *Mentha aquatica, M. arvensis, M. cablin, M. canadensis, M. citrata, M. japonica, M. longifolia, M. piperita, M. pulegium, M. rotundifolia, M. spicata, M. sylvestris, M. verticillata, M. viridis*
- *Perilla citriodora, P. frutescens, P. nankinensis, P. ocymoides*
- *Pogostemon cablin, P. heyneanus, P. hortensis, P. patchouli*

- *Ocimum americanum, O. album, O. anisatum, O. basilicum, O. canum, O. carnosum, O. gratissimum, O. kilimandscharicum, O. menthaefolium, O. micranthum, O. minimum, O. nakurense, O. pilosum, O. sanctum, O. suave, O. viride*
- *Mosla/Orthodon angustifolia, M. chinesis, M. formosana, M. hadai, M. japonica, M. lanceolata, M. lysimachiiflora, M. punctata, M. thymolifera*
- *Pycnanthemum incanum, P. lanceolatum, P. muticum, P. pilosum*
- *Coridothymus capitatus*

Lauraceae:

- *Cinnamomum aromaticum, C. infers, C. glanduliferum, C. camphora, C. cassia, C. culilawan, C. kanahirai, C. loureirii, C. micranthum, C. obtusifolium, C. xanthoneuron, C. zeylanicum, C. tamala*
- *Ocotea caudata, O. cymbarum, O. parviflora, O. pretiosa, O. sassafras*
- *Sassafras albidum*
- *Cryptocaria massoia*
- *Laurus nobilis*
- *Umbellularia californica*
- *Aniba parviflora, A. rosaeodora*

Leguminosae:

- *Acacia cavenia, A. dealbata, A. decurrens, A. farnesiana, A. floribunda*
- *Copaifera coriacea, C. glycycarpa, C. guianensis, C. martii, C. multijuga, C. officinalis, C. reticulata*
- *Myroxylon balsamum, M. pereirae*
- *Lupinus luteus*
- *Genista sibirica, G. tinctoria*
- *Spartium junceum*
- *Wistaria sinensis*
- *Hardwickia mannii*
- *Myrocarpus fastigiatus, M. frondosus*

Magnoliaceae:

- *Magnolia grandiflora*
- *Michelia champaca, M. longifolia, M. excelsa, M. figo, M. kisopa, M. nilagirica, M. rheedi*
- *Illicium anisatum, I. japonicum, I. religiosum, I. verum*

Malvaceae:

- *Hibiscus abelmoschus*

Moraceae:

- *Humulus americanus, H. lupulus*

Myoporaceae:

- *Eremophila mitchelli*

Myrtaceae:

- *Myrtus aeris, M. caryophyllata, M. communis, M. pimenta*
- *Pimenta acris, P. citrifolia, P. officinalis, P. racemosa*
- *Eugenia acris, E. caryophyllata, E. pimenta*
- *Leptospermum citratum, L. flavescens*
- *Melaleuca alternifolia, M. bracteata, M. cajeputi, M. leucodendron, M. linariifolia, M. maideni minor, M. smithii, M. trichyostachya, M. viridiflora*
- *Eucalyptus amygdalina, E. australiana, E. bicostata, E. citriodora, E. cneorifolia, E. dives, E. dumosa, E. elaeophora, E. fruticetorum, E. globulus, E. leucoxylon, E. lindleyana, E. macarthuri, E. maculosa, E. numerosa, E. phellandra, E. polybractea, E. radiata, E. sideroxylon, E. smithii, E. viridis*

Myristicaceae:

- *Myristica argentea, M. fragrans, M. malabarica, M. succedanea*

Oleaceae:

- *Syringa vulgaris*
- *Jasminum officinale, J. grandiflorum, J. auriculatum, J. sambac, J. undulatum*

Piperaceae:

- *Piper acutifolium, P. angustifolium, P. asperifolium, P. camphoriferum, P. clusii, P. crassipes, P. cubeba, P. guineense, P. lineatum, P. longum,* *P. lowong, P. mollicomum, P. molissimum, P. nigrum, P. officinarum, P. ribesioides*

Primulaceae:

- *Cyclamen europaeum*

Ranunculaceae:

- *Nigella damascena*

Resedaceae:

- *Reseda odorata*

Rosaceae:

- *Spiraea ulmaria*
- *Rosa alba, R. canina, R. centiflolia, R. damascena, R. gallica, R. indica, R. glandulifera, R. moschata, R. pubescens*
- *Prunus amygdalus, P. laurocerasus*

Rubiaceae:

- *Gardenia citriodora, G. florida, G. grandiflora, G. longistyla, G. resinifera, G. floribunda, G. latifolia*
- *Leptactina senegambica*

Rutaceae:

- *Xanthoxylum piperitum*
- *Ruta angustifolia, R. bracteosa, R. graveolens, R. montana*
- *Pilocarpus jaborandi, P. microphyllus, P. racemosus, P. spicatus*
- *Cusparia trifoliata*
- *Boronia megastigma*
- *Barosma betulina, B. crenulata, B. serratifolia*
- *Amyris balsamifera*
- *Clausena anisata, C. anisum-olens, C. excavata*

- *Citrus acida, C. aurantifolia, C. decumana, C. aurantium, C. deliciosa, C. limetta, C. limon, C. medica, C. nobilis, C. paradisi, C. reticulata, C. sinesis, C. unshiu*

Santalaceae:

- *Osyris tenuifolia*
- *Santalum album, S. lanceolatum, S. preissianum, S. spicatum, S. zygnorum*
- *Fusanus spicatus*

Saxifragaceae:

- *Philadelphus coronarius*

Tiliaceae:

- *Tilea cordata, T. platyphyllos, T. tomentosa*

Umbelliferae (Apiaceae):

- *Coriandrum sativum*
- *Cuminum cyminum*
- *Apium graveolens, A. petroselinum*
- *Petroselinum hortense, P. sativum*
- *Carum ajowan, C. bulbocastanum, C. carvi, C. copticum, C. petroselinum, C. verticillatum*
- *Pimpinella anisum, P. diversifolia, P. saxifragra*
- *Foeniculum vulgare*
- *Anethum graveolens, A. sowa*
- *Oenanthe phellandrium*
- *Levisticum officinale*
- *Angelica archangelica, A. atropurpurea, A. glabra, A. levisticum*
- *Ferula alliacea, F. asafoetida, F. badra-kema, F. ceratophylla, F. foetida, F. galbaniflua, F. rubricaulis, F. suaveolens, F. sumbul*
- *Peucedanum ostruthium*
- *Daucus carota*
- *Crithmum maritimum*

Valerianaceae:

- *Valeriana celfica, V. officinalis, V. wallichii, V. brunoniana, V. hardwickii*

Verbenaceae:

- *Lippia citriodora/Aloysia citriodora*

Violaceae:

- *Viola odorata*

Zygophyllaceae:

- *Bulnesia sarmient*

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Chapter 3

STATUS, SCENARIO, SCOPE AND TRENDS OF AROMATIC MEDICINAL PLANTS

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ABSTRACT

From the ancient era, medicinal and aromatic plants have been a basic component of our day-to-day life; they have been in use as herbs, spices, food as well as medicine. Through the utilization of these plants from the ancestors, the plants were verified as to convey the curative properties, targeting to curative managements of various diseases and ailments. Traditional medicine continues to being practice till date due to increase in population, inadequate supply of commercial drugs, exorbitant price of medication, high hazardous implications of chemical medicines and innovation of drug resistance towards disease causing pathogens. For the recent past decades there has been quick growth of interest on medicinal and aromatic plants globally. The plants continue to promote good health. Currently, public ambition for community has increased towards the use of the plants. Medicinal and aromatic plants have gained enormous scope in pharmacological aspect due to their readily availability, accessibility, affordability, Eco friendliness, and

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efficacy with additional property of less toxicity compared to commercial, synthetic drugs. Medicinal and aromatic plants are also the prime sources for plant secondary metabolites which have potential effect on human therapy. The aromatic plants are right now mainly exploited for essential oil extraction and these oils are used in drug discovery, pharmaceutical industry and in various sectors including cosmetics, health and food productions. The biological activities of potential naturally pure compounds like essential oil have human remedy due to their time-tested antimicrobial, anti-inflammatory, antioxidant, anti-cancerous and many other pharmacological activities. In order to maintain ecofriendly and conducive environment to the human health and biodiversity at large, the initiatives and implementation of medicinal and aromatic plants should be investigated by various stakeholders, non-government and government sectors to put more efforts in developed technology for the actual conservation and effectual initiatives and to synchronize research on them. As the reimbursements from therapeutic and aromatic plants are acknowledged, these therapeutic and aromatic floras have a distinctive impact in human health in the present and future.

Keywords: medicinal, aromatic plants, pharmacological, secondary metabolites, essential oils, human health

INTRODUCTION

The conventional use of medicinal plants for therapy has been from the ancient times and is considered as an old treatment scheme. As man was struggling against numerous ailments, the erudite healing properties from the various parts of the plants like leaves, barks, fruits and seeds were the only boon for survival. Therefore, current knowledge on medicinal plants is due to man's ancient discovery. This has contributed significantly in modern pharmacology which has acknowledged the bioactive compounds in the plants as a drug. These properties in plants as healing remedies during the ancient era are presently significant equally and has a promising impact in future as the acquaintance have recognized to the pharmacists and physicians in development of the drugs (Kumar Srivastava 2018).

Traditional medicines have been used globally in human health care since ancient days of mankind. Certain plants have been known to possess therapeutic agents which have efficacy to heal and to cure various diseases and disorders. They henceforth occupy an imperative place in the medicinal field, socio-cultural and spiritual well-being (Eddouks and Ghanimi 2013).

Medicinal and aromatic plants are known to produce bioactive compound which are secondary metabolites and have found their uses in various industries as dyes, insecticides, fragrances flavoring agents and drugs. Biotechnological approach which has possibility to exploit secondary metabolism in aromatic medicinal plants offer the high quantity and quality production of phytochemicals, reduction of toxicity or even production of novel chemicals (Gandhi et al. 2015).

Plants have been discovered to contain abundant natural compounds which have significant bioactive properties. These compounds can offer an alternative to commercial synthetic drugs and discovery of effective new drug. Plants have played a significant role in health as well as to culture and traditional sectors. Conservation of these medicinal plants will be of great importance in order to preserve the plant species for sustainability. More studies and research have to be made on medicinal plants for more exciting discoveries (Cock 2011). The occurrence of the bioactive compounds like flavonoids and phenol in aromatic and medicinal plants has been significantly found to hold antioxidants and antifungal activities (Amri et al. 2015).

The determination of polycyclic aromatic hydrocarbons from the different parts of aromatic medicinal plants using ultrasonic extraction with dichloromethane, silica gel clean-up and analyzed high-performance liquid chromatography fixed to both fluorescence and ultraviolet detection on sage plant samples showed the highest polycyclic aromatic hydrocarbons. Several samples with the presence of polycyclic aromatic hydrocarbons have shown suppression against cancer cells (Krajian and Odeh 2013).

Herbal medicines have advantageous aspects as compared to modern allopathic drug therapy since they are safe, effective, cheaper and readily available. Phytochemicals confer greater therapy potential with least level of toxicity (Sanghi and Tiwle 2013).They also contain varieties of large amounts of nutrients and are also rich in metals like magnesium, calcium, potassium, zinc, copper iron, calcium, sodium and many other metals. These are significant in conveying therapy as well as antioxidative properties. It is, therefore, vital to explore the traditional plants for their numerous activities and properties (Gjorgieva Ackova et al. 2011).

The anti-aging and neuroprotective essential oils and their various modes of actions have been globally assessed by many researchers. The clinically significant essential oils obtained from *Piper nigrum*, *Jasminumsambac*, *Rosmarinus officinalis*, *Menthapiperita*, *Eucalyptus globulus*, *Lavandula angustifolia*, *Acorusgramineus* and *Nigella sativa* along with other aromatic plants have been found with neuroprotective effects. These essential oils can therefore be developed as an effective agent against neurological syndromes (Ayaz et al. 2017).

In the evaluation of total phenolic content in *Hyssopus officinalis* L., *Salvia officinalis* L., *Origanumdictamnus* L., *Origanum vulgare* L. and *Melissa officinalis* L. which are liable for antioxidant and toxicity value, *Melissa officinalis* L. showed the highest phenolic content and thus possessing potent antioxidant activity (Skotti et al. 2014). Plants like rosemary, basil, laurel and sage possess antioxidants and antifungal activities (Juhaimi 2011). Additionally, plants such as winter savory and oregano contain abundant amounts of polyphenols. In quantification of the phytochemicals, solvent extraction has a significant role and mostly phenolic components are isolated in aqueous and ethanol extracts. Lately, mild alcohol solution has been recommended to recover phenol bond compounds. Time and temperature provided during extraction also has an effect on the quantity and purity of these compounds (Oreopoulou et al. 2019).

Rosmarinus officinalis L (Rosemary) is an aromatic medicinal plant which belongs to the family of Lamiaceae. The plants have numerous bioactive compounds; carnosol, rosmarinic acid, caffeic acid and carnosic acid and its derivative. The plant has an enormous range of industrial applications in food production, cosmetics and perfumery industries as well as pharmaceutical since it has been discovered to have antimicrobial properties, antioxidants, anti-inflammatory, anti-cancer and many other more benefits (Ribeiro-Santos et al. 2015).

The essential oils derived from these therapeutic aromatic plants have antimicrobial activities. The plants contain various bioactive compounds of terpenes and terpenoids; carvacrol, cinnamaldehyde, geraniol menthol and thymol analogues Due to these components, the oils can be used in preservation of food in food industries (Solórzano-Santos and Miranda-Novales 2012). Those oils which possess antioxidants ability can be obtained from the aromatic and medicinal plants. These antioxidants have however been found of great diversity due to their variance in chemical composition and assortment of tests used. *In vitro* demonstration of antioxidants are correlated with those that quantify free radical scavenging activities or those that estimate lipid peroxidation hence evaluation of antioxidant activity is significant to obtain the effective aromatic and medicinal plant (Miguel 2010).

GLOBAL SCENARIO

The World Health Organization (WHO) designates that 80% of the Asian and African populations depend on herbal medicine as the main method for their wellbeing. From the ancient times, these plants have been used in community treatment of numerous health problems and related discomforts (Neergheen-Bhujun 2013).

The Indian Himalayan region is regarded as an abundant source of the medicinal and aromatic plants and has knowledge on varied traditional as well as modern line of therapy. The community is well familiar with the natural aromatic plants on their region and, therefore, mostly depend on them for prime healthcare forms which have been essential part of their life. Furthermore, the modern pharmaceuticals industries also depend on the plants in development of new drugs or search for new other biological components. Unfortunately, the overexploitation and habitation destruction have decreased population of indigenous types and threatened the sustainability of numerous species. This situation urgently calls for a long-term commercial and conservation sustainability of the medicinal and aromatic plants (Negi et al. 2018).

Sudanese traditional medicines signify a unique mixture of African, Islamic and Arabic traditions. The different climate in different places within Sudan has enhanced the growth of massive diversity of indigenous plants in the region. The connection of varieties of species and the complex geography convey a great potential for Sudanese aromatic medicinal plants. These plants have been a source of therapy for the people who live in the rural areas and cannot be able to access to healthcare. It is, therefore, important for pharmacological research to determine on the safety of the used plants and enhance their efficacy of these plants so that to be used as herbal medicines in Sudan (Khalid et al. 2012).

Global changes in weather speculated to have negative impact even to the coming future especially if human activities continue to carry out features that lead to environmental destructions. Aromatic medicinal plants are not protected to the effects of alteration on climate just like all other living community of the environment. There has been noticeable effect on changes in lifecycle and distribution of the global vegetations including indigenous aromatic medicinal plants. This has, however, indicated that the species are at risk which can eventually lead to extinction if conservation and sustainability is not rendered. It is, therefore, a great concern globally to come up with ways to necessitate the survival of the aromatic medicinal plants (Das et al. 2016).

Medicinal plants are threatened due to over-exploitation, late cultivation and poor seed germination or the sorry state of the seedling survival in nature. It is, therefore, essential to determine the optimum germination conditions like hot-water pre-treatment to enhance growth of aromatic medicinal plants (Kandari et al. 2012).

Controlled environment technology enhances the cultivation and growth of plants and their products inside structures such as growth chambers, indoor plants and green houses. The growth of the plants is subjected to appropriate optimum conditions to maximize the yields, optimize high value concentration of phytochemicals and minimize pathogen contamination from micro-organisms and insects throughout the year. Controlled environment technology converses a solution towards geographical constraints like climatic changes to enhance production. This technology has a capability to sustainability, quality improvement, increased availability and reduction of over exploitation of aromatic medicinal plant. Controlled environment technology has extended the scope for future cultivation and sustainability of medicinal and aromatic medicinal plants (Stutte 2016).

The knowledge through botany, the science of plants is related with aromatic and medicinal plants in diverse ways. The study seems to render promising perceptions for the breeding of novel, highly powerful phytocultivars of aromatic and medicinal plant species (Mathe 2015).

The herbal technology in the current scenario globally is going to be significant elements that are ultimate for success on being acquainted more with herbs. This technology has a great significance in production of nutraceuticals, cosmeceuticals, biopesticides, herbal drugs and many more other products. Nutraceuticals are food produced from natural plants that grant health benefits in prevention and curing of various diseases. The demand for cosmetic products with drugs in the skin care market has exponentially increased, alternation from conventional pesticides to biopesticides which are more eco-friendly, readily available and affordable is being encountered and use of herbal drugs for human wellbeing and therapy represents a most important contribute to health system globally (Agarwal et al. 2013).

The role of novel drug system is to ensure safety, efficiency and bioavailability of precise herbal drugs. This can be enhanced by the current advanced technologies like pronisomes, ethosomesnano emulsions, phyotosomes, liposomes, nanocapsules and phytocomplex. These technologies were widely acknowledged by many pharmaceutical industries and cosmetic companies for maintaining the effectiveness of their products (Mathur 2013).

The explication of pathways to elaborate on metabolites in aromatic medicinal plants has been primarily very slow. However, current technological advances in subsequent generation sequences and innovative new approaches to gene discovery have expanded the acquaintance. Further, new developments have to be invented for the elucidation for more complex plant pathways (Lange 2016). Biotechnical approaches like cell cultures, conventional propagation and synthetic seed technology should be applied to advance yield production and modify the potency of aromatic medicinal plants (Bajaj 2012).

Government Policy

Aromatic and medicinal plants are well thought globally as a significant source for production of drugs. However, indigenous rate of extinction is very fast due to overharvesting and destruction of their habitat. This indicates conservation and sustainability of these plants is wanting. The government and non-governmental organizations are urged to make strictly adherable recommendations and strategies for conservation and enhancing sustainability of these endangered plant as well as the wild medicinal species. Botanical and natural reserves should be instituted, establishment on in-situ and ex-situ and cultivation practices, advancement in biotechnological approach and commercial cultivation by providing massive disease-free plant seedlings (Thakuri 2018).

The knowledge on aromatic and medicinal plants should be widely transmitted globally and communities educated on the importance of preservation and protection these plants from extinction. International congresses can be motivated by both the governmental and non-governmental stakeholders in order to enlighten the significance of conservation of these aromatic, medicinal plants worldwide (Montanari 2014).The protection and bearable application of medicinal plants will reduce extinction of global medicinal plants. The conservation strategies like cultivation practices and *in situ* and *ex situ* conservation and resource management like sustainable use solutions good agricultural practices can be of great significance when implemented (Chen et al. 2016).

More advanced strategies aimed to conservation and enhancing sustainability of natural remedies are at urge. Even though *in situ* and *ex situ* protection exercise protocols should be continued to be used, other long-term objectives can be attained by conservation by means of farming, augmenting productive constraints for enhanced yield, evading disparaging harvesting and establishment of good quality seedling (Raina et al. 2011).

The increased demand of aromatic and medicinal plants has augmented interest in several areas of researchers in various fields like pharmacognosy, ethnobotany, phytochemistry and many other sub-disciplines interrelated to medicine and pharmacy as well as wide ranging in cosmetology and chemical industry. Due to high demand of these plants by consumers and manufacturers, there is an urgent need to identify and assess these wild species to threat of their extinct due to over-harvesting without consideration of effective cultivation practices. These perceptions could be useful to progress the conservation policies and guide the sustainable management as well to enclosure appropriate economic evaluations plans to implement the aromatic medicinal and aromatic plants strategy (Lamrani-Alaoui and Hassikou 2018).

SCOPE OF AROMATIC MEDICINAL PLANTS

From the ancient times, aromatic and medicinal plants were used by our ancestors to cure their illness, for body ease, heal their wounds and against many other ailments and diseases. This kind of approaches has extended till date since approximately 80% of the global population still depends on aromatic and medicinal plants in their therapy. The regeneration of aromatic and medicinal plants in developed countries in the world has advanced about on diverse type of usage in the form of herbal medicines. These plants have become a raw material for industrial production of various products like pharmacological, cosmeceuticals, nutraceuticals, aromatherapy and many more products including veterinary welfare uses. This has widened the scope of aromatic and medicinal plants utilization. New application has advanced in food industry, animal husbandry and in agriculture as plant protection (Mathe 2015).

The demand for foods preserved by natural essential oils from medicinal herbal plants is highly increasing since the use of artificial and chemicals have harmful effect to health. This has therefore heightened more interest in use of natural aromatic plants as an alternative in extending food shelf life and control of food borne pathogens since they have been found to be inhibitors of bacterial growth (Calo et al. 2015).

The aromatic and medicinal plants are widely used in pharmaceutical, food and beverages industry, nutraceuticals, cosmetics and perfumery manufactures. These plants are also used as a source of natural dye, flavoring, antimicrobial, antioxidants and biopesticides (Peter and Shylaja 2012). They have been an important means in therapy and perfumery since ancient times. Currently, there is enormous scope for enterprise development of these plants. The greatest knowledge on the use of aromatic medicinal in various sectors in consideration of harvesting, cultivation, industrial processing, certification, marketing and many more others will be essential in potential establishment up entrepreneurship in these aromatic medicinal plants (Kala 2015).

Present life style and some of the environmental exposures have contributed in male infertility. The causative factors can be directly or indirect cause sexual dysfunctions. Male infertility is progressively increasing in almost all the parts globally. Many of the Modern medicines used although have been effective to aid therapy, they have, however, found to comprise negative effect on physiological processes. Herbal plants provide remedy to problems associated with male infertility. The herbs are termed as herbal aphrodisiac. The analysis has been demonstrated in several plants and has showed to be effective which has provided a base work for several herb products preparation (Mathur 2012).

Aromatic and medicinal plants till date form the basis of traditional health system in most developing countries. As a result of expanding interest on these plants, new income generating prospects are opening up for the community. This has generated income for the poor rural population (Barata et al. 2016).

The use of aromatic and medicinal plants in various industries as stirred the need to cultivate and enhance sustainability. Protection of plant diversity will render abundant production of raw materials to be processed and increase the opportunity to the farmers to grow the plants improving their statues. It is therefore significant for the potential producers to be well knowledgeable about the aromatic medicinal plants on demand and enforce their cultivation and sustainability (Lubbe and Verpoorte 2011).

TRADE IN AROMATIC PLANTS

Global demand for biochemicals and products manufactured from plants has created an incredible opportunity for natural product manufacturers. This has created a scope for aromatic and medicinal plants products for small also medium enterprises. India own medicinal herb wealth of about 8000 species and 1200-2500 species of aromatic plant treasure has gain global attention target for secondary metabolites and phytoceuticals. Different protocols are currently accessible for increased profitable consumption by trivial and medium enterprises and international market is equipped to be supplied with high quality natural products from India (Rajeswara et al. 2012).

In the interior 24 different provinces of Turkey, the demographic profile on the trade and use of aromatic and medicinal plants was examined. The most sold aromatic herbs were *Ceratonia siliqua*, *Salvia* species, *Zingiber officinale*, *Tiliato mentosa*, and *Mentha pulegium*. These plants were mainly used as food spices and other complications associated with ingestion, dermatological, respiratory system and neurological disorders. The regularly used part of the herb was leaves, fruits and flowers and the common means was of administration were; infusion, decoction and powder (Akbulut and Bayramoglu 2013).

Aromatic and medicinal plants have crucial participation in meeting demand of traditional medicine within the country as well as overseas market. Using the examination on the Herfindahl-Hirschman index during the period of 2000-2014, it was indicated that the United States, Malaysia, Germany Japan, Singapore have the highest importing advantages for aromatic and medicinal plants. The structure of worldwide market of these plants indicates they are of high demand hence competitive (Roosta et al. 2017).

The processing of plants extracts to produce various natural ingredients and final products in many countries using plant raw materials has led to enhance trade henceforth growth of global scale. To subsume, the trade of aromatic and medicinal plants and their natural products has stunned the technological holdups from the past periods (Durbeck and Huttenhofer 2015).

Cultivation of aromatic and medicinal plants has potential to yield higher increased financial return than traditional crops. Knowledge on proper conservation and sustainability through trainings on proper cultivation practices, collection of the plants, means of preservation and marketing as well as biotechnology and proper post-harvest management will be of great significance in increment of financial return (Sher et al. 2017).

GLOBAL MARKET STATUS

The global trade international market reveal that the export- import herbal trade of plant originated products and from herbal technology is approximately US $250 billion (Agarwal et al. 2013). Herbal, medicinal and aromatic plants are common therapeutic agents which have such an excellent biocompatibility that it can become the source of alternative medicine and other supplements used in health care. The trade of these plants is rising in market either as herbal constituent of health food or preventive medicines. Herbal, medicinal and aromatic products have attained global market through two diverse categories of suppliers. These are local producers and distributors of imported products who can market the end product. In 2010, the global level attained a gradually growing niche market of the herbal, medicinal and aromatic products having an approximate value of $13 billion. There is prospective growth of market from these products since there is an increasing demand from the consumers. Establishment of standards and regulation to govern the market of herbal, medicinal and aromatic plant products is mostly desired (Mafimisebi et al. 2013).

In these present years, conservation and sustainable exploitation and cultivation of aromatic and medicinal plants have attained much consideration. These plants are very much significant for the ecosystem and has sustained livelihood more especially in developing regions. Regardless of the traditional trade, implications and observance for cohesive progress of aromatic plants in these developing regions should be initiated. Determination of priorities and developing some follow-ups on the progress can be noteworthy in the conservation and sustainability of these species. This will be well facilitated with sustainable harvesting, cultivation and final marketing. These have led to achievement of the substantial improvement in production of planting materials, profile-raising cultivation and sustainable harvesting of the yield and final marketing (Kuniyal et al. 2015).

Intercropping of aromatic medicinal plants with other cultivated crops has a potential to improve the production and increase financial return. Both large scale and small-scale farmers are recommended to cultivate aromatic medicinal plants since there is a high demand from industries as well as from local community in order to increase their income statues (Sujatha et al. 2011).

WORLD PRODUCTION OF AROMA

Aromatic and medicinal plants are offered in a diverse range of product in the market. The massive demand of these products worldwide has brought a vast business from native to international phase. In the last century, the stated yearly globally trading of medicinal plants was averagely 400,000 tones with approximate value of $1,224 million. The international business is conquered by some known nations. Nearly 80% of the global ingresses and trades are assigned to only 12 nations with the dominancy of European and temperate Asian countries. India and China are the leading product producing nations in the world. USA, Germany and Hong Kong stand as important trade centers while the Republic of Korea and Japan are the vital market for pharmaceutical plants. Aromatic and therapeutic flora has crucial part in substantial role in their upcoming trade (Lange 2002).

The Asia region has an extensive tradition of usage on herbal medicines and has very rich variety of aromatic and medicinal plants. About 8,000 of those species possess ethnobotanical properties, out of those, 2500 species are used for medicinal purpose and only about 250 species are traded in massive capacities. The global trade in natural plants is estimated at US $ 32.702 billion while in Asia is about $ 14.505 billion which accounts about 44.35%. The market trade has improved the livelihood income for farmers as well as growth in country's economy (Paroda et al. 2013).

China has also made a remarkable advancement in utilizing herbal medicines by endorsing its use in the industrialized world. The country produces herbal products annually valued at US$ 48 billion and export estimated to US$ 3.6 billion. The global market for plant derived drugs upsurge from US$ 9.50 billion in the year 2008 to US$ 32.90 billion in the year 2013, an annual advancement of about 11% (Ghosh and General 2013).

India in Global Scenario of Aroma

In, India, the consumption of aroma is in practice since the Vedic period. The main market of aroma is in incense sticks known as *Agarbatti* (Hazarika et al. 2018) which is derived from a Sanskrit word Agaravarthi where, Agar means aroma and varthi means grief. Generally stick size differs from 8-12 cm in length, while, their size may vary from area to area (See et al. 2007). The scorching of 2-3 incense sticks at a time is a routine trend in most of the Indian houses during the worshipping God. The petition of incense sticks in India considerably increases during the major festive season, i.e., Diwali and Dussehra. The incense sticks in India are prepared either by traditional method at home or alternatively, by using large machines in the industries. In India, incense sticks manufacturing is included as a sub-class of cottage industries that engrosses mainly women's of rural area (Hazarika et al. 2018). Currently, the incense sticks manufacturing is categorized under ministry of commerce and trade, Government of India (GOI). Though the ingredients of incense sticks varies from one industry to another, its major parts are sticky powder, raw bamboo sticks charcoal powder, such as Sal resin, Jigat, Nargis powder and Guggul(Hazarika et al. 2018) water, natural and chemical aromatic ingredients, sandalwood oil, rose petals, different kinds of oils, flower essence, aromatic flavor sawdust and various color powder.

Further, based on the requirement in market and fragrances rules, two types of incense sticks are commercially manufactured in India, i.e., perfumed and masala. In the process for manufacturing perfumed incense, charcoal powders, white chips, Gigatu, etc. are perforated with water to obtain a semi-solid paste. Formation of this cocktail is taken on the wooden plank and further it is applied to sticks through rolling with hands or with an automatic tool having incense stick. Since India is one of the expanding markets, it is sold by all means of trade, and scattered to locals by retail mode. Due to the retail mode, there is positive effect in selling due to which the growth will be around 7% in the coming years. The Indian incense sticks and *dhoop* (a form of incense product) industry is the broad ranged business concerned with industry, which encashes large contribution to the Indian economy. The Indian export of incense sticks and *dhoop* is gaining lot of attention every year, thus making large contribution in GDP and thus balancing trade deficit in Indian economy.

The major consumption caused boost in demand of aroma flavored sticks in India for religious purpose, mainly in all the rituals and ceremonies (Staub et al. 2011). India is one of the largest manufacturer and exporter of incense sticks leaving behind USA and Brazil. Further, as per statistical data, there are 10,000 industrial units of incense sticks in India, including both minute and small-scale level, along with 200 well-established units having more than 50 marked incense sticks, creating business opportunities to about 8,00,000 family household workers. In India, generally two-three incense sticks are burned during worshipping while African countries like Nigeria lights up ten or more than ten incense sticks at a time. The urge of incense sticks industry is totally rooted on the internal resources such as availability of the raw materials for incense sticks like fragrance, bamboo, and cheap labour.

Incense sticks made of aroma is a rapidly gaining attention in local community with an increase life tolerance (Hazarika et al. 2018). The whole business protocol is shared in between mutual manoeuvres of farmers, local and international traders, retailers and customers, raw material providers and manufacturers. India has dominance in incense sticks production, rewarding a substantial portion of world's requirements. The increase in these industries including manufacturing and trade in India has crucial role in enticing local and distant markets. The urge for incense sticks is increasing in local as well as international markets which are mainly due to the unremitting perfection in quality and increase in product types. The new planning for import exchange control came into drive in the 1942, assisting the incense sticks industry to start importing chemicals, fragrances and other ingredients, specifically as opposed to heading towards the importer (Ramya et al. 2013).

As per report in June 2018, Indian incense sticks creates employability to 20 lakh people across country which includes 80% women alone (Hazarika et al. 2018). It was also reported that Indian incense sticks market are elevating at rate of 15%, thus increasing exponentially reaching 12,000 crores in the coming decade transforming this particular aroma industry even more.

Increasing Demand of Essential Oils, Fragrance and Flavour: Possible Reasons

In recent scenario, human community has shown keen interest towards the feasting of edibles with featuring of flavor, fragrance and reduced processing time (Roman et al. 2017). These features are apparent by this community as tantamount with health and are key factors for approval with improved health (Granata et al. 2018). The report released by WHO, in 2015, estimated that 620 million cases annually (almost 1 in 10 people in the world) are suffered with food borne diseases and 4,20,000 mortality occur in whole world is of prime urge of attention (WHO 2015). Degradation in food items is a scientific and metabolic method which is leading cause for such kind of cases due to variations in sensual features. Spoiled foods undergo variations in taste, smell, texture or appearance making them not suitable for consumption (Rawat 2015). The USDA Economic Research Service reported that more than 98 billion pounds of edibles were vanished by various market-allied sectors, retailers and consumers in 1995. Freshly prepared beverages like milk contributed for almost 22% of this loss while minute contribution were accredited for by caloric sweeteners (12.4%), meat, poultry and fish (8.5%), processed fruits and vegetables (8.6%), grain products (15.2%) and fat and oils (7.1%) (Kantor et al. 1997). Losses in postharvest stages of fruits and vegetables are as high as 30 to 40% globally with increased rate in developing countries. Control in postharvest losses is important, confirming that adequate edibles, both in amount and in excellence are obtainable to every individual (Rawat 2015). There is need of lot of attention towards food safety in current scenario. So, attempts are being made to guarantee shelter and protect food in turn confirming its security and availability of fresh and healthy items. Food manufacturers depend mostly on food preservatives to protect and extend the shelf life of their items (Regnier et al. 2012). The ingestion of food additives, including artificial preservatives, is the root cause of rising cases of allergies and attention-deficit hyperactivity disease in infants (Eigenmann and Haenggeli 2004). Compounds derived from plants are a tool that focuses to isolate certain phytochemicals present in plants. These natural products with high biological potential are then dissolved within the solvent, thus yielding desired extract. Plant oils and extracts have been used for a broad range of applications since many decades recently; they have created broad spectrum attention as antimicrobial agents (McInerney et al. 2011).

Since many decades, essential oils have been recommended in various traditions for medicinal and health purposes. They are composed of hydrophobic liquid containing volatile (easily evaporated at room temperatures) natural products from plants. Due to their detoxifying, stimulating, antibacterial, antiviral, antidepressant and calming potential, they are gaining lot of attention as a natural, safe and economical tool for curing various disorders. Essential oils (EOs) are aromatic substances mainly found in optimum quantities in oil sacs or oil glands found at various pits in the fruit peel, like flavedo and cuticles (Mahato et al. 2019). Furthermore, these are aromatic oily liquids isolated and characterized from various plant parts viz., barks, flowers, seeds, leaves and peels (Tongnuanchan and Benjakul 2014). They are extracted by fermentation, expression, solvent distillation which is most efficient, along with that hydro distillation are broadly recommended for commercial synthesis of EO’s (Tajkarimi et al. 2010). EOs has various therapeutic ventures and recommended as a potential source of novel antimicrobial agents, substitutes to hazardous chemical compounds playing crucial role in food preservation (Solórzano-Santos and Miranda-Novales 2012). Essential oils have been studied extensively but its motivation and natural stingy capacity has generated keen interest in scientific community and experimental protocols due to their extremely focused variety of natural oils in plants. Recently, there is a tendency in the food industry tilted in the following the protocol of mild preservation techniques, permitting care of flavour and texture of the natural products (van Schaik and Abee 2005). Some scientific reports briefed about handling, preparation and storage of food in varieties of methods that cures food-borne disease with the use of EOs acting as a potential solution including fungus, yeasts and bacteria (Rangel et al. 2010). Besides these essential oils bears analgesic antiprotozoal, anti-carcinogenic, gastro protective, anti-inflammatory and acetyl cholinesterase potentials. These biological properties is of great interest in management of Alzheimer's disease, progressive neurodegenerative disease that initially targets the old aged people which is about for 55 to 63% of cases of dementia in people over 65 years (Asuquo et al. 2013). Essential oils also contribute to the food industry in management of food borne microbes and thus keen consideration is now paid to phytochemicals as a substitute for traditional antimicrobials agents.

Essential Oils with Antibacterial, Antiviral, Antifungal, and Cytotoxic Properties

There are lot of reports which revealed about essential oils to combat against numerous pathogenic viruses causing respiratory malfunctioning and influenza. Influenza is a transmittable respiratory ailment initially rises from different types of virus like, type A, B, and C (Glezen and Couch 1997). The drastic hazards have been reported by type A, which act as carrier in several bird and mammal organisms (Baigent and McCauley 2003). Some subtypes or mutated strains of influenza type A have caused flu pandemic (Guan et al. 2010). For example, H1N1, responsible for Spanish flu causing 40–50 million deaths globally (Johnson and Mueller 2002) and the swine flu which was detected in 2009 (Schnitzler and Schnitzler 2009). The influenza A H2N2 serotype caused Asian flu that led to 1.5 million deaths at global level and the Hong Kong flu cause by H3N2 virus (Hsieh et al. 2006) and H5N1, which gained lot of attention was responsible for bird flu (Gauthier-Clerc et al. 2007). Influenza virus type B is generally found as host in human (Earn et al. 2002).

Till now about 20 different chemo types has been analyzed for thyme essential oil. These oils possess different thymol in the range of 31–50% (average 45%), with tremendous amount of p-cymene in the range of 0.1%–26.6% (average 15.6%) and terpinene in the range of0.1%– 22.8% (average 9.3%). Further some other chemotypes of *T. vulgaris* having adequate quantity of thymol and carvacrol (Satyal et al. 2016). Thymol has been reported as antiviral agent to fight against para-influenza type 3 and influenza type A virus (Lafhal et al. 2016). Essential oils isolated from *Lavandula angustifolia* have adequate quantity of geraniol (up to 9.3%), lavandulyl acetate (up to 5.5%), linalool (19.7–39.1%), linalyl acetate (37.0–43.6%), terpinen-4-ol (up to 14.9%), caryophyllene (up to 5.1%),and borneol (up to 6.4%) (Lafhal et al. 2016).Besides this, tea tree oil isolated from the *Melaleuca alternifolia* (Myrtaceae) leaves also having significant anti-viral property. Commercial tea tree oil containing p-cymene (0.5–12%), terpinene (10–28%), terpinene (5–13%), terpinen-4-ol in the range of 30–48%), terpinolene in the range of 1.5–5%), 1,8-cineole (up to 15%), pinene in the range of 1–6% and terpineol in the range of 1.5–8%). Tea tree oil exhibited tremendous potentiality against H1N1 influenza type A virus at dose level of 6 mg/mL (Garozzo et al. 2011). Further treatment with this oil for half an hour gave excellent outcome as it caused 100% inhibition in growth of virus (Usachev et al. 2013). The essential oils isolated from treeterpinen-4-ol, terpineol, and terpinolene, were found to be potent against H1N1 type A, at dose level of 25, 250, and 12 mg/mL, respectively while terpinene, p-cymeneand terpinene, were not have potent activity.

The essential oil isolated from *Fortunella margarita* leaves contains lot of phytochemicals like gurjunene (10.0%), muurolene (10.3%) and eudesmol (28.3%), etc. Beside this, the essential oil isolated from the *Fortunella margarita* fruits possessed monoterpenoids which is key natural product. Oils isolated from both plants parts were screened for their antiviral activity against H5N1 avian influenza virus. The outcome showed that the oils isolated from fruits were having potent 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide possessing 80% virus activity in the MTT assay and for virus propagation Madin Darby canine kidney (MDCK) cells used. The dose level of leaves and fruit were found to be 38.89 and 6.77 mg/mL which possessed significant potential against the virus (Ibrahim et al. 2015).

Some other viral infections like Dengue fever, is rooted by dengue virus (DENV) having 4 serotypes (DENV-1, -2, -3, and -4), each one possessing different mechanism for infections. In current decades, the graph of mortality caused by this virus has been increased in developing tropical countries (Tsai et al., 2019). The essential oils isolated from two *Lippia* species were screened against DENV-1, DENV-3, DENV-2, and DENV-4 dengue serotypes (Ocazionez et al. 2010). *Lippiaalba* oil has phytochemicals like limonene (30.6%), bicycle sesquiphellandrene (8.9%) and carvone (39.7%), and the activity was possessed at dose level of 0.4 and 32.6 mg/mL. Essential oil isolated from the *Lippiacitriodora*, had 1, 8-cineole (5.0%), neral (15.6%), limonene (10.7%), and geranial (18.9%) and having activity at dose level of 1.9 to 33.7 mg/mL. No potent activity has been noticed by accumulation of the essential oil subsequently adsorption of virus; the main mechanism was that the inhibitory outcomes of the essential oil caused inactivation of virus before adsorption on the host cell. The essential oil of *L. citriodora*, having adequate quantity of phytochemical like geranial (18.9%), neral (15.6%) and limonene (10.7%) (Gómez et al. 2013).

Antibiotic resistance in current scenario is one of the major challenges faced globally in scientific world. So it is a tedious task to control the hazardous effects, along with screening and to treat the intensive contaminations (Veras et al. 2017). At present, attention has been devoted to isolate natural products having prominent antimicrobial potentials (Ginovyan and Trchounian 2019; Ma et al. 2019). In the past centuries, there has been keen attention in isolation of phytochemicals extracted from medicinal plants to innovate nutraceuticals or new herbal medicines. The drugs obtained from medicinal plants are enriched in natural products (e.g., carotenoids, flavonoids and polyphenols) with therapeutic potential, like deferring the inception of some disorders such as diabetes, cancer, and cardiovascular diseases (Singh et al. 2016).

Essential oils obtained from aromatic and medicinal plants have nifty submissions in ethno medicine, preservation, fragrance, food beverages, cosmetics and pharmaceutical companies. These phytochemicals specify various therapeutic ventures like antibacterial, antifungal, insecticidal, antiviral, antioxidant and anticancer activities (Shakeri et al. 2014). Essential oils can assist their antiproliferation by several ways like (i) inducing apoptosis (ii) disintegrating integrity of cell membrane through permeability increment, depolarization, or declining membrane-embedded enzymes potency (iii) fluctuating mevalonate metabolism pathway. Essential oil isolated from *C. zeylanicum* having tremendous antiproliferative efficacy which has been reported several cell lines, like F2408 (normal rat fibroblasts)and 5RP7 (H-ras active-rat fibroblasts) which is due to synergic potential of some volatile components that have antioxidant potential found in these essential oils (Unlu et al. 2010).

Generally scientific community is working against these antibiotic resistance of several microbes. For example, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, *Escherichia coli*, have studied with decreased antibiotic susceptibility (WHO 2014). *Candida albicans* possessing enhanced resistance to known antifungal compounds, hence candidiasis has now becomes challenging task (Goncalves et al. 2016).The current contagion of mutating strains and H1N1 influenza viral strains resistant to very well antiviral drugs also focus the urge to screen novel natural products to resist and combat viral infections (Agarwal et al. 2013; James and Prichard 2014). This enhanced potentiality has shaped an urge to innovate novel antimicrobial compounds. EOs are found to be have excellent potential which has been reported and they have specific derived compounds like terpenes and terpenoids (1,8-cineole, carvacrol) and aromatic agents (cinnamaldehyde and eugenol) have antimicrobial potential against a broad kind of microbes, with other biological applications (Bassolé and Juliani 2012).

This potentiality of EOs is related due to phytochemicals which possess cytotoxic effects, can affect membrane integrity. Compounds of EOs are lipophilic, so they can cross cytoplasmic membrane and cell wall. They disintegrate the composition of the phospholipid layers, polysaccharide, and fatty acid allowing the permeability of membrane (Bakkali et al. 2008). Beside this there is a drawback that EOs does not explicitly target pathogens and be able to target eukaryotic cells in irreversible or reversible pathway (Carson et al. 2006). It has been reported that EO cytotoxicity results in necrosis, apoptosis, and malfunctioning of organs (Tisserand and Young 2013). Consequently, EOs must be utilized in proper manner, within the perfect dose level as per recommendations.

Many essential oils have been used in the traditional medicine since many decades. These are recommended as ethereal or volatile oils, which are scented oily liquid that extracted from the different plant parts and mostly consumed as the food flavours. These EO possessed different therapeutic ventures viz., the antioxidant, antiviral, insecticidal and antibacterial, etc. (Abu-Shanab et al. 2005). These oils are having prominent anticancer potential, besides this they have been recommended in preservation of food, aromatherapy, and in the perfumery companies (Kelen and Tepe 2008). The antimicrobial and antioxidant potential of essential oil are bases of different tenders counting the pharmaceuticals, natural therapies, processed and fresh food preservations and alternative medicines. Essential oils are also recommended as a substitute foundation of wound curative due to presence of aromatic compounds extracted in essential oils.

TREATMENT OF AILMENTS WITH ESSENTIAL OILS OF SOME AROMATIC PLANTS

EOs is possessing volatile phytochemicals from variety of natural products like monoterpenes, sesquiterpenes and phenylpropanoids. There are lot of reports about antibacterial, antiviral antifungal potential and antioxidant properties of Eos that have tremendous potential to combat against as influenza virus (IFV), human immunodeficiency virus (HIV), human herpes viruses (HSV), avian influenza, and yellow fever virus (Ma and Yao 2020). HSV-1 and HSV-2 are considered as most dangerous hazardous microbes which specially targets in humans and is the root cause for mortality in patients having immune-compromised condition. HSV-1 is triggered by HSV-prompted grazes in the epidermis and oral pathway, whereas HSV-2 results in genital herpes that is a sexually transmitted ailment. *In vitro* reports suggested that oil extracted from lemon balm has reserved plague formation caused by HSV-2 and HSV-1 viruses in reference to a dose-dependent manner.

Increase in dose level totally inhibited the viral infection (Schnitzler et al. 2008). Pre-treatment by using EOs isolated from *Matricaria recutita and Melaleuca alternifolia*, *Illicium verum* and *Leptospermum scoparium*, possessed potency activity against acyclovir-sensitive and resistant HSV stains, thus elucidating antiviral potential of EOs. Anti-viral activity against influenza virus was attributed to liquid and vapours forms of essential oils isolated from different plant species which was studied *in vitro*. Vapours of these oils isolated from *Eucalyptus globules and Citrus bergamia* and compounds isolated from *Eucalyptus globules, and Citrus bergamia*, such as eugenol and citronellol had hasty anti-viral properties. In liquid phase, these oils isolated from *Cymbopogon flexuosus*, *Citrus bergamia*, *Thymus vulgaris* and *Cinnamomum zeylanicum* showed potent anti-viral properties i.e., 100% complete inhibition of growth of virus at dose level of 3.1μL/mL. The study finally recommends that these essential oils in vapour form could be advantage in influenza (Vimalanathan and Hudson 2014). Carvacrol and their isomer thymol isolated from oregano possessed antiviral property via exhaustion of cholesterol from the HIV-1 envelope, thus resisting the admittance of the HIV-1 virus in the host defense mechanism (Mediouni et al. 2020).

IMPACTS OF AROMATIC PLANTS ON HUMAN HEALTH

Essential oils isolated from *Eucalyptus globulus* are conventionally recommended to combat different respiratory disorders like bronchitis, sinusitis and pharyngitis. The essential oil and its potent compounds 1,8-cineole is reported having relaxation in muscles potential by reducing flexible muscle shrinkages of airways tempted by various compounds (Coelho-de-Souza et al. 2005; Bastos et al. 2009). Further, scientific reports have reported that pant of cineole extracted from eucalyptus tempted anti-inflammatory potential and analgesic potential that block cytokines release therefore it can be incorporated in patients suffering from COPD and asthma (Juergens et al. 2020). EOs extracted from Eucalyptus also possess potentiality against different viral strains like herpes simplex viruses-1 (HSV-1), herpes simplex viruses-2 (HSV-2), and enveloped mumps viruses (MV) (Lau et al. 2010). EOs and 1, 8-cineole exhibits activity against disarm free influenza A virus by damaging the virus envelope (Brochot et al. 2017) 1, 8-cineole is experimented in mice for its activity against HSV-2 virus (Bourne et al. 1999). Various experimental reports revealed the potentiality of oils extracted from eucalyptus and their isolated bioactive compound eucalyptol used to treat lung infections and inflammations by mobilization monocytes and macrophage. All reports showed immunomodulatory potency of both EOs of eucalyptus and its potent component, i.e., eucalyptol. All cures decreased the discharged of pro-inflammatory cytokines from macrophages and monocytes, without effecting their phagocytic features (Sadlon and Lamson 2010; Juergens et al. 2020). Eucalyptol has therapeutic potential like mucolytic and bronchodilator features (Juergens et al. 2020). Stimulatingly, EOs extracted from eucalyptus has been recommended having decontamination features and resisted the growth and development of viruses on different tackles and filter devices (Usachev et al. 2013). Thus earlier reports depicted promising therapeutic efficacy in the curing and treatment of COVID-19. Therefore, further studies are still required to understand its exact mechanism of action.

CONCLUSION

Thus abundant bioactive metabolites originated through plants are there and their value in medicine is undisputed. This has generated tremendous interest and optimism among the scientists and created unprecedented opportunities in the field of biotechnology and rapidly expanding natural product industries. One of the effective strategies for the exploration of medicinal and aromatic agents from higher plants and pharmacological screening of essentials includes bioassay guided fraction leading to the isolation of pure constituents. Nevertheless, in order to ensure a constant quality and therapeutic efficacy, one of the challenges of herbal product is standardization before making it a commercially usable product. Essential oils having synergistic activity should apparently not be exploited if isolated from herbs that are toxic and crucially dose dependent. Hence emphasis is to be given on the exclusive abilities of herbal medicines resulting in noticeable effects in managing disease efficiently and with insignificant adverse and side effects. EOs has long been recognized to have anti-inflammatory, immunomodulatory, antioxidant, and antiviral potential. In addition, a relook at diverse pharmacological benefits of essential oils confirms the combination of essential oils in which the pharmacodynamics and pharmacokinetic properties of synthetic drugs are there, suggested to combat this viral disease and their associated complications. Therefore, we recommend that documented plants can be identified and screened for future ethno pharmacological studies. In order to decipher this traditional knowledge into a scientific knowledge, novel compounds can be isolated as a starting point for the development of novel drugs and other valuable products.

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Chapter 4

THE ROOT OF AROMATHERAPY IN THE EARLY ISLAMIC ERA AND ARAB REGION

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ABSTRACT

The origin of perfumes dates back in prehistoric times when men already burned fragrant woods, practice still to be used nowadays. The history of aromas and flavors is very old; they were used especially in religious ceremonies and to treat some diseases in many civilizations. Islam does not restrict the use of perfume to the cult, because the aroma and flavors are signs of purity. The use of perfumes is a practice for everyday life since about 1400 years ago mentioned in the Quran and Sunna. Islam encourages the use of beneficial things for men such as olive oil, honey, black seed and ginger, which have proved their medicinal virtue with the development of science and technology. Natural perfumes are also beneficial, because plant fragrances or essential oils have many physiological and psychological effects. Early Muslim doctors used essential oils in their treatments, centuries before the invention of the science of Aromatherapy in the beginning of the twentieth century, guided by Quran and Sunna.

INTRODUCTION

The name of "Perfume" comes from the Latin "per fumum" meaning "through smoke" (Guerrato 2004). Perfumes can be defined as substances that emit and diffuse a

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pleasant and fragrant odour. They consist of manmade mixtures of aromatic chemicals and essential oils. Until the nineteenth century, perfumes were usually composed of natural aromatic oils. Nowadays, most perfumes are synthetic and may contain many components (Salvador-Carr and Chisvert 2005).The origin of perfumes dates back to prehistoric times when men already burned fragrant woods, a practice still used today. The history of fragrances is very old; they were used in religious ceremonies, as “Money” or as “Gifts” between sovereign because of their high cost (Teisseire 1991). Perfumes are part of men history in Egyptian, Chinese and Babylonian civilizations before 3500 years ago and more. It was a tradition of preparing some aromatic oils to practice the art of embalming or burning cypress wood to combat epidemics. But the use of perfume remains for centuries restricted only to religion and wealthy persons, while general public were condemned when using it (Baba-Aïssa 2000).

Islam does not restrict the use of perfume to the cult because the aroma and flavors are signs of purity (Guerrato 2004). The use of perfumes is a practice for everyday life since about 1400 years ago mentioned in the Holy Quran and Sunna which encourage the use of beneficial things such as olive oil, honey, manna (desert truffles), dates and black seed. Early Islamic medicine was based on prevention first then treatment of many diseases such as microbial infections (El-Jozeyah 2003). Islamic medicine refers also to most famous physicians: Al-Razi (864-923), Al-Zahrawi (936-1013), Ibn Sina (980-1037), Ibn Zohr (1094-1162), Ibn Al-Nafis (1213-1288) and many others, they developed ancient medicines especially Greek and Roman, added a lot of principles and substances to these medicines from ancient Indian and Chinese medicines and made numerous important advances in this field, according to Islamic principles, which still the leading medical bases till 19th century in Europe (Benzeggouta 2012; Majeed 2005).

This paper will give some aspects of ancient “Natural Perfumes” cited in Quran and Sunna and used in Arab region, their origin, diversity and therapeutic effects as a root of aromatherapy in Islamic civilization, to fill the lack in the field of researches on heritage of Islamic perfumes and their use.

Perfumes and Fragrances in Holy Quran and Sunna

In many verses in The Noble Quran Allah orders Muslims to be clean and pure and talks about aromatic substances and plants:

> “As to the Righteous, they shall drink of a Cup mixed with Camphor.” (Al Insan 5);
> “And they will be given to drink there of a Cup mixed with Ginger.” (Al Insan 17);
> “The seal thereof will be Musk: And for this let those aspire, who have aspirations.” (Al Motafifin 26);

> "Also corn with (its) leaves and stalks for fodder, and sweet-smelling plants." (Al Rahman 12).

The Prophet Mohamed (SAW) has a particular passion to perfume, he used it frequently and didn't like foul doors, he taught Muslims to be clean and use perfumes in their day life, he said:

> "Whoever was presented with Rayhan (aromatic plants or substances) should not refuse it, because it is easy to carry and has a good scent," "The best type of perfume is Musk," "Each Muslim must take a bath in every seven days, and if he has a perfume he use it," "Use this Indian wood, because it contains seven types of cures, among them a cure for pleurisy," "Cupping and marine costus are the best of your remedies".

For the first time he distinguished between perfumes for men and those for woman, he said:

> "Perfume for man has apparent scent and invisible colour; perfume for woman has apparent colour and invisible scent" (El-Jozeyah 2003).

Giving great importance to perfumes in Islamic religion for everyone is due to beneficial effects of aroma and fragrances for body and mind, and to motivate searching and thinking about them. For this purpose Al-Kindi (805-873) the Arab philosopher and also physician from Kufa (Iraq) wrote a book on perfumes called "Book of the Chemistry of Perfume and Distillation." His book contained a hundred of recipes for fragrant oils, aromatic waters and salves. Al- Zahrawi a famous physician and surgeon from Cordoba (Spain) had been inspired from Prophet's Sunna referring to cleanliness, management of dress and care of hair and body; included in his medical book "Al Tasrif" a chapter concerning cosmetics and consider cosmetics a definite branch of medicine calling it "The Medicine of Beauty" (Al-Hassani et al., 2007). Muslim physician used perfumes to treat headache, stimulate the heart and stomach, insomnia, colds and other illnesses. Perfume is the fuel of the soul; therefore various strengths and power in the body are nurtured in the presence of perfume, which has a good effect on preserving good health and removing many ailments because it stimulate the power of the body (El-Jozeyah 2003; Al-Hassani et al., 2007).

ANCIENT ARABIC PERFUMES

Trade of aromatic plants and substances flourished in the antiquity and the Arabs had a key role in their expansion, they were already beginning with India, China, the Middle East and Africa, although the Greeks believed that many plant substances came from

Arabia (Guerrato 2004). Aromatic plants and substances were given especially from China, India, Tibet, Somalia, Ethiopia, Yemen and Oman. Arabs were great traders and they brought back: musk, ambergris, agarwood, costus, sandalwood, myrrh, camphor, frankincense (olibanum), cloves, ginger, yew, saffron, safflower and many other substances to prepare their perfumes (Al-Hassani et al., 2007), which were in several forms: aromatic woods to burn, fats and gums, they used one simple substance or they mixed many substances to have new pleasant odor (Al-Murikhi 2006).

The most important and first class perfumes in that period were: musk, ambergris, agarwood, sandalwood, camphor, frankincense, aloe, myrrh and mastic which have been used as perfume or to prevent and treat diseases (Table 1). Other important flowers were also used as perfume, include but not limited to: saffron, jasmine, *Rosa* sp., *Viola* sp., *Moringa* sp., spikenard, wallflower, *Iris* sp., nenuphar, *Narcissus* sp. (daffodil), chrysanths, lavender, myrtle, lily, marjoram and bigarade orange (Al-Murikhi 2006; Al-Jameeh 2000; Hamed and Salem 2012; Shakeel 1999).

Table 1. Important Arabic perfumes and their uses

Arabic / Latin name	**Aspect**	**Main Composition**	**Traditional medicinal uses**	**References**
Misk/True musk	Pods-Powder	Muscone	Head, heart, fear, vision, earache	(Al-Murikhi 2006; Kraft 2005)
Ambar/Ambergris	Wax	Ambrein	Brain, senses, stomach, intestines	(Al-Murikhi 2006; Raza et al. 2007)
Oud/Agarwood (*Aquilaria* sp.)	Wood-Resin	Sesquiterpenes and aromatics such: guaiol, α-copaen-11-ol, baimuxinal	Nerves, mood, stomach, liver, heart	(Al-Murikhi 2006; Chen et al. 2011)
Sandal/Sandalwood (*Santalum* sp.)	Wood	α-Santalol	Body and stomach tonic, headache, bandage	(Al-Murikhi 2006; Misra and Dey 2013)
Kafur/Camphor (*Cinnamomum comphora*)	Wood-oil	Camphor	Headache, nosebleed, bad moods, heart tonic	(Al-Murikhi 2006; Pragadheesh et al. 2013)
Louban/Frankincense or olibanum (*Boswellia* sp.)	Resin	Verticiol, caryophyllene, boswellic acid	Oblivion, stomachache, antiseptic	(El-Jozeyah 2003; Qurishi et al. 2010; Awadh Ali et al. 2008)
Al-ssabr/*Aloe* sp.	Gel	Water, polysaccharides	Nose and mouth ulcers, skin, eyes	(El-Jozeyah 2003; Benitez et al. 2015)
Mourr/Myrrh (*Commiphora myrrha*)	Resin	Furano-sesquiterpenes	Antiseptic, expectorant, emollient	(Baba-Aïssa 2000; Ibn Sina 1999)
Mostaka/Mastic (*Pistacia lentiscus*)	Resin	Mastichorezenes, pinene	Furuncle, wound, phlegm purifier, cough	(Baba-Aïssa 2000; Ibn Sina 1999)

Another kind of perfumes were made by mixture of aromatic substances but data about their preparation, composition, supplementary uses and correct names were lost, it remains only few among them. For example "Al-Khalouk" a very popular perfume in pre- and post-Islamic era composed mainly by saffron, cloves, spikenard, sandalwood, costus and aromatic seashells, was used especially by women. "Al-Ghawali", means very expensive, was made by musk, agarwood, ambergris and moringa oil, this perfume was devoted especially to Caliphs, but these ingredients were varying by additional substances such as cinnamon, clove buds, saffron or camphor. Arabs were the best who mix perfumes; they imported crud substances and prepared complex and new fragrances to be exported to Sindh and India by the sea, and to Persia and Rome by the road (Al-Murikhi 2006; Hamed and Salem 2012).

Special types of perfumes were particularly used in Badia (villages) such as: clove buds, ginger, *Styrax officinalis* resin and yew or *Taxus baccata* for simple fragrances. Complex perfumes existed such as: "Al-Ramek" was prepared with raisins, dates, honey and *Thuja* sp., they may add cinnamon, cloves, Chinese cinnamon and rose, used as perfume and medicine for fever (febrifuge), diarrhoea, cough and chest pain (Al-Murikhi 2006). "Al-Sakhabb" another kind of mixture composed by musk, cloves and mahaleb cherry (*Prunus mahaleb*) seeds, in some regions they added Al-Ramek, this perfume has special use as fragrant necklace for women and this tradition still exists in many regions in Algeria.

These perfumes were gummy aromatic past (cooked preparations), woods, resins, aromatic oils or fats prepared by infusion, enfleurage, or aromatic waters obtained by distillation, this technique was developed first by Jabir Ibn Hayyan (721-815), Al-Kindi and finally by Ibn-Sina to have for the first time pure essential oils from aromatic plants (Shakeel 1999).

ANCIENT PERFUMES IN MODERN AROMATHERAPY

The word "Aromatherapy" is very recent but its principles are ancient; it was introduced since the beginning of the twentieth century by the French chemist R.M. Gattefaussé to designate the therapeutic use of plant essential oils. His book entitled "Aromathérapie" published in 1937 marks the first scientific return to natural aromatic treatments especially as antiseptics. Forgotten for decades during the golden age of antibiotics, the return to natural remedies in the last years gives new life to aromatherapy which may be used by inhalation, vaporized, in baths or for massage. These routes are the safest and most common ways of using essential oils. However, oral, vaginal or rectal ways of application must be used with caution after consultation of health professionals (Bernadet 2000; Cristina 2004).

Many researches are interested nowadays in pharmacological properties and mode of action by direct or gaseous contact of aromatic substances which are especially antimicrobial (i.e., antibacterial, antiviral and antifungal) but have more effect like antioxidant, anti-inflammatory, immuno-stimulant, anti-vomiting, anxiolytic and anti-rheumatic, according to the nature of plant (Bajpai et al., 2012; Bakkaliet al., 2008; Daglia 2012; Di Domenico et al., 2012; Dorman et al., 2000; Goetz 2007; Hili et al., 1997; Inouye et al., 2001; Janssen et al., 1987; Kuriyama et al., 2005; Sugawara et al., 2013; Suzuki et al., 2010).

The most important and valuable traditional Arabic natural fragrant materials were subjected to scientific researches on their therapeutic activities as following:

Musk: is the dried secretion from an internal pouch found between the hind legs of the male musk deer *Moschus* sp., its tinctures were very expensive perfumery ingredients, because to obtain 1 kg of musk grains, between 30 and 50 animals had to be sacrificed (Kraft 2005). Other musk natural resources are civet cat and ambrette seed oil (distilled from seeds of *Hibiscus abelmoschus*) (Fortineau 2004). Studies in its therapeutic effects are little. Musk is shown to have antifungal and anti-inflammatory activities (Morishita et al., 1987; Siddik 2006); also it may be used in aromatherapy since it has very pleasant scent for treating psychological disorders.

Ambergris: is a metabolic product formed in the stomach of whales (sperm whale) probably as a protection against intestinal damage by the shelly parts of plankton. It is occasionally found washed up on beaches but the major source was the whaling industry. Unsurprisingly, this is now a rare and expensive material, driving the search for synthetic alternatives (Rowe 2005). It has many properties such as hypoglycemic and antioxidant activities (Raza et al., 2007; Taha 1991).

Agarwood: is the resinous heartwood from *Aquilaria* species (*Thymelaeaceae* family), large evergreen trees native to Southeast Asia; it is highly valued for its uses in medicine as incense perfume and in other fields especially relating to its unique fragrance (Yang et al., 2013). Agarwood was studied for its biological effects and shown to possess antimicrobial, cytotoxic and antitumor activities (Dash et al., 2008; Ibrahim et al. 2011).

Frankincense: is the common name given to the aromatic resin produced by a group of trees belonging to the genus *Boswellia* (*Burseraceae* family). The three main frankincense-producing species are *Boswellia carteri* Birdw., *B.frereana* Birdw. (Somalia) and *B.serrata* Roxb. from North-Western India. Incisions are made in the trunks of the aged trees where the resinous exudates are tapped. This gum hardens into an orange-brown gum resin known as olibanum or more commonly known as frankincense. The oil is obtained through steam distillation of the frankincense gum resin (Van Vuuren et al., 2010). It possesses anti inflammatory, anti-arthritic, anti-rheumatic, antidiarrhoeal, antihyperlipidemic, anti-asthmatic, anti-microbial, analgesic, hepatoprotective, immunomodulatory and anticancer activities (Akihisa et al., 2006; Qurishi et al., 2010).

CONCLUSION

The practice of cosmetics and aromatherapy in Arab region flourished especially in Islamic era. Quran and Sunna supported the use of perfumes and fragrances for everyone for many purposes, as a sign of civism and to prevent or treat psychological and physiological disorders. All perfume ingredients used traditionally were from natural origin. Scientific proofs are not limited to musk, ambergris, aromatic woods and resins which were found to have medicinal virtues especially antimicrobial, antioxidant, anti-inflammatory and anti-psychiatric. Other fragrant ingredients like camphor, ginger, clove buds, saffron, sandalwood, myrrh, mastic, moringa and myrtle have also medicinal properties (Aksoy et al., 2006; Aleksic and Knezevic 2014;Ali et al., 2008; Lee et al., 2006; Misra and Dey2013; Pragadheesh et al., 2013; Singh et al. 2013; Su et al., 2002; Viuda-Martos et al., 2010; Xu et al., 2012). Ethnopharmacology is a never-ending story of benefits; it is a mine of useful information in all civilizations.

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Chapter 5

AROMATIC PLANTS FOR HEALTH AND HUMAN WELFARE

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ABSTRACT

Aromatic plantsbelong to the category of plants which is collectively known as medicinal and aromatic plants (MAP). It includes herbs, spices and essential oils which are traditional, classic, therapeutic, folk medicine for different diseases. Essential oils of aromatic plants possess many biological activities such as antimicrobial, antifungal, antiviral, anti-inflammatory, analgesics etc. and thus, forms a wide part of aromatherapy. Increased realization of the benefits of medicinal and aromatic plants since time immemorial is pushing large scale industries such as pharmaceutical, food, cosmetic and drug industries towards production of natural high valued products such as essential oils, secondary metabolites etc. This chapter focuses on aromatic plants with wide pharmacological and other properties which serves the health and humanity.

Keywords: aromatic plants, essential oil, aromatherapy, health, human welfare

INTRODUCTION

The growing attention of aromatic plants has increased many folds in the recent decades due to its natural properties, long history of consumption since human

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civilization and increased side effects of synthetic products in various arena of productions such as pharmaceuticals industry, food industry, cosmetic and feed industries. Since time immemorial, these aromatic plants have been used as a rich source of secondary metabolites and essential oils has again gaining popularity by rising to a sky-high and grasping the consumer's attention. Industries are focusing on these medicinal aromatic plants for their eco-friendly, cheap and traditional indigenous knowledge and benefits.

Aromatic plants are a sole part of medicinal and aromatic plants (MAP) which harbor a range of secondary metabolites. Incredible valued phytocompounds in medicinal and aromatic plants are serving the human and mankind from past till future in various aspects such as medicine, food, healing and recreation. Reserpine, asiaticoside, withanolide, camptothecin, ajmalicine, podophyllotoxin etc. are very useful plant drugs. The aromatic plants contain herbs and spices such as rosemary, oregano, thymus, peppermint and garlic. These herbs contain phytoconstituents such as polyphenol, flavanol, flavonoids, quinines, alkaloids, and polypeptides which act synergistically and enhance the bioactivity of these compounds.

The word aromatic itself explains its meaning as aroma. This plant is a category of plant specially known for their aroma and flavors in food, feed, perfumery, cosmetic to pharmacological aspects. In Ayurveda, the aromatic parts of plants are administered by various ways such as inhalation, oral intake, gargles and mouthwash. Aromatic plants possess antioxidant and anti-inflammatory properties due to which it is used in the treatment of large number of disease and disorders. Besides this, the bioactive compounds in aromatic plants have the potential to protect body from the damage caused by free radicals by taking away the singlet oxygen. The aromatic herbs also have the ability to stop the oxidative rancidity and slow down the flavorings of products. Antimicrobial properties of aromatic plants prevent the microbial growth in food.

Aromatic plants are rich in essential or volatile oils and aromatic substances present in various parts of plants such as roots, seeds, fruits, buds etc. Detailed compositional information of the volatile compound present in aromatic plants can be obtained by gas chromatography and mass spectrometry. Aromatic plants contain a mixture of different bioactive compounds like terpenoids such as linalool, geraniol, borneol, menthol, alpha terpineol; phenols such as thymol, carvacrol, eugenol and also aromatic aldehydes such as cinnamaldehyde, cuminal, phellandral. The essential oils are a mixture of secondary metabolites consisting of low boiling points phenylpropenes, monoterpenoids, sesquiterpenoids and terpenes (Benchaar et al. 2009). It has a distinct pleasing aroma with oily feature rich in bioactive constituents of plants. These essential oils have been used in all sphere of mankind such as cosmetic, soaps, pharmaceuticals, perfumery, food, feed, confectionaries etc. The wide aspect of aromatic plants has a bright future. Essential oils are called volatile oils as they evaporate at exposing to air at normal room temperature (Giannenas, 2013). Essential oils have widened their value from narrow aspect by getting an attention in different fields such as pharmaceutical, cosmetics, food industries, etc.

The essential oils of aromatic plants possess antimicrobial activity. The hydrophobicity properties of essential oils render them to accumulate in the lipid bilayer of microorganism and thus disturb the membranes. In some cases, it causes destruction of the homeostasis of cell hence in turns causes cell death. Lemon has essential oils which neutralize the effects of bacteria such as *Typhus bacillus* and *Staphylococcus aureus* so, it is used in cleaning of wounds. Besides this, lemon has widespread use in perfumes, cosmetic, and household cleaning products.

Antioxidants rich property of essential oils plays a contributory role in disease of oxidative stress such as diabetes, cardiovascular disease, Alzheimer's disease and cancer. These aromatic essential oils have the potential to neutralize the enteritis, colitis and putrid fermentations and provide relief from diseases such as chronic bronchitis and pulmonary tuberculosis.

Essential oils possess multiple properties such as antimicrobial, antiviral, antioxidant, analgesic, anti-inflammatory, as a therapeutic in respiratory disease, in urinary disease, vascular disease and last but not the least the most important nervous disease. The antioxidant property of aromatic plants possesses therapeutic potential which lowers down the risk of diseases such as cancer and cardiovascular disease and besides this, finds its utilization in cure and treatment of many other diseases such as respiratory, nervous disease etc. Thus, aromatic plants are serving as an organic hub for treatment of various ailments and diseases and creating an opportunity for human being to live a healthy life.

ESSENTIAL OILS AND AROMATHERAPY

An important feature of aromatic plant is presence of odorous, highly concentrated compound or mixture of compounds called essential oil. The smell of essential oils stimulates the emotional center of brain and also, a rhythm of calmness is induced upon inhalation of the oil. These oils have a sedative effect on the brain which in turns lower down the stress of the body. Oils present in plants such as cedar wood and lemon have anti-stress property. Essential oils that are present in aromatic plants such as clove, basil, peppermint, jasmine energize the central nervous system causing the brain to be alert.

Aromatherapy is a holistic healing treatment that is based on the magical art and science of using aromatic essential oils and herbs for psychological, spiritual and emotional improvement of man and enhancing the health of body, mind, soul and spirit. Hence, it is a therapeutic science for improvement of human being via essential oils. Essential oils have the potential of providing calmness, a balance in emotions and hormones, stress full mood and last but not the least rejuvenation of body (Wiart 2006).

Essential oils play a central role in aromatherapy. Since long, Egyptian uses the essential oils as a magical tool of healing the body. Even Babylon's used these perfumes in temples and mosques for the cleaning the premises and rejuvenating it with aromas. Besides being the primary source of energy on this mother earth, plants are also a source of energy for human and mankind by enhancing the overall health of the body.

Essential oils are produced in secretory cells of aromatic plants. Besides oils, even vapours are also used in aromatherapy which is inhaled. Many essential oils are used for their anti-bacterial, anti-inflammatory and antifungal properties. Lavender oils are used in burns and also relaxes the body from anxiety and depression. Lavender is also used as an herbal tea for refreshment of morning mood and also for rheumatic conditions, cold and flu. Tea tree oil is another example of aromatherapy being used in ringworm, athlete's foot disease and fungal infections. Rose oil is another remedy for depression. The different oils in aromatherapy includes lavender, tee tree, rose, thyme, clove, eucalyptus, sandalwood etc. The two therapeutic way of healing the body by aromatherapy includes either by inhalations of fragrance or by body massage of essential oils. Oils of geranium and *Ylang ylang* possess the apoptogenic properties. Essential oils are a mixture of terpenoids.

Oils present in eucalyptus and cinnamon are best for respiratory disorders while ginger and black pepper oil causes soothing calm to the body in bronchitis and cough. Oils possess good antibacterial property. Besides this, aromatic oils heal the body and causes blood flow in skin when applied to throughout the body as a body massage. Clove and thyme oil possess antispasmodic property. Clove is extensively used in toothaches and provides relief from pain. Leaves of *Ocimum* possess properties such as neurotonic, anti-atherosclerosis, for varicose veins and circulatory problems. Bioactive compound in essential oils includes linalool, eugenol etc. Hence these aromatic oils have pharmacological properties such as hypolipidemic, digestive stimulant, antioxidant, and also helps in ammonia control etc. Out of 3000 plants as a source of essential oils, only 300 are commercialized for fragrance and aromatic flavors.

Chamomile oil has proved to be multifunctional in different activities such as anti-inflammatory, analgesic, to strengthen the immune system and also for massage. Around 120 different secondary metabolites are present in chamomile oil, which contains 28 terpenoids and 36 flavonoids (Mann and Staba 1986; MacKay and Blumberg 2000). The flowers of chamomile oil have proved to be scientific in bioactivity such as anti-inflammatory activities, antiphlogistic activities due to metabolites such as alpha bisabolol, matricin present in the essential oil of chamomile flowers (Lemberkovics et al. 1998; Carnat et al. 2004; Sakai and Misawa 2005). By inhibiting the LPS induced prostaglandin, the anti-inflammatory activity of chamomile oil is carried out in chamomile (Srivastava et al. 2009). Chamomile oil is also shown with anticancerous activity by causing apoptosis in cancerous cell as compared to normal cells when treated with equal doses of chamomile constituents (Srivastava and Gupta 2007). The flavonoids present in chamomile proved to be efficient in cardiovascular diseases.

Chamomile oil taken either as a tea or its oil as aromatherapy reduces insomnia and act as a tranquilizer wherein the calming effects are result of incredible properties of a flavonoid, apigenin. Increase in stress causes an increase in ACTH (adrenocorticotropic hormone) levels. Upon inhalation of chamomile oil vapor, there is reduction in the ACTH levels (Paladini et al. 1999). Literature studies confirm that chamomile oils have effective activity in diabetes by lowering down the blood sugar level, increasing the capacity of glycogen storage of liver and inhibiting the sorbitol in erythrocytic system of human (Kato et al. 2008). The chamomile tea has been reported to be beneficial in osteoporosis treatment and is effective in common cold.

Lavender oil possesses several botanical and therapeutic properties for human health in all dimensions especially nervous system. Lipopolysaccharides stimulates inflammatory effect which may be associated with HPS70 exhibition is severely interrupted and inhibited in monocyte THP1 cell of human by the immense effect of lavender (Huang et al. 2012). Linalool present in lavender inhibits the rigorous release of acetylcholinesterase and also affects the functions of ion channels in neuromuscular junction (Re et al. 2000). The antioxidant property of lavender due to its secondary metabolites protects the cerebral ischemia injury in mice and hence acts as neuroprotective therapeutics (Wang et al. 2012).The intraperitoneal use of lavender oil tremendously enhances the activity of rotarod and besidesthis, the subtype D3 receptors of dopamine also increased in the olfactory bulbs of mice (Kim et al. 2009).Three clinical trials studies reported that daily oral administration of lavender oil preparation in three different patients suffering from anxiety disorder, generalized anxiety and restlessness shown that anxiolytic effects of lavender was more effective in as compared to placebo in 221 patients suffering severe anxiety situation. Beside this, it also showed improvement in restlessness and insomnia which in turn improves the quality and serene of mind and body (Kasper et al. 2010).

Continuous administration of lavender oil for 4 weeks in women of high-risk postpartum suffering from anxiety and stressful depression had shown a good improvement with two different scales namely Edinburg postnatal depression scale along with generalized anxiety disorder scale (Conrad and Adams 2012).Lavender also has a significant effect on various neurological disorders. It plays a functional role in change in EEG pattern along with anxiolytic effects. Studies suggested that administration of lavender in dilute concentration of 10% for 3 minutes enhances the alpha power of EEG, hence the anxiety, lowering down the stress level in 40 normal healthy individual and providing a refresh mood (Diego et al. 1998).

Foeniculum vulgare also known as fennel is used for treatment of variety of ailments such as respiratory, reproductory, and digestive disorders. Essential oils from *Foeniculum vulgare* possess a hepatoprotective property against CCl4 toxicity due to the constituents d-limnone and B myrcene (Ozbek et al. 2003). This oil also has anticolitic activity. Essential oils from *Foeniculum vulgare* help in treatment of different gastrointestinal disorders such as chronic colitis, dyspepsia with disorders in stomach. Reports suggested that fennel along with anthraquinonic components lowers down the abdominal pain (Chakŭrski et al. 1981). Fennel oil shows significant estrogenic activity. Literature survey shows that administration of fennel oil in concentration of 10, 20 and 40 causes inhibition of prostaglandin E2 which in turns lowers down the rate of uterine contraction (Ostad et al. 2001).Besides this, fennel oil also exhibits expectorant activity helpful in bronchial disorders as the essential fennel oils induces the contraction of muscles of respiratory tracts which causes expectoration of mucus, bacteria extraneous to the tracheal sacs (Ostad et al. 2001).

Garlic possesses a cardiovascular property such as reduction in blood pressure, atherosclerosis prevention, induction of fibrinolytic activity etc. (Chan et al. 2013). Garlic oil possess diallylic sulfide which have anti atherosclerotic effects (Gebhardt and Beck 1996). Garlic causes enhancement of fibrinolytic activity in both patients suffering from myocardial infarction and healthy normal person (Bordia, Verma and Srivastava 1989). Administration of garlic shows inhibition of LDL oxidation while increase HDL which is one of the beneficial functions of garlic in cardiovascular disorders (Rahman and Lowe 2006).A sulphur-rich compound derived from garlic and soluble in garlic oil known as ajoene are effective in causing apoptosis of leukemic cells along with other cells in leukemic patients. Ajoene stimulates apoptosis by causing induction of peroxide production, inductions of components activity such as caspase 3 and caspase 8 activity. Besides this, garlic oil also enhances the effect of eicosapentanoic acid which is a breast cancer suppressor and inhibits the effects of linoleic acid which act as an enhancer of breast cancer (Tsubura et al. 2011).

Citrus bergamia oil has many essential components with strong potential to be used in treatment of various diseases. It is commonly known as ‘Bergamot’. Literature suggests that volatile oil of bergamot possess an anti-inflammatory activity. The study conducted via carrageenan induced rat paw odema test showed that the best anti-inflammatory activity was shown by bergamot volatile oil at dosage of 0.10 ml/kg (Karaca et al. 2007). Besides this, Bergemot essential oil interrupts the proliferation of SH SY5Y of neuroblastoma cells by activation of various metabolic pathways causing apoptosis of cells (Celia et al. 2013). The anxiolytic property of bergamot essential oils tested by conducting a study in which three different concentrations of sampleviz.,1%, 2.5% and 5% were administered in rat which were already in anxiety situations. The board test is also conducted for rats. The stress levels were calculated of plasma corticosterone and compared with effects obtained from the administration of diazepam and the diazepam showed an anxiolytic activity in corticosterone against the stress in rat (Saiyudthong and Marsden 2010). Administration of bergamot essential oil lowers down the nociceptive response mediated by capsaicin in the hind paw of rat (Sakurada et al. 2009).

The components of bergamot essential oil namely linalool and linalyl acetate compounds play a significant role in analgesic activity. Besides this, in another study, neuropathy hypersensitivity was stimulated via partial sciatic nerve ligation method (PSNL) in mice and then the mice suffering was administered with linalool of essential oil. The essential oils lowered down the severe effects of PSNL in a dependent manner according to dose administered and also reduced the effects of extracellular regulated protein kinase (ERK) (Kuwahata et al. 2013). Cardiovascular system too seems to improve via bergamot essential oils. Study carried out in guinea pig subject to cardiac arrhythmia via pitressin administration of bergamottin showed lowering down effect in electrocardiograph (ECG). Besides this, bergamottin also enhanced the dose of oubain which causes ventricular tachyarrhythmia hence possess antianginal and antiarrhythmic activities (Occhiuto and Circosta 1996).

Eucalyptus oil plays a major role in respiratory disorders. Study conducted by Juergens et al. (1998) showed that the aromatic properties of eucalyptus oil act as an inhibitory factor for inhibition of production of several cytokines such as leukotriene B4, tumor necrosis factor alpha and interleukin 1B in monocyte of human blood and thus eucalyptol plays a significant role in respiratory disorders such as bronchial asthma which cause inflammation of passage of respiratory airways. These studies show the efficacy of eucalyptus essential oil in anti-inflammatory disorders. Eucalyptus has a potent effect in immune system.

Monocyte or macrophagic system is the main support system that protects the body from foreign attacks. Study carried out on rat by administration of eucalyptus essential oil showed that the essential oil stimulation which then causes activation of monocyte derived macrophages that in turns speed up the phagocytic response and reduces the action of pro inflammatory cytokines effects (Serafino et al. 2008).Aromatherapy of Eucalyptus oil has a soothing relief in common cold by widening the respiratory pathways and stimulation the passages of nasal and bronchial cells (Dixit et al. 2012). Compound sideroxylonal from eucalyptus plays a significant importance in thrombotic diseases by inhibition of plasminogen activator inhibitor I (PAI-1) which is associated with pathogenesis of arterial disease and thus causes stimulation of fibrinolysis (Dawson and Henney 1992). The administration of eucalyptus oil helps in treatment of respiratory infections such as bacterial infection by acting both against gram-positive and gram-negative bacteria and providing soothing relief in common cold, flu etc. (Ait-Ouazzou et al. 2011).

Studies conducted on animal models showed enhancement of anti-inflammatory activity exhibited by thyme essential oils by inhibition of prostaglandin production (El-Nekeety et al. 2011). Efficiency of thymol oil was studied by conducting research on animals by feeding same amount of thymol and carvacrol and enhanced activity of gastrointestinal enzymes such as trypsin, protease was found along with increased liver function activity as a consequence (Thompson et al. 2003). Administration of secondary metabolite flavonoid in thyme essential oils shows relaxing effect on the smooth muscles of ileum by causing blockade of cell receptors such as histamine and acetylcholine receptors (Van Den Broucke and Lemli1983). Before stimulation of acute gastric lesions, a dose carvacrol was administered to rat which in turns prevented the damage caused to gastric epithelium. Carvacrol enhanced the gastric mucus but did not cause a change in volume of acidity level of gastric juice. As compared to control, the Carvacrol protected the gastric line from damage and injury after14 days of administration (Silva et al. 2012).

Berberis vulgaris possess an antidiabetic effect. Studies showed that secondary metabolites from *B. vulgaris* administration of low concentration causes an improvement in secretion of insulin from Islets of Langerhans of liver cells (Ahangarpour et al. 2012). The protective activity of *B. vulgaris* for Parkinson's disease showed that the secondary metabolites cause inhibition of ACE enzymes present in brains cells (Alar et al. 2010).

Table 1. Details of aromatic plants used for different diseases

Medicinal Aromatic Plants	**Disease**	**References**
Plectranthus amboinicus	Cardiovascular complaints and circulatory diseases such as congestive heart failure,	Mortan et al. 1992; Hole et al. 2009
Perilla frutescens L.	Cough, fever, headache and respiratory disorders	Yu et al. 2017; Saklani., et al. 2011
Ocimum micranthum	Antinociceptive Antispasmodic	Pinho et al. 2012; Viera et al. 2000
Caenorhabditis albicans	Dental problems	De Carvalho et al. 2006;Raja et al. 2010
Morbus alba	Anti-hyperglycemic, Anti-hyperlipidemic	Cai et al. 2016; Zinjarde et al. 2011
Berberis vulgaris	Genito-urinary aliments	Yazein et al. 2014; Bashir et al. 2010
Bidens pilosa *Centella asiatica*	Other uses (cuts, wounds, etc.)	Mato et al. 2009; Saikh et al. 2018
Abelmoschus moschatus	Eye diseases, Vomiting, Gastric disorders	Akbar et al. 2020
Kaempferia galanga	Cough, cold, asthma	Khare et al. 2007
Andrographics paniculate	Fevers, jaundice and hepatic disease, diabetes disease	Chaturvedi et al. 1983
Hemidesmus indicus	Memory booster, improved learning	Shete et al. 2009
Artemisia roxburghiana	Insulin secretion, regeneration of pancreatic cell	Romaiyan et al. 2010
Withania sominifera	Immunity booster, Skin diseases, Depression relief, Strength building	Davis et al. 2002

The essential oils from plant *Houttuynia* were tested against viral disease HIV (Hayashi et al. 1995). It was suggested that the antiviral activity of this oil interfere with the protein envelope of the virus. One important essential oil having multi potential biological activities includes antimicrobial, antioxidant, analgesic, anti-inflammatory, antiplatelet, antithrombotic, insecticidal, and antifungal. It is possible due to the presence of different phytocompound in these plants such as monoterpenoids, triterpenoids, sesquiterpenoids, phytosterols, flavonoids, glycosides and aldehydes thus conferring it a multiple pharmacological feature for the health of human being. It also provides the body calmness, pure spirit, stress free body and hence an inclusive part of aromatherapy. Table 1 summarizes the diseases treated about aromatic plants.

As essential oils are concentrated innature, so it must be diluted before use to avoid burning sensation, skin irritations, etc. The oils should be pure to get the immense benefits of it. The different properties of essential oils and fragrances for human heath includes following.

Heart and Circulation

Lymph nodes are present in different parts of the body such as groins, arms, underarms and acting as filtering organs for blood. True bay and lemon oils are two important kinds of essential oils used for lymphatic massage, thus facilitating proper circulation of bloods in the body. Essential oils have immense potential in providing relief in cardiovascular disease.

The pharmacological details of essential oils for circulatory system are given in Table 2.

Table 2. Summarization of essential oils for circulatory system

Essential oils	Component	Route	Effects	References
Dendropanex morbiferus	Zingiberene, Selinene	Wistar rats	Antiatherogenic activity	Chung et al. 2009
Allium sativum	Diallyl trisulphide	Indian albino rabbit	Myocardial infarction	Bordia et al. 1977
Syzygium aromaticum	Eugenol, Eugenyl acetate	Rat	Improved dyslipidemia	Al okbi et al. 2014
Citrus bergamia risso	Limonene	Wistar rat	Angiogenesis inhibition	Mollace et al. 2008
Foeniculum vulgarae	Anethol	Swiss mouse	Vasorelaxation Anti-thrombosis	Togonallini et al. 2007
Aframomum melegueta	Eugenol, Eucalyptol	Rat	Antidiabetic, Antihypertensive	Adefegha et al. 2017

Digestive System

Essentials oils such as basil, coriander, cinnamon, ginger is used in culinary practices. Brain stimulates the digestive system by receiving different aromas of food and, in turn, helps in secretion of digestive fluids in mouth, stomach and digestive system. Aromatic plants *Zingiber officinale* and *Eucalyptus globulus* were reported to be used for antigiardial activity by killing the cyst of the intestinal lining (Dehghani-Samani et al. 2019). *Syzygium cordatum* helps in treatment of gastrointestinal diseases and also digestive ailments (Maroyi 2018).

Bowel System

The bowel system of the body gets irritated on eating a variety of foods and disturbs the body and mind. Even anxiety and depression and stress also play an important role in bowel disturbance. Herbs such as peppermint are used in irritated bowel syndrome.

Since long time, black pepper is used in providing relief from constipation and acidity. Cinnamon and Myrrha are used in diarrhea. Garlic, thymes and tee tree are potential able to kill different types of worms. A mixture of essential oils from peppermint and caraway known as menthacarin, proved to have potential in treatment of irritable bowel syndrome (IBS) (Botschuijver et al. 2018). A mixing of peppermint, zinger, caraway oil and *Iberis amara* possess a magical property for treatment of bowel syndrome of gastrointestinal disorders (Saller et al. 2011).

Respiratory System

90% of respiratory ailments arises due to foreign particle such as virus. Peppermint, tee tree, black pepper, thyme rosemary oils are effective against viruses by inhibiting them. Lemon and eucalyptus oils are essentials oil that fight against bacteria that causes bacterial disease such as pneumonia etc. Gargling with 2% of this oil provides relief from respiratory syndromes. Another method is steam treatment in which the essential oils are directly goes the lungs where it heals the body by providing warm moist to bronchial passage to open it. A clinical trial conducted by Cohen and Dressler proved that mixture of volatile oils of eucalyptus, menthol and camphor hasbeneficial effect for improvement in breathing from a patient of runny nose. The details of essential oils in respiratory disorders are explained in Table 3.

Table 3. Summarization of essential oils in respiratory disorders

Essential oils	Constituents	Respiratory	References
Eucalyptus globulus oil	Cineol	Administration of eucalyptus oil has an anti-inflammatory effect on chronic bronchitis and hence stops the secretion of airway mucins.	Liu et al. 2004
Curcuma longa oil	Curcuminoids	Doses of curcuma longa oil inhibited carbachol and K+ induced contractions	Gilani et al. 2005
Tea tree oil	Terpinene -4-ol	Administration of tea volatile oils provide antimicrobial effects in the lung's airways	Carson et al. 2004
Cinnamon bark oil	Cinnamic aldehyde	The cinnamon bark oil has toxicant activity against fungi such as *Aspergillus niger, A. fumigatus, Candida albicans, C. tropicalis* involved in respiratory mycoses	Singh et al. 1995

Nervous System

Nervous system is a connection between the body and mind. Any issue in one part of body affects the other. Chamomile, lavender, rose, jasmine oils are very effective in stress while *Ylang ylang*, marjoram are best in insomnia. Migraine is a neurovascular disease leading to nausea, vomiting, and mental problems. The patients suffering from migraine seriously affects the quality of their life in all the social, physical and psychological terms. The alternative of migraine treatment includes aromatherapy, as it is a natural therapy which comforts the brain and mind. Chamomile essential oils, *Angelicaedahuricae* Radix essential oils, *Chuanxiong* rhizome essential oils are therapeutic oils for different types of migraine. These oils provide relief to the patients from nausea, vomiting etc. The aromatic plant *Salvia sclarea* contains clary essential oils whose administration of 5% exhibit an anti-stress effect in FST (Seal et al. 2010). Coriander essential oils possess an anti-depressant property from plant *Coriandrum sativum* (Cioanca et al. 2014). An experiment conducted by Komiaya et al. (2006) on three different aromatic plants essential oils such as lavender, rose, and lemon for testing the behavior change via force swimming test on miceand reported that lemon oils show a strong anti-depressant effects pot of the three (Komiya et al. 2006). *Mellisa officinalis*volatile oil has been reported for treatment in Alzheimer's disease by conducting a placebo-controlled experiment in 72 Alzheimer's patients (Ballard et al. 2002). The summarization of essential oils against anti-migraine activityis given in Table 4.

Table 4. Anti-migraine activity of essential oils

Essential oil	Component	Experimental type	Anti-migraine activity	References
Lavender essential oils	Linalool;1,8 cineole; camphor; borneol	Animal experiments, clinical trials	Administration of lavender oil for 15 minutes recorded for 2 hours provides that the number of responders in lavender group were higher than placebo patients; also provide relief in acute management of migraine headaches.	Sassanejad et al. 2012
Angelicae dahuricae radix essential oil	Elemene; α pinene; 1pentadecanol; dodecyl alcohol	Animal experiment (Rat model)	140 mg/kg, 70 mg/kg, 35 mg/kg lowers down the head scratching, head shaking, serum and NO level of brain	Sun et al. 2017
Garlic essential oils	Diallyl trisulphide	Animal experiment (adult rats)	Five different doses of garlic oil prevented the rate of rats cortical spreading and hence also prevented its harmful effect on astrocyte cells of brain.	Marschollek et al. 2017
Basil essential oils	Estragole; linalool	Clinical trials	Reduction in pain intensity	Ahmadifard et al. 2020
Peppermint oil	Limonene; menthol; menthone; α pinene	Clinical trials	Administration of peppermint oil produces a relief from the symptoms like tension type headache and even the intensity of headache also lowers down	Rafieiankopaei et al. 2019; Gobel et al. 2016
Chamomile essential oils	Chamazulene; bisabolene oxide A; bisabolol oxide a	Clinical trials	Administration of chamomile oil provide relief from migraine pain due to anti-inflammatory activity and neuroprotective effects.	Zagaran et al. 2018
Chuanxiong Rhizoma essential oil	Ligustilide; sabinene	Animal experiments, clinical trials	Administration of essential oil lowers down the severe pain acute within 2 hours	Ping et al. 2009; Li et al. 2012

Urinary Tract

The main function of urinary system is regulation of body’s water content, balancing the salt level and removal of water from the body. Cedar wood oil and tea tree oils are effective in bladder infections. *Kaempferia pulchra* is widely used in treatment of urinary infection (Ekor 2013). Antibacterial effects of essential oils prevent urinary infections.

The essential oil of rose and thymus has proven treatment against genitor-urinary tract infections by the antimicrobial properties of these essential oils (Lagha et al. 2019).

CONCLUSION

The attempt of this chapter was to shed light on magical benefits of medicinal and aromatic plants whose pharmacological potential can enrich positive impacts worldwide by providing health and wealth to mankind. The immense quantity of phytochemicals present in these plants has the ability to treat almost diverse range of diseases in an ecofriendly way. The indigenous knowledge of these plants is a hope of the current era to look forward for different health benefits. These aromatic plants contain different herbs, spices and the most important essential oils which act as a prevention or therapy of different range of diseases from cough, cold fever to heart, respiratory, nervous disease and even viral diseases such as HIV. Since long time these were used, but now with rising population it needs to be upgraded at upstream level. Aromatic plants and herbs are important natural resources having potential to be used in industry at a large scale. It is getting popularity day by day as compared to synthetic medicine and other products. Industries such as pharmaceutical industry, food industries are focusing more on aromatic plants. Cultivation and marketing of aromatic plants will raise the economy of global market making it prosperous along with sustainable development and thus serving the mankind. However, these medicinal plants and their compound needs rigorous standardization protocols along with their extraction process of phytocompounds in order to achieve a fruitful and standard result which make it easy for the large- scale industry for their upstream process to begin. More and more *in vitro* research needs to be done in disease treatment and prevention from different bioactivity properties of standardized bioactive extracts of aromatic plants. More the research, more the data and hence more the reliability and confirmed efficacy of aromatic extract, thus more the herbal drug compatible with the sustainable environment and human being. Hence there will be harmony and development in the field of pharmaceutical and other areas such as cosmetic and food industry thus satisfying the demands of consumers for a cheaper, readily available and nature- based product or drug.

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Chapter 6

THE AGROTECHNOLOGY OF SOME AROMATIC CROPS

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ABSTRACT

The aromatic plants are valued for the quantity and quality of inherent natural volatile or essential oil which contains a range of chemical compounds. The essential oil can be extracted from leaves, flowers, seeds, bark, fruits, roots by several methods such as, steam distillation, solvent extraction, supercritical fluid extraction, pressurized liquid extraction (PLE), etc. based on suitable methods. In the present situation, the demand of essential oils of aromatic plants is high, both in national and international market. These aromatic plants are valuable and mainly utilized in food industry, cosmetics, perfumery, beverages, soft drinks, ice-creams and in aromatherapy. In this chapter, botanical species, cultivation technique, climatic condition, chemical constituents, uses, distillation methods of important aromatic plants have been discussed.

Keywords: aromatic plants, botanical species, uses, agro-technique, climatic condition, chemical constituents, distillation methods

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SCENTED ROSE

Botanical Name	*Rosa damascena, R. gallica, R. centifolia, R. moschata*
Family	Rosaceae
Chromosome No.	*Rosa damascena*: 2n=28

Introduction

Rose is one of the oldest flower crops which are still in cultivation and continues to be the most preferred crop both in the international and domestic market. It is valued for its exquisite fragrance and beauty worldwide. The genus Rosa, belonging to the family of Rosaceae has more than hundreds of species and thousands of cultivars. Although the genus Rosa has more than hundreds of species, only few of them are highly scented and have found application as essential oil. Scented rose species are highly-prized for essential oil production and as garden roses. Some of the scented species are *Rosa damascena* Mill., *R. gallica* Linn., *R. centifolia* Linn., *R. moschata* Herrm., *R. bourboniana* Desportes., *R. chinensis* Jacq., and *R. alba* Linn. (Kaur et al. 2007).The rose essential oil is one of the most valuable flavour and fragrance products used. Some of the products from scented rose include rose oil, rose water, rose concrete, and rose absolute which are used in food industry, cosmetics, perfumery, beverages, soft drinks, ice-creams and in aromatherapy.

Botany

The genus Rosa represents hundreds of species of prickly shrubs, evergreen or deciduous that may either have a climbing, rambling or trailing habit. Leaves are alternate, pinnate, with 3-15 leaflets and basal stipules. Leaflets have serrated margins with few thorns on the underside of the stem. Most of the rose species have five petals, except of *Rosa sericea* which has 4 petals. Stamens and pistils many in number and ovary is inferior. Flowers may be white, pink, red, yellow, orange, etc. and seeds are produced in a fleshy percicarp called as rose hips. Rose hips contain 5-25 seeds and are a rich source of vitamin C.

Rosa damascena is a deciduous shrub that grows up to 2.0 m with strong shoots covered with hook type thorns. Leaves are pinnate with five leaflets which are oval and toothed. Flowers are large, born in clusters, highly fragrant, semi double, with a colour ranging from blush white to deep pink with stripes.

Rosa moschata, also known as 'Musk rose' has a distinct musky scent that emanates from the stamens and is highly valued species. Plant habit is a shrub that grows up to 3.0

m, with straight or slightly curved prickles, light or greyish leaves and 5-7 ovate shaped leaflets. Flowers are single, loose cyme or corymb that bears on new growth.

Rosa gallica (French rose) is a large deciduous shrub with prickles and glandular bristles. Leaves are pinnate with 3-7 leaflets. Flowers are borne in clusters, deep pink in colour and are highly fragrant.

Rosa centifolia, a complex hybrid, is a shrub with a height of 1.5-2 m. Leaves are pinnate with 5-7 leaflets. Flowers are round, globular, usually pink and highly scented.

Origin and Distribution

The genus *Rosa* is endemic to the cooler regions of Northern Hemisphere viz. Europe, Asia, Middle East, North America, with the maximum number of diversities being found in Western China. However, there are no known species of rose occurring in Southern Hemisphere. It is widely grown in Middle East countries, Bulgaria, Russia, Egypt, France, Morocco and India. *Rosa damascena*, one the highly preferred species for essential oil extraction has been reported to have originated from Asia Minor which later on was introduced to Central Europe. *Rosa moschata* have their origin in western Himalayas, while *Rosa gallica* is native to Southern and Central Europe. *Rosa centifolia* and *Rosa alba* is widely spread near Caucasia and Asia, respectively.

Flowering and Fruiting Period: March- April in Plains; April-May in Hills

Agro-Techniques

Scented roses grow well in mild climatic regions with a good amount of sunlight. The ideal temperature for growing scented roses ranges from 19-27°C. Low night temperatures during the flowering period result in the reduction of oil synthesis considerably. A relative humidity of 65-70% is considered optimum for good harvest of scented roses. Rain and dew during its blooming period enhance its quality.It can be grown in a wide range of soil types ranging from sandy to clay loam. However, it grows best in well drained, rich loam soil with slightly acidic to alkaline soil of pH 6-7.5.

Damask rose cultivars can be propagated through stem cutting, budding and grafting. Cuttings of 20-25 cm length and thickness of 0.75-1.25 cm are prepared from one-year-old stems. It is taken during November- December and takes about 3 months for the root initiation. The plants are ready for transplanting in the main field in about 9- 12 months. Ideal temperature for proper rooting and growth of cuttings is 19- 27°C and a humidity of above 60%. Damask roses are a heavy feeder of fertilizers. For its proper growth and development, it requires 200 kg N, 100 kg P_2O_5 and 50 kg K_2O per hectare under Indian soil conditions. In addition, micronutrients are also supplied that influences the crop growth as well as quality attributes viz., length and thickness of stem, colour, and longevity of flowers. The suggested micro nutrient concentrations in the soil for the roses are as follows: boron 0.05- 0.5, iron 0.3- 3.0, manganese 0.2- 3.0, and zinc 0.03- 3.0, copper 0.001- 0.5, and molybdenum 0.01- 0.1 ppm (Karlik et al. 2003). *Rosa damascena* plants face a severe weed infestation during their early stages of growth and development and more particularly during the monsoon season. Uses of organic mulches are recommended to reduce the weed population and to make hand weeding easier. Alternatively, application of herbicides like Simazine or Atrazine @ 3 kg a.i. ha-1 in light soils and 5 kg a.i. ha-1 in medium and heavy soils are also used to control weeds.

Scented roses are prone to attack by black spot (*Diplocarpon rosae* Wolf), rust (*Phragmidium mucronatum* Pers.), mildew (*Sphaerotheca pannosa* Wallr.) and botrytis blight (*Botrytis cinerea* Pers.: Fr.). Fungal diseases can be controlled by regular spray of 1% Bordeaux mixture or 0.2% Mancozeb. Oil bearing roses are also attacked by a number of insects *viz*. aphids, cane borer, scale insect, chafer beetle, and red spider mite.

Pruning is a very essential practice in roses in general to induce artificial dormancy and to get the maximum yield of flowers. It is also carried out to attain proper shape of bushes and to promote branching. During October - January, rose plants are pruned to a height of 60–75 cm, with six to eight main branches that facilitates flower picking. The pruned plants take 70- 90 days to flower after pruning. The commercial bearing starts after the third year of their growth. *Rosa damascena* flowers are harvested once a year, commencing in the second week of March through early June. The ideal stage of harvesting is blossoming stage.Flowers are picked early in the morning for maximum recovery of oil. Average yield of the scented roses varies from 2000-3000 kg/ha; however, the improved varieties has been reported to give yield of 5000 kg/ha under Indian conditions. It takes about 3000 kg of rose petals to yield one kg of rose oil.

Chemical Constituents Structure of Major Compound(s)

Rose essential oil is composed of more than hundreds of chemical components and phenyl-ethyl alcohol is one of the major components of rose oil. The other main components are citronellol, nerol, phenyl ethyl alcohol, geraniol, heptadecane, nonadecane, heneicosane, linalool, geranial, methyl eugenol, eicosane, eugenol, heptacosane, tricosane and geranyl acetate. The key flavour components that contribute to the distinctive scent of rose are beta damascenone, beta-ionone and rose oxide. Many others are present only in trace amounts but are very important for the overall quality of the oil. An example is the compound damascenone, which is an important odour constituent and is only present in minute amounts.

Table 1. Chemical composition of *Rosa* species

Crop	Chemical constituents
Rose	Citronellol, geraniol, nonadecane/1-nonadecene, nerol, heneicosane, phenyl-ethyl alcohol, methyl eugenol, ethanol, eugenol, heptadecane, alfapinene, geranyl acetate, linalool, farnezole, terpinene-1-ol-4, citronelyl acetate, neryl acetate, linalyl acetate, free acids, geranial, neral, ketones, phenols phenol esters, hydrocarbons, rose oxide and steroptene

Methods of Oil Extraction

Different traditional and modern methods are being adopted for extraction of rose oil.

"Hydro-distillation" is the most widely used and economical extraction method ofrose essential oils. This whole method is carried out in still. Coils inside the bottom of the still carry the steam which heats the water in the still. In this method, fresh rose flowers are placed in the chamber and heated either by placing it in water which is brought to the boil or by-passing steam through it. The heat generated from the steam causes the tiny intercellular spaces that hold the essential oils to burst and break down which releases the essential oils. The essential oil molecules along with the steam are carried along the tube into the condensation chamber, where they are collected in a liquid form once it cools down. The collected liquid is a mixture of oil and water known as hydrosols. The rose water obtained from hydro distillation unit has a thin layer of rose oil on the surface of rose water. Essential oils which are lighter than water will float on the surface and can be recovered by using organic solvent (n-hexane).Oil is separated from organic solvent (n-hexane) by using process of distillation in a recovery evaporator. Remaining traces of n-hexane can be removed by bubbling nitrogen gas through this oil. Consequently, rose water is a by-product obtained during the hydro-distillation of rose flowers to produce rose oil. Rose water contains very little rose oil.

"Solvent extraction" method is employed to yield concretes, absolutes and resinoids. Hydrocarbon solvents such as hexane, petroleum ether, benzene are used for extraction. This method involves the use of Soxhlet's apparatus where freshly harvested rose petals are placed in the cylinders. A hydro-carbon solvent such as n-hexane is kept in the flask which is evaporated and vaporized through the side tube into the condenser where the rose petals are kept. The vapours pass through the rose petals which soften the cell and allow the extraction of all the volatile compounds from petals. As the time increases the vapour production increases which extract the oil from the petals at the boiling point of the water. The volatile compounds are deposited in the flask along with the solvent. This product is called concrete which is a semi solid wax like substance. Further extraction of the concrete is carried out through a distillation process using a rotary evaporator to recover solvent from concrete oil (organic solvent + Rose oil). The concrete is added in the rotary evaporator which is set at a temperature of 50°C which separates the solvent from concrete oil. The remaining traces of solvent can be recovered by increasing temperature of rotary evaporator. The last traces of solvents were removed by bubbling nitrogen gas through the oil. Rose absolute is a product obtained from the concrete with ethyl alcohol extraction. To recover the absolute oil from concrete, absolute alcohol is added to concrete to dissolve and absorb the fragrant material from the concrete. The oil is filtered and absolute alcohol is evaporated off under vacuum. The thick, viscous, reddish coloured liquid with a typical rose odour known as the absolute is left behind.

The method of “Super Critical Carbon Dioxide Extraction” has been introduced recently to produce extracts for food, pharmaceuticals and for perfume industry. Oils recovered through this method is considered to be superior, pure, free from residues of carbon dioxide and very close to the natural essential oil as it exists in the plant. More recently, method of ‘Hydro-diffusion/Percolation’ is being used for rose essential oil extraction which is considered to be faster and simpler method than other techniques. In this method, steam spray is passed through the plant material (which is suspended on a grind) from above. The emerging liquid composed of oil and condensed steam is then cooled. The result is a mixture of essential oil and waste (as in the distillation process) which can be easily separated.

LEMON SCENTED GUM

Botanical Name	*Eucalyptus citriodora*
Family	Myrtaceae
Chromosome No.	2n=22

Introduction

The genus Eucalyptus is a group of large evergreen hardy trees with over 700 known species. Eucalyptus is derived from two Greek words *viz.* ‘eu’ means ‘well’ and “kalyptus” meaning “I cover”; which refers to the lid of operculum which seals the flower till it blooms. They are used worldwide as a major source of pulp wood for high quality paper production, for construction and fuel, essential oil extraction and as medicine. Amongst these known species, *Eucalyptus citriodora* is one of the economically important species in trade and commercial cultivation for both medicinal and perfume properties. The term *Eucalyptus* oil denotes three distinct group of essential oils *viz.* medicinal-type, perfumery-type and phellandrene-rich type. *Eucalyptus* has been valued as a rich source of essential oils and more particularly ‘hydroxy citronella’ used in manufacture of high-grade perfumes. Essential oils of various species have been used in the pharmaceutical, cosmetics, food, industries and medicinal purposes. Essential oils of

Eucalyptus species possess the properties of being diaphoretic, disinfectant, anti-malarial, antiseptic, analgesic, anti-inflammatory, antibacterial, expectorant and antioxidant properties. *Eucalyptus* gum is used for diarrhoea and as an astringent in dentistry.

Botany

Eucalyptus citriodora is a broadleaf tall evergreen tree that attains a height of nearly 60 m. Trees are slender, straight with clean bole and smooth greyish white bark, shedding in strips or irregular flakes. Matured leaves alternate, drooping or straight, often curved or sword shaped and leathery in texture. Immature young leaves are broad, opposite, sessile, cordate-ovate, and glacous-grey. Leaves have a distinct citrus scent when crushed. Flowers are small, rarely single, and white-coloured borne in 3-5 umbels. Axillary umbels are enclosed at the outset within envelope like bracts, which disappears as soon as the umbels begin to grow. Fruits formed in depressed disc, surrounded by a woody, cup shaped receptacle known as calycine rings. It contains numerous minute seeds.

Flowering and Fruiting period: April-August

Origin and Distribution

Eucalyptus have a natural latitude range from 7˚N to 43˚39' S. The large genus of *Eucalyptus* is native to Australia, Tasmania, New Guinea and the neighbouring islands. From these places it has been introduced to many countries and are now grow worldwide, particularly in subtropical and warm temperate regions. *Eucalyptus citriodora* has been introduced to India as a source of firewood from Tasmania and Australia. At present, it is grown all throughout the country wherever sufficient soil moisture is present.

Agro-Techniques

The genus *Eucalyptus* as a whole has a very extensive altitudinal range from sea level up to 2,000 m, suitable for moderate rainfall regimes of 700-1,500 mm and will grow on a wide range of soils and low nutrient status. *Eucalyptus citriodora* prefers a well-drained, fertile soil with a pH range of 6.0-7.5. The tree can survive a severe dry season for 5-7 months and hence can be cultivated in drought affected areas and waste lands. It can withstand a temperature of 29-39°C and light frosts. Eucalyptus can be propagated through vegetative means or by seeds. Commercially, propagation is done by seeds which can be done round the year. Seeds are sown in nursery beds filled with a mixture of 1:1 ratio of fertile soil and sand. Germination starts in 10-15 days and is transplanted to polybags when they are of 5-7 cm in height. Seedlings are ready for transplanting to the main field after 4-5 months when they reach a height of at least 1 foot and have 5-6 true leaves. Pit size of 30 x 30 x 45 cm is dug and spacing of 2m x 2m is followed. Time of planting is the onset of monsoons but with irrigation facilities, it can be planted any time. Eucalyptus responds well to application of nitrogen and phosphorous. General recommended dose is 200 g of NP per tree at planting time for its good growth and establishment. Eucalyptus is slow growing and does not have the ability to cope up with weed growth, thereby facing a serious weed problem. During the initial years of planting, extensive weeding (2-3 times or more) has to be carried out in high rainfall areas. For good yield and returns, a copious irrigation should be given specially during summer or hot dry season. Thinning is carried out to get larger sized and straight poles after one year of planting. Eucalyptus responds well to coppicing and in India, coppice rotation is followed to a maximum of three times. After three rotations, the below ground biomass is taken out and replanted with seedlings. Coppicing is carried at a height of 20 cm above ground level with a slanting cut to ensure that rainwater does not cause rot. Following the development of successful coppice shoots, reduction of the number of shoots might be necessary. For pole production this would be down to 1-3 shoots, for biomass production, the upper limit is more flexible. After the shoots reach utilizable size they are normally removed in a single operation, throughout the crop. In the initial years, the space can be used for intercropping of shade loving crops like ginger, turmeric, medicinal and aromatic plants.

Leaves are the economic part and are used for essential oil extraction. The trees reach maturity after 3-5 years of planting. The oil content is the highest at higher temperatures and harvesting should be done from June to September after which it drops down as winter approaches. The trees are not allowed to mature to timber stage for the purpose of oil extraction. Instead, they are lopped for foliage and the sucker shoots produce copious foliage. The leaves are collected for distillation and are dried in shade for one day and processed. The yield of essential oil ranges from 0.75 to in 1.25%.

Chemical Constituents Structure of Major Compound(s)

The volatile oils in Eucalyptus are secreted in the leaf cavities which are present in abundance in the leaf mesophyll. Depending on the species, oil content ranges from 0.1-7% of the fresh weight of the leaves. The main constituent of the volatile oil of Eucalyptus is 1, 8-cineole. Beside 1, 8-cineole, the oil contains cymene, α-pinene, β-pinene, α-terpineol, limonene, geraniol, camphene, estragole, eugenol, aromadendrene, cuminaldehyde, globulol, pinocarveol, citronellal, citronellol, isopulegol, citronellyl acetate, caryophyllene and bicyclogermaerene.

Method of Oil Extraction

Essential oils from the leaves of Eucalyptus are extracted though hydro-distillation method. Fresh and healthy leaves was harvested and washed with water. The leaves are drained free of water and kept refrigerated for one night and on second day, it is taken out and shade dried under a fan for an hour. The dried leaves are then chopped in to different sizes like 2.5 cm, 2.0cm, 1.5cm and 0.5cm. Hydro-Distillation process is carried out using Clevenger apparatus. For this, distilled water is taken in round bottom flask and the finely chopped leaves are placed in the flask. The pipe connecting the flask to the condenser and mercury thermometer is inserted in hole of the flask. Thereafter, heating mantle was switched on and working temperature maintained at 100ºC and distillated for one hour. The sample starts boiling within 5 minutes and the vapors are formed. The vapours are cooled down with the help of condenser and the condensed material collected at the end of setup. The end product is a mixture of oil and water which has to be separated by rotary evaporator.

GERANIUM

Botanical Name	*Pelargonium graveolens* L.
Family	Geraniaceae
Chromosome No.	2n=8x=88

Introduction

Rose scented geranium (*Pelargonium spp.*) is an aromatic shrub having rose like odour valued for its medicinal properties. It belongs to the family Geraniaceae and is a native of South Africa. About 700 species of geraniums have been reported but only 10 species viz. *Pelargonium odorantissimum, P. graveolens, P. aspermum, P. graveolens, P. crispum, P. radula, P. capitatum, P. roseus, P. tomentosum, P. zonale and P. roseum* are used for essential oil extraction. The commercial oil of geranium is obtained from *Pelargonium graveolens*, L. Herit. Several cultivars of geranium are commercially grown for the production of essential oil. The main cultivars of geranium are the Reunion/Bourbon type (best quality oil), the African type (Egypt, Morocco) and the Chinese type. In India, three cultivars of geranium are available *viz.* Bipuli (Reunion type), Hemanti (Algerian type) and Kunti (Egyptian type) (Sharopov et al. 2014). Essential oils of *Pelargonium* have a lot to offer in terms of health as herbal medicine, in cosmetic industry, perfumery, aromatherapy, food and beverage industry. *Pelargonium* has the properties of antibacterial, antifungal, antidepressant, antiseptic, antioxidant activity and anti-malarial. Traditionally, the plant has been used to treat a variety of symptoms including nephritis, wounds, fever, colds and sore throats, inflammation, heavy menstrual flow, hemorrhoids, dysentery, cancer gastrointestinal diseases, hyperglycemia, insomnia, heart disease, asthma, nausea and vomiting, fever and tuberculosis to name a few.

Botany

Pelargonium graveolens is an erect, aromatic herbaceous shrub reaching a height up to 1-1.5 m with a plant spread up to 1m.Leaves are simple, alternate, soft to touch with numerous glandular trichomes. The stem is cylindrical, woody at the base, pubescent, green when young and turning brown with age. Inflorescence type is umbellate and flower is bisexual, hypogenous, with a pink corolla. There are 10 stamens, the filaments are sub equal, united at the base; the anthers are 7, dithecous and shed easily.The ovary is hairy, superior, pentacarpellary and syncarpous; the style is hairy, breaking up distally into five stigmata. The oil is obtained from leaves, flowers and stalks.

Flowering and Fruiting Period: Feb-March and September

Origin and Distribution

The genus Pelargonium are known to have originated from South Africa and from nearby countries. The majority of Pelargonium species are found growing naturally in the Cape region. From there, the cultivation has been spread to other countries and now is commercially cultivated in France, Belgium, Spain, Morocco, Madagascar, Egypt, Reunion Island, Congo, China, India and the former USSR countries.Geranium was introduced to South India around 1900s where it got acclimatized. In India, it is being cultivated in Nilgiris, Pulney hills of Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra and Uttar Pradesh.

Agro-Techniques

Geranium prefers a well-drained, porous red laterite soil with a pH range of 6-8. The ideal temperature for best growth of geraniums ranges from 5 to 25ºC and a relative humidity of 50-60%. The crop is very sensitive to frost. Geraniums are propagated through terminal cuttings (20 cm long with 7-8 nodes). The cuttings can be treated with rooting hormones like IBA, IAA 100-200 ppm to enhance the rooting. The time of taking the cuttings is November-December in plains and March-April/August-September in hills. Rooting takes place after 40-45 days and can be transplanted to well-prepared raised beds of soil and FYM. Spacing adopted is 60x60 cm which can accommodate nearly 30,000 cuttings per hectare. Irrigation should be judiciously given during the initial stages and thereafter, given according to the weather conditions. The crop is drought tolerant but cannot tolerate water logging, excessive rain and frost. Intercropping with garlic, cowpea, blackgram, and marigold has been found to be beneficial. Weeding should be done regularly to keep the field weed free. The crop responds well to application of fertilizers and the dose varies according to the soil types. CIMAP KodaikanalCentre recommends basal application of 120 kg N, 60 kg P and 60 kg K per hectare. The frequency of application is three splits for N to be applied at 1/3rd at planting, 1/3rd after first harvest and 1/3rd after second harvest. Under Bangalore conditions, recommended dose is 150 kg N, 40 kg each of P_2O_5 and K_2O per hectare per year which should be applied at the time of planting. Nitrogen is applied in six equal splits at two monthly intervals. In Hyderabad, FYM @10t/ha along with 100 kg N/ha and 40 kg each of P_2O_5 and K_2O is recommended. Nitrogen is applied in four splits 1/3rd after planting and remaining after every harvest. Geraniums are relatively resistant to pest and diseases except for wilt caused by *Fusarium oxysporum* var. *rodolens* and *Botrydeplodiatheobromae*. It can be controlled by either spraying of 0.03% Benlate solution after every harvest or by dipping the cuttings prior to planting in the nursery.

Geraniums are ready for harvesting about 4-5 months after transplanting. Leaves are the commercial part of geraniums that contains the maximum oil followed by petioles and woody parts. Maturity of leaves is judged by the change in color which turns light green and emission of lemon like door when leaves are crushed. Leaves are harvested with a sharp sickle and distillation should be done as soon as possible for maximum oil recovery. The plants after harvest should be maintained following proper cultural operations which will enable the plant to put forth fresh shoots that can later be harvested again. On an average, up to 4 harvests can be taken in a year. Summer harvesting has benefits of higher oil content in geraniums. With oil recovery of 0.1%, 30 kg of oil/ha per year could be obtained by cultivation of geranium.

Chemical Constituents and Structure of Major Compound(s)

The chief constituent of the oil are geranial and citronellol, linalool, citronellyl. The essential oil compositions of *P. graveolens* are given in Table 2.

Table 2. Chemical constituents of *P. graveolens*

Crop	Chemical constituents
Pelargonium graveolens	Limonene, Linalool, Rose oxide, Phenyl ethyl alcohol, Menthone, Isoborneol, Borneol, Isomenthone, α-Terpineol, Endo-Fenchyl acetate, Citronellol, Geraniol, Citronellylformate, Geranyl formate, Geranyl acetate, β-Bourbonene, Phenyl ethyl isobutanoate, (e)-Caryophyllene, Citronellyl propanoate, Allo Aromadendrene, Geranyl propanoate, Neryl isobutanoate, Epizonarene, Zonarene, Citronellylbutanoate, Geranylbutanoate, 2-Phenyl ethyl tiglate, α-Muurolol, (e)-Citronellyltiglate, Geranyl tiglate

Method of Oil Extraction

The essential oil of *Pelargonium graveolens* is obtained by hydro-distillation of the fresh herbage. The freshly-harvested terminals are cut into small pieces and immediately transferred to round bottom flask of the distillation unit. Water was added till the plant material was completely submerged and then subjected to hydro-distillation. The material has to be distilled for 3 hours after reaching the boiling point. The oil volatilizes and escapes along with the steam vapors, which is later condensed by passing it through a condenser with running cold water.The condensed oil is separated from the water by the differential density method and clarified by filtering it with activated carbon. The chemical composition of the obtained essential oil can be determined by gas chromatography and mass spectrometry.

JASMINE

Scientific Name	*Jasminum spp*
Family	Oleaceae
Vernacular Name	*Jasminum grandiflorum* Linn: (Spanish jasmine, Chameli, Jati, Jathimalli (or) Pitchi) *Jasminum sambac*: (Arabian jasmine, Indian jasmine, Sampaguita, Mogra, Gundumalli/Malligai) *Jasminum officinale*: (Royal jasmine, Summer jasmine, White jasmine, Hindi: Juhi; Bengali: Gunica)
Chromosome No.	*J. grandiflorum, J.sambac* 2n=26

Introduction

Jasmine flowers are one of the important traditional flowers highly valued for its fragrance, as loose flowers and as medicine. Jasmine has been derived from Arabic word 'Yasmyn' which means fragrance and is considered as "the perfume of love" by the Hindus and Muslims. Jasmine belongs to the family Oleaceae comprising of 29 genera and about600 species. The jasminum plants may either be a shrub, climbing or trailing type and native to tropical or warm temperate regions. *Jasminum grandiflorum, Jasminum sambac* and *Jasminum officinale* are amongst the hundreds of species commercially important for the production of essential oils. Essential oil of *Jasminum* species has been described as heavenly smelling, exotic, exquisite, sensuously rich, intense and intoxicating. Jasmine oil is widely used in various industries viz. perfume, soap, cosmetics and as flavoring agent and in hair oils. *Jasminum* species has medicinal benefits as well and used to treat ailments like amenorrhoea, ringworm, leprosy, skin diseases and also as an analgesic, antidepressant, anti-inflammatory, antiseptic, aphrodisiac, sedative, expectorants, diuretics and among others.

Botany

Jasminum grandiflorum is a scrambling nearly erect shrub that grows up to a height of 2-5 metres. The leaves are imparipinnate, opposite, long, entire ovate to somewhat elliptic in shape, glossy green. Flowers are borne terminally and axillary cymes with long, linear calyx lobes. Flowers are pinkish white in colour. Fruit is a 2 lobed berry, ellipsoid and black when ripe.

Jasminum officinale is a large sprawling, twining shrub and deciduous. Branchlets are angular or grooved, glabrous, sparsely pubescent or appressed hairy. Leaves opposite, pinnate with 3-7 leaflets ovate or lanceolate, acute or acuminate. Inflorescence is terminal corymb or cyme. Flowers are star shaped, white or pale pink and have fragrance. Fruits are ovoid in shape and turn black when ripe.

*Jasminum sambac*is an evergreen bushy vine or sub-erect shrub that reaches a height of 1-3 m. Leaves are smooth and dark green throughout the year; ovate, arranged oppositely or in whorls of three, glabrous, shining above; nerves prominent beneath with short petioles. The waxy snow-white flowers are highly fragrant and produce blooms throughout the year. Flowers are borne in 3-12 clusters together in terminal cymes. Fruit's type is berry, 2 lobed, dark purple to black when ripe.

Flowering and Fruiting Period: *J. grandiflorum*: June-October; *J. officinale*: June-August; *J. sambac*: Throughout the Year

Origin and Distribution

Jasminum species are native to tropical and warm temperate regions of Europe, Asia, Australia and Africa with the greatest diversity in India and China. India is one of the important centres of origin where nearly 40 species have been reported. *Jasminum sambac* (Arabian jasmine) is native to India, Myanmar, South West Asia, Sri Lanka and Phillipines. *Jasminum officinale* (Royal jasmine) is native to Georgia, China, Tajikistan, Afghanistan, Iran, Iraq, Turkey, Bhutan, India, Nepal and Pakistan. The famous Spanish jasmine (*J. grandiflorum*) is native to India, France, Italy, China, Japan, Morocco and Egypt.

Cultivation of different jasmine species is distributed worldwide and is being grown in France, Italy, Morocco, Algeria, North Africa, Egypt and Spain. In India, commercial cultivation is taken up in states like Tamil Nadu, Karnataka, Andhra Pradesh, Madhya Pradesh, Bihar and West Bengal.

Agro-Techniques

Jasmine performs well under mild tropical climate and is grown under open field conditions. The crop does well in sandy loam and red loam type of soils with a pH range of 6.5-7.5. It grows best under mild winter, warm summer with a good amount of sunshine. It requires a well distributed annual rainfall of 1000 mm and can be grown up to a height of 1200 m. Jasmines is commercially propagated either by cutting or layering. Layering (simple or compound) is done two times in a year viz. June-July and October-November. For layering, matured one year old shoots are chosen, given a slanting cut and is buried in 10-15 cm soil. Layers take root after 90-120 days and can be planted. Most of the commercial jasmine species viz. *J. grandiflorum*, *J. officinale*, *J. sambac* are propagated by terminal cuttings except of *J. auriculatum* which is propagated by semi hardwood cuttings. Cuttings are taken from April onwards till September from the terminal portion having a length of 15-20 cm with 3-4 nodes. To enhance the rooting, hormones like NAA @ 500 ppm or IAA @1000 ppm can be used. Rooting takes place after 4-6 weeks and is ready to be transplanted in the main field after 4-5 months. Pit size of 45 cm^3 are dug one month before planting and filled with FYM, soil and coarse sand (2:1:1). Jasmines are best planted during monsoon time June-August. Spacing adopted for *J. grandiflorum* and *J.officinale* is 2.0 x 1.5 m and for *J. sambac* is 1.5x1.5 m. The recommended dose of fertilizer for different jasmine species are as follows:

J. auriculatum- 60:120:120 g/plant of N, P_2O_5, K_2O in 6 split doses at bi-monthly interval

J. grandiflorum- 100:150:100 g/plant of N, P_2O_5, K_2O in 2 split doses viz. June-July and after pruning in December

J.sambac- 60:120:120 g/plant of N, P_2O_5, K_2O in 2 split doses viz. June-July and after pruning in November

In addition, micronutrient spray of zinc 0.25% and magnesium 0.5% before flowering is advisable to get higher yield of flowers. There should be adequate soil moisture in the jasmine field and flood irrigation once in a week in summer can be done. Weeding is another essential operation that can be solved with the help of using mulch materials or chemically. To stimulate growth and flower bud initiation and differentiation, pruning should be done at 45 cm from the ground level and removing the leaves. Time of pruning varies from end of November to last week of January depending on different species. Jasmine plants are prone to attack by bud worm (*Hendecasis duplifasciallis*), red spider mite (*Steneotarsonemus pallidus*), blossom midge (*Contarinia maculipennis*) and leaf webber (*Nausinoe heometralis*). Common diseases include leaf blight (*Cercospora jasminicola* and *Alternaria jasmine*), wilt (*Fusarium solani*), Alternaria leaf spot and root rot. Blight and wilt can be controlled by spraying or soil drenching with Bordeaux mixture 1%, while, root rot by soil drenching with copper oxychloride 2.5g/l and leaf spot by foliar spray with Mancozeb 2.5g/l or Azoxystrobin 1g/l.

Jasmine flowers reach the commercial bearing age by third year and keep giving yield up to 12 years with good management practices. For the purpose of essential oil extraction, fully opened flowers should be harvested in the morning hours. Yield of jasmine flowers varies according to the species viz. *J. auriculatum*- 4636 – 9022 kg/ha; *J. grandiflorum*: 4329 – 10144 kg/ha and *J. sambac*: 739 – 8129 kg/ha.

Chemical Constituents Structure of Major Compound(s)

More than 100 chemical constituents are found in jasmine oil, but the main chemical components are benzyl acetate, linalool, benzyl alcohol, indole, benzyl benzoate, cis-jasmone, geraniol, methyl anthranilate and trace amounts of p. cresol, farnesol, cis-3-hexenyl benzoate, eugenol, nerol, ceosol, benzoic acid, benzaldehyde, y-terpineol, nerolidol, isohytol, phytol etc. The chemical composition recovered from different jasmine species and plant parts as reported are given in Table 3.

Method of Oil Extraction

Jasmine flowers have very fewer essential oils and take approximately 10000 flowers to yield 1 kg of concrete jasmine. The aromatic properties in jasmine are extracted using a chemical solvent and their end product is known as an absolute that contains essential oil along with other plant constituents. Extraction of jasmine oil firstly yield 'concrete', which is made by solvent extraction, after which an 'absolute' is obtained from the concrete, by separation with alcohol. The essential oil is then produced off the absolute by steam distillation.

Solvent Extraction

Fully blossomed flowers are used for oil extraction and concrete. A hydrocarbon solvent such as hexane is added to the plant material to help dissolve the aromatic compound in flowers. On evaporation of hexane, “concrete” remains as a combination ofwax, semisolid substance and essential.The concrete is repeatedly washed in warm alcohol (ethanol) which allows extraction of the volatile aromatics from the concrete while leaving behind the non-polar plant waxes which do not dissolved in the ethanol. When the alcohol evaporates, the oil is left behind which will typically have 1-5% ethanol remaining in it and sometimes a trace of hexane.

Another advanced method adopted for extracting essential oils from jasmine is the *hydro-distillation* method which has the advantage of its ability to maintain the original quality of plants. In this method, fully opened flowers are harvested, dried and ground and kept inside a 1000 ml globe jar. The hydro-distillation process is carried out at the flower water ratio of 1:1 to 1:5 at a temperature range from 110°C to 150°Cfor 4 hours to 8 hours. After the distillation process is over, the essential oil is collected, dehydrated by Na_2SO_4 and stored in the jar.

Table 3. Chemical composition of *Jasminum* species

Species	Plant part	Chemical composition
Jasminum grandiflorum	Leaves	2”-epifraxamoside, demethyl-2”- epifraxamoside, jasminanhydride, oleacein, 2-(3, 4- dihydroxy phenyl)-ethanol, isoquercitrin, ursolic acid, resin, salicylic acid, jasminine, indole oxygenase, 3, 4- dihydroxy benzoic acid, 2-hydroxy-30, 40-dihydroxyacetophenone and oleanolic acid
	Flowers	Cis-3-hexenol, 2-vinyl pyridine, indole, myrcene, linalool, geranyl linalool, α-terpineol, geraniol, linalyl acetate, nerolidol, phytol, isophytol, farnesol, eugenol, benzyl alcohol, p-cresol, methyl benzoate, benzyl cyanide, benzyl acetate, methyl dihydrojasmonate, methyl anthranilate, jasmone, methyl- N-methyl anthranilate, vanillin, cis-3-hexenyl benzoate, benzyl benzoate, methyl palmitate, methyl linoleate, jasgranoside, jaspolyoside, 8-epi-kingiside, 10-hydroxy-oleuropein, 10-hydroxyligstroside, oleoside-7,11-dimethylester, 3-O-α-L-rhamnopyranosyl(1→2)-β-D-xylopyranosyl-hederagenin-28-O-βD-galactopyranosyl(1→6)-β-D galactopyranosylester,hederahederagenin-3-O-β Dglucopyranosyl(1→3)-α-L-arabinopyranoside, 2-α,3β,23-trihydroxyolean-12-en-28-oic–O-βD-glucopyranosyl ester, hederagenin-3-O-β-Dxylopyranosyl(1→3)-α-L-rhamnopyranosyl (1→2)-α-L-arabinopyranoside, 2α,3β,23-trihydroxyolean-12-en-28-oic–O-α-Lrhamnopyranosyl(1→4)-β-D-glucopyranosyl(1→6)-β-D-glucopyranosyl ester, hederagenin3-O-α-L-rhamnopyranosyl(1→2)-α-Larabinopyranoside[19], kaempferol-3-O-α-Lrhamnopyranosyl(1→3)-[α-L-rhamnopyranosyl(1→6)-β-D-galactopyranoside, kaempferol-3- O-rutinoside, 7-ketologanin, oleoside-11-methyl ester, 7-glucosyl-11-methyloleoside, ligstroside and oleuropein
	Oil	methyl jasmonate, benzyl benzoate, linalool, linalyl acetate, benzyl alcohol, indole, jasmone, methyl anthranilate, Pcresol, geraniol, racemic (5-pent-2-enyl)-5, 1-pentanolide, benzyl benzoate, nerol, 1-αterpineol, d and dl-linalool, γ-jasmolactone, farnesol, nerolidol and eugenol
Jasminum sambac	Leaves	Rutin, quercitrin, isoquercitrin, quercitrin-3dirhamnoglycoside, kaempherol-3- rhamnoglycosides, α-amyrin, β-sitisterol, Chlorocoumarin, coumarin derivative and kaempferol a flavanoidal derivative
	Flowers and buds	Trimeric iridoidal glycoside, sambacoside A, molihuasides A-E, Benzyl 6-O-beta-D-xylopyranosyl-beta-D-glucopyranoside [beta-primeveroside], 2-phenylethyl betaprimeveroside, and 2-phenylethyl 6-O-alpha-Lrhamnopyranosyl-beta-D-glucopyranoside [betarutinoside]
	Stem	2, 3 -Dihydro- Benzofuran, 1-Nonadecene, 2, 6, 10Trimethyl,14-Ethylene-14-Pentadecne,1-Nonadecene, 1-Heptacosanol, alpha.-Tocopherol-.beta.-Dmannoside, Nonacosane were isolated from the leaves, and1-Nonadecene, Nonadecyl trifluoroacetate, 1-Heptacosanol, 1-Heptacosanol, 1Heptacosanol, E-14-Hexadecenal
	Roots	Dotriacontanoic acid, dotriacontanol, oleanolic acid, daucosterol, hesperidin, [+]-jasminoids A, B, C, and D
	Volatile oils	Benzyl alcohol, Cycloheptasiloxane tetradecamethyl- Methyl benzoate, Linalool, Benzyl acetate, Indole, Cyclohexasiloxanedodecamethyl- Hexadeca methyl cyclooctasiloxane, [-]-[R]-Jasmine Lactone, [E,E] Farnsene, [Z]-3-Hexenyl benzoate, N-Acetyl Methyl anthranilate, Cyclohexasiloxane, [E]-Methyl jasmonete Benzyl benzoate andIsophytol

Species	Plant part	Chemical composition
J. officinale	Flower buds	3-O-α-Lrhamnopyranosyl [1→2]-β-D-xylopyranosylhederagenin28-O-β-D-galactopyranosyl[1→6]-β-Dgalactopyranosyl ester; hederagenin-3-O-β-Dglucopyranosyl[1→3]α-L-arabino pyranoside; 2α,3β,23-trihydroxyolean-12-en-28-oic-O-β-Dglucopyranosyl ester; hederagenin-3-O-β-Dxylopyranosyl[1→3]-α-Lrhamnopyranosyl[1→2]-αL-arabino pyranoside; 2α,3β,23-trihydroxyolean-12en-28-oic-O-α-L-rhamnopyranosyl[1→4]-β-Dglucopyranosyl[1→6]-β-D-glucopyranosyl ester andhederagenin-3-O-α-L-rhamnopyranosyl[1→2]-α-Larabinopyranoside, jasgranoside B, 6-O-methy-catalpol, deacetyl asperulosidic acid, aucubin, 8-dehydroxy shanzhiside and loganin, jasgranoside, jaspolyoside, 8-epi-kingiside, 10hydroxy-oleuropein, 10-hydroxy-ligstroside and oleoside-7, 11-dimethyl ester, kaempferol-3-O-alpha-L-rhamnopyranosyl [1→3][alpha-L-rhamno pyranosyl [1→6]]-beta-Dgalactopyranoside, kaempferol-3-O-rutinoside, 7ketolo ganin, oleoside-11-methyl ester, 7-glucosyl-l1methyl oleoside, ligstroside and oleuropein
	Leaves	Secoiridoid glucosides: [20R]-20-methoxyoleuropein,[20S]-20-methoxyoleuropein, oleuropein, ligstroside, demethyloleuropein and oleoside dimethyl ester, a lignan, [2]-olivil and p-hydroxyphenethyl alcohol
	Oil	benzyl acetate; nerolidol; methyl myristate; 7-tetradecene; benzyl benzoate; neophytadiene; perhydrofarnesyl acetone; phytol acetate; nonadecane; geranyl linalool; methyl palmitate; 3,7,11,15- tetramethyl -1-hexadecen-3-ol; hexadecanoic acid; 3,7,11-trimethyl-1,6,10-dodecatrien-3-ol; 3,7,11,15-tetramethylhexadecanoic acid methyl ester; 9,12,15-octadecatrienoic acid methyl ester; heneicosane; Phytol; octadecanoic acid methyl ester; 9,12,15octadecatrienoic acid; docosane; tricosane; tetracosane; pentacosane; hexacosane; heptacosane; octacosane; squalene and nonacosane

LAVENDER (*LAVANDULA ANGUSTIFOLIA* MILLER)

Scientific Name	*Lavandula angustifolia* Miller
Family	Lamiaceae
Vernacular names	True lavender, Common lavender, Medicinal lavender
Chromosome No.	2n=18

Introduction

Lavender (*Lavandula angustifolia* Mill.) is an aromatic plant that has been used and cherished for centuries for exquisite aroma and myriad benefits. The genus Lavenders are a group of about 25 - 30 species of flowering plants belonging to Lamiaceae family. The genus, Lavandula has been derived from the Latin word 'lavo' or 'lavare' which means 'to wash' and was regularly used to perfume bathing water. There are three main species that are important for essential oil extraction viz. *L. angustifolia* (True lavender), *L. latifolia* (spika, broad leaves), Lavandin (*L. angustifolia* x *L. latifolia*). The true lavender oil is derived from *L. angustifolia* and is commercially grown worldwide. Lavender yields a highly effective essential oil with calming scent and is one of the most widely-used essential oils in aromatherapy and the perfume industry. Lavender essential oil is believed to be of benefit for a multitude of problems, including stress, anxiety, exhaustion, irritability, headaches, migraines, insomnia, depression, colds, digestion, flatulence, upset stomach, liver and gallbladder problems, nervousness, loss of appetite, and as a breath freshener and mouthwash. Oil has the properties of antibacterial, antifungal, carminative, sedative, anti-depressive, antilithiasic, hypoglycaemic, anti-rheumatism, anti-inflammatory, antioxidant activities and effective for burns and insect bites. Volatile oil obtained by distillation of inflorescences has wide uses in: perfume industry, aromatherapy, integrative medicine, cosmetics industry, pharmaceutical industry, food industry.

Botany

Lavandula angustifolia is a small evergreen, herbaceous shrub that grows up to a height of 40-80 cm and has highly aromatic foliage and flowers. The plant is woody at the base and semi woody and green in the upper part. Leaves are lanceolate, linear, silvery green, curly edges and sparingly hairy. Plant is highly branch, stiff and has a fibrous root system. Inflorescence of lavender is a spike borne terminally, with 3-5 flowers arranged in circles, mostly pale violet/purple in color and may be available in white or pink. The flowering spikes are covered with brown beard branched in brim, bushy. Fruits are nut, oblong obovate and reddish brown in color.

Flowering and Fruiting Period: June-August

Origin and Distribution

Lavenders have been reported to have originated in poor, rocky soils and mild coastal climates of Mediterranean region (France, Spain, Andorra and Italy). The natural populations of lavenders are found in Southern Europe, Northern Africa, Bulgaria and Russia. The cultivation of lavender is widely distributed in the Mediterranean coast of North Africa and Europe, Turkey, India, Japan, North America and Australia. In India, the plant is successfully cultivated in Kashmir, low rainfall region and hilly slopes of Himachal Pradesh and Uttar Pradesh.

Agro-Techniques

Lavenders are best cultivated under open fields on well-drained, stony calcareous lime-rich soils under full sun. Light, sandy or sandy loam soils with a pH ranging from 6.0-8.0 are suitable for its cultivation. Plants cannot tolerate soggy soil; however, once it is established, they can tolerate drought. Lavender is a temperate plant that prefers cool winter and summers. The plants are very sensitive to high humidity and high temperature and oil quality is adversely affected. Lavenders flowers abundantly in higher altitudes and can be grown successfully up to 1700 m above mean sea level.

Lavenders can be propagated through cuttings, division, layering, seeds or tissue culture. Commercially, softwood cuttings are used as means of propagation. Best time for taking the cuttings is right after the plants have finished their bloom. Cuttings should be taken from strong and healthy stems with no flower's buds on them.Cuttings of 10-15 cm length are prepared by stripping the bottom two thirds of leaves. Rooting hormones can be used to encourage rooting.The cutting is inserted in a well-drained growing medium, comprising of fine compost and sand. Rooting takes place after 3 weeks and can be transplanted to the main field from spring onwards through fall season. Lavenders are generally planted at a spacing of 0.5–1.0 m (2–3 ft) between plants and 1–2 m (3–6 ft) between rows depending on the varieties.Once the plants are established, cultural operations should be followed accordingly. Lavender responds well to pruning and keeps the plant from splitting open and becoming too woody. Flowering takes place on newly emerged shoots making it necessary to be pruned every year. The time of pruning is during the spring when new leaves start to emerge from the base of the plant and one third portion should be removed from the top portion. Lavender can be grown in poor soil conditions; however, it also responds well to fertilizer application.

In India, recommended dose of fertilizers is 100:40:40 kg/ha of NPK as a basal application at the time of planting. Nitrogen 20 kg is applied at the time of planting and remaining 80 kg is to be in four splits at the beginning of each year. Lavender plants are quite resistant to pest and diseases but it is susceptible to soil diseases such as *Phytophthora, Fusarium, Pythium, Rhizoctonia*, etc. Proper care should be taken to avoid over watering and to keep the soil well drained.

In lavender plantation, irrigation is needed for the first one to two years till the time the crop establishes and at flower initiation stage plants must not be water stressed. Weeding should also be carried from time to time either by hand weeding or by mechanical means. Practice of mulching, drip irrigation, cover cropping will decrease weed population. Generally, 2 to 3 weeding are necessary during the year. With good management practices, lavenders are ready for harvest from second year onwards and can stay in the field for nearly 10-15 years. For extraction of essential oil, flower heads should be harvested when only 1/2 to 1/3 of the florets are open. Harvesting should be done in the morning hours when the volatile oil content is most concentrated and when approximately 75 percent of the flower buds have opened. Harvested flowers are bunched, tied into bundles and dried hung upside down in a room with a good air circulation.

Chemical Constituents Structure of Major Compound(s)

The essential oil of lavenders is mainly composed of linalool, linalyl acetate, cineole, camphor and β-ocimene. The composition of oil varies according to the climate and place. In India, the major constituents reported were linalyl acetate (47.56%), linalool (28.06%), lavandulyl acetate (4.34%), α-terpineol (3.75%), geranyl acetate (1.94%), caryophyllene oxide (1.38%) and 1,8-cineole (1.14%), β-caryophyllene (0.93%), borneol (0.85%), epi-α-cadinol (0.70%), nerol (0.59%), terpinen-4-ol (0.56%), β-myrcene (0.55%), limonene (0.55%) and 1-octen-3-ol (0.53%) (Verma etal. 2010).

Method of Oil Extraction

In lavenders, the essential oils are deposited in the secretory glands found in between fine hairs covering the flowers, leaves as well as stems. Fresh as well as dried flowers including the leaves can be used for extraction of oil. Essential oils can be extracted either by steam distillation of hydro-distillation method. The method of steam distillation makes use of steam to vaporize and extract the oil. As the water vaporizes, the steam passes through the distillation flask which contains the plant materials which may be stems, fresh or dried flowers, leaves in lavender. As it passes through, the steam carries both the volatile oils and other plant essences into a receiving container. Once the distillate is cooled off, the essential oils being lighter, floats on top and is siphoned away. The liquid left behind is known as hydrosol.

In hydro-distillation method, freshly harvested plant materials are boiled together along with water in a Clevenger's apparatus for 3 hours for the extraction of the essential oil. The oils obtained were dried over anhydrous sodium sulphate and stored in a refrigerator at 5°C for further analysis.

Solvent extraction is further used to extract the lavender and lavandin concrete by using solvents such as toluene and hexane and petroleum ether. The solvents are evaporated off leaving residues called concretes which are mostly used in the perfumery industry. Absolute, a more concentrated form of oil is obtained by mixing the concretes with ethanol. The mixture is cooled, filtered and the ethanol is evaporated to produce a wax free residue called an absolute which is widely used in fine perfumery.

MENTHA ARVENSIS L. (FIELD MINT, CORN MINT)

Scientific Name	*Mentha arvensis* L.
Family	Lamiaceae
Chromosome No.	2n=72, 96

Introduction

Mentha arvensis is a perennial plant belonging to the Mentha genus and Lamiaceae family. This mint plant is found in various parts of Europe, Asia and North America. Its common names include Field Mint, Wild Mint or Corn Mint. The leaves of this herbal plant have a fresh minty flavor and are used for culinary and medicinal purposes. The essential oil extracted from the leaves also has many uses. *Mentha arvensis* leaves are used asherbal remedy for stomach disorders like indigestion and gas. The leaves are used as anti-inflammatory and used in the treatments of fever, headache, cold and asthma. Leaves are used to make cough syrups. A decoction made from the Field Mint plants are used to treat stomach pain, diarrhoea, vomiting and influenza. It can also be used to reduce toothaches and swellings of gum. The oil extraction of these leaves is used in the treatments of insomnia and nervous tension.

Origin and Distribution

Mint is believed to have originated in the Mediterranean basin and, from there, spread to the rest of the world by both natural and artificial means. Among the mints, Japanese mint is cultivated on a large scale in Brazil, Paraguay, China, Argentina, Japan, Thailand, Angola and India. In India, Uttar Pradesh accounts for around 90% of Indian mint production, with the remaining 10% coming from smaller areas in the Punjab, Rajasthan etc. Although India now produces a wider range of mint types, production is dominated by *Mentha arvensis*.

Agro-Techniques

Corn mint is found primarily on moist soils in full sun. It can be grown in semi-shade (light woodland) or no shade. These plants can survive in cold weather up to -15°C. Propagation of corn mint is generally done through suckers as well as pre-raised plants in nurseries. Best time for planting is during December to January where herb and essential oil is known to be the highest. At the time of land preparation, FYM @50 cart loads per hectare is recommended. Approximately 500 kg suckers are required to plant one ha area. Plants should be spaced 30 cm apart in rows 60 cm apart. In order to keep the top soil loose for better penetration of water, air, sun light and weed free *Mentha* needs frequent inter culturing including weeding and hoeing. Weeds are best managed by combining manual, mechanical and chemical control methods. *Mentha* crop requires considerable moisture well distributed throughout the entire growing season. As roots do not penetrate deep in the soil, light and frequent irrigations are recommended. *Mentha arvensis* leaves can be harvested as soon as they begin growing in the springtime. Approximately 150 kg of Oil per hectare during the first year and subsequently 200 - 250 kg per hectare can be obtained under good management.

Chemical Constituents with Structure

Mentha arvensis leaf and oil contain acetaldehyde, amyl alcohol, methyl esters, limonene, pinene, phellandrene, cadinene, dimethyl sulphide, and traces of pinene, sabinene, terpinoline, g-terpinene, fenchene, citronellol and luteolin-7-O-rutinoside. *M. arvensis* consists of menthol (35-70%), menthone (15-30%), (-)-menthyl acetate (4-14%) and pulegone (1-4%). Flower of *Mentha arvensis* is known to contain linarin (acacetin -7-O--rutinoside).

MENTHA PIPERITA L. (PEPPERMINT)

Scientific Name *Mentha piperita* L.
Family Lamiaceae
Chromosome No. 2n= 72

Introduction

Mentha piperita L., a scent herb of the Lamiaceae family known by the common names of mint, peppermint, spearmint, American mint, brandy mint, lamb mint or lammint may present branches of different colours varying from dark-green to purple-violet. The species is a natural inter specific hybrid involving a cross between *M. aquatica* x *M. spicata*. The leaves are strongly scented due to the presence of essential oils. Mint is widely used for its medicinal properties such as antispasmodic, anti-sickness, anti-helminthic, carminative, stomachic and others. The essential oil is widely used as flavouring and/or additive in foods, toothpaste, and other hygienic products, and in pharmaceutical formulations.

Origin and Distribution

Mentha piperita is a species of mint native to the temperate regions of Europe and Western and Central Asia, eastern to the Himalaya and eastern Siberia USA, France, Brazil and India are major peppermint producing countries. In India, It is cultivated on small scale in Punjab and parts of Himachal Pradesh.

Agro-Techniques

Peppermint generally thrives well in moist, shaded locations and grows best with a good supply of water. Peppermint is grown in cool to temperate regions. It needs long day lengths with warm to hot conditions and cool nights for the right balance of oil compounds to be produced during the growing phase.The best soils are deep, well-drained, and rich in humus, with good moisture retention.A pH range of 6-7.5 is best. Peppermint is propagated through stolons and underground runners. Planting time is during last week of December to January. Land is prepared by bringing the soil to a fine tilth and at the time of land preparation FYM @ 25 to 30 t/ha should be incorporated. The stolons are cut into small pieces (7-10cm) and planted shallow furrows about 7-10 cm deep with a row-to-row distance of 45-60 cm, manually or mechanically. Peppermint requires frequent and adequate irrigation, which is used to supplement rainfall. When the plants are fully developed, they are watered at least three times a week. It is important to keep the soil constantly moist, although well drained. The crop has high water demands in summer. Mint requires weeding and hoeing at regular intervals. In low temperature areas, the plant becomes dormant in November. In order to give a perennial crop in peppermint, it is cultivated again during autumn (November-December) or in spring

(March-April). When peppermint is grown as a perennial crop, the first year is called 'Row mint', while the second- and third-year crop is called 'Meadow mint'.

Timing of harvest is critical to the quality of the oil. Optimum oil yield and quality is usually obtained when 10% of the crop is in the flowering stage. The crop is cut and the cut mint is left in the field to wilt, after which it is chopped up with a forage harvester into a mobile distillation pot or trailer to be transported to the stationary distillation facility. Lower moisture content ensures economic oil extraction. If the crop is well irrigated and matured in time, a second crop can be obtained in the same year. Average yield is 20 tonnes of fresh herbage per hectare which in turn yield around 250 kg oil per year.

Chemical Constituents

Peppermint essential oil is composed of various secondary metabolites. The main chemical compounds of mint consist of limonene, cineole, menthone, menthofuran, isomenthone, menthyl acetate, isopulegol, menthol, pulegone and carvone. Other constituents include flavonoid glycoside (Narirutin, Luteolin-7-o-rutinoside, Isorhoifolin and Hesperidin etc) polyphenols (Rosmaric acid, Eriocitrin, Cinamic acid, Caffeic acid and Narigenin-7-oglucoside), luteolin-diglucoronide and eriodictyol glucopyranosyl-rhamnopyranoside.

Method of Essential Oil Extraction in Peppermint

Peppermint oil can be extracted either by adopting hydro-distillation or steam distillation method. Before distillation, leaves are separated and partially dried.

In hydro-distillation method, peppermint leaves are immersed and boiled along with water in round bottom flask of Clevenger apparatus. A temperature of 80ºC is set for the extraction of essential oil. Condensation occurs as the vapours of essential oil and steam mixture passes through a condenser. At the end of the distillation process, the essential oil is vaporized along with the steam which is a mixture of oil and water which has to be separated. The distilled mint essential oil is desiccated over anhydrous sodium sulfate which is filtered later to get the oil and stored at −4ºC for further analysis.

In steam distillation method, the plant materials are placed in the chamber of the distillation still, and steam is allowed to pass through the plant matter. When heated, the steam passes through it and carries the volatile oils along with it to another chamber where it is cooled and condensed. The essential oil collected in condenser has to be separated from the water which floats on top being lighter in weight.

ARTEMISIA ANNUA

Scientific Name	*Artemisia annua*
Family	Asteraceae
Vernacular names	English: Sagewort, Worm wood
Chromosome No.	2n=18

Introduction

Artemisia is a widespread genus of the Asteraceae family comprising of over 500 diverse species and is one of the largest genera. The word 'Artemisia' is derived from ancient Greek word 'Artemis' which refers to a Greek Goddess named 'Diana'. Artemisia genus includes notable species like *A. vulgaris* (Common mugwort), *A. tridentata* (Big sagebrush), *A. annua* (Sagewort), *A. absinthum* (Worm wood), *A. dracunculus* (Tarragon) and *A. abrotanum* (Southern wood).The members of the genus *Artemisia* have pharmaceutical and industrial importance owing to their characteristic scent or taste and are used in the traditional medicine throughout the world. The famous anti-malarial drug atremisinin is isolated from *Artemisia annua.* Some of the *Artemisia* species produce essential oils which are used in medicines, perfumes, cosmetics, and pharmaceutical industry. It includes species like *Artemisia annua, A. arborescens, A. campestris, A. dracunculus, A. lobelia, A. absinthium, A. nilagirica.* Artemisia species have been used in folk medicine since the ancient times and is credited with a number of medicinal properties including, anti-bacterial, anti-fungal, anti-viral, anti-malarial, anti-inflammatory, anti-cancer, anti-tumor, anti-diabetic, anti-spasmodic, anti-oxidant, anti-fertility, anti-cholesterolemic, choleretic, balsamic, depurative, digestive, emmenagogue, anti-leukaemia, anti-migraine, insecticidal, anti-feedant, abortifacient, anti-herpes virus and antidote to insect poison to name a few. In India, there are two important species of Artemisia which is being cultivated viz. *A. annua* and *A. pallens*.

Botany

Artemisia annua is an aromatic, annual, green, glabrous shrub with slender angular stems. It is an erect aromatic annual under shrub, stem angular. Plants are branched reaching a height up to 2.5 m. Leaves are feathery, alternately arranged, dark green or brownish green with varying lobe shapes viz. bi or tri pinnatifid, linear or lanceolate. Inflorescence type is paniculate racemose with yellow-green flower heads, 2-3 mm in diameter and has a pleasant odour. Fruit type is an achene with a single seed inside, approximately 1 mm in length, oblong ovate, flattened, and yellow brownish with a lustrous surface. Seed endosperm is creamy white in colour and fatty in content. Seeds do not undergo dormancy and can be sown directly.

Flowering and Fruiting Period: Summer to Autumn

Origin and Distribution

Members of the genus Artemisia are naturalized in the northern temperate regions and are mainly found growing in Asia, Europe and North America. Asia has the greatest concentration of species, with 150 accessions for China, 174 in the ex-USSR, about 50 reported for Japan, and 35 species of the genus found in Iran (Abad et al. 2012). *A. Annua* is widely distributed in the temperate, cool temperate and subtropical zones of Asia and Europe mainly in Asia. It is native to China and Eastern Europe. The cultivation of *A. annua* is spread over Middle, Eastern and Southern parts of Europe and in the Northern, Middle and Eastern parts of Asia. In India, it is cultivated in medium to low temperature conditions in Kashmir valley and hills of Himachal Pradesh and also in Uttar Pradesh to a limited scale.

Agro-Techniques

Artemisia annua is found growing on hill slopes, forests areas and in wasteland. It is a temperate plant and prefers cold winter and moderate summer. The optimum growing range of temperature for *A. annua* is 20-25ºC. Based on the photoperiod, it is classified as a short-day plant with a critical photoperiod of 12-16 hours. It prefers light sandy loam soil rich in organic matter with a pH range of 5.0-8.0. It can tolerate drought and water logging unlike other Artemisia species. As the name implies, *A. annua* is propagated by means of seeds which can be sown either directly or by nursery raising and transplanting but the later method is preferred owing to its better growth results. Seed rate is 250-500 g per hectare and are sown during September-October in plains and November-December in hills. Seeds are sown in well prepared nursery beds filled with a mixture of soil and well decomposed FYM. Germination occurs within 7-8 days and is ready for transplanting to the main field after 6-8 weeks when the plants have 4-5 true leaves. Spacing adopted is 45 x 45 cm under Indian conditions. *A. annua* requires a good soil moisture levels and frequent light irrigations are necessary to ensure good crop establishment. Critical stage of irrigation is up to the development of sixth leaf blade and thereafter, the plants exhibit strong adaptability and resistance to drought or water logging, because of their abundant and dense lateral roots. Mulching of the crops also helps to serve the purpose of moisture conservation and weed control in *A. annua* plantations. Weed control is very critical during the initial growth stages; however, once the plant establishes, the plant canopy can provide a good weed control. As per the

ICAR-DMAPR, Boriavi the recommended dose of fertilizers are FYM @ 10 t/ha along with60-80 kg N, 40-60 kg P_2O_5 and 60 kg K_2O/ha with full dose of P and K, two third dose of N at the time of land preparation. Remaining one third dose of N is applied in two equal split doses at 30 and 60 days after transplanting. Basal application of borax @8kg/ha is also advised to correct the boron deficiency. The plants are extremely vigorous and no serious disease and pest have been reported in *A. annua*. Occasionally the plants may be attacked by aphids and ants which can be managed chemically. Diseases like leaf blight, root rot, damping off may be observed at times and can be controlled by following proper cultural practices and by chemical means.

The plants are ready for harvesting after 4-5 months of transplanting at early stage of flower budding. Thereafter, the artemisinin content is reported to drop rapidly. Harvesting is done by cutting the whole plant and the aerial parts are separated from plant. The leaves have to be dried (sun drying preferably) and later the leaves should be detached from the stalk and kept separately in a lined mesh bag or sack for further use/analysis.

Chemical Constituents Structure of Major Compound(s)

Artemissia annua is comprised of many chemical constituents including the major compounds such as sesquiterpenoids, including artemisinin I, artemisinin II, artemisinin III, artemisinin IV, artemisinin V, artemisic acid, artemisilactone, artemisinol and epoxyarteannuinic acid.Analysis of *A. annua* essential oils revealed the presence of the volatile components comprising of alpha-pinene, camphene, β-camphene, iso-artemisia ketone, ß-pinene, myrcene, 1,8-cineole, artemisia ketone, linalool, camphor, borneol, ßcaryophyllene, artemisia ketone, 1,8-cineole, camphene hydrate, and cuminal. The non-volatile compounds are composed of sesquiterpenoids, flavonoids and coumarins, proteins (β-galactosidase, β-glucosidase) and steroids (β-sitosterol and stigmasterol).

Method of Oil Extraction

Essential oils in *A. annua* can be extracted either through steam distillation or hydro-distillation methods. The plant samples have to be collected at its peak flowering stage and subjected to air drying. These samples are placed in a round bottom flask along with sufficient quantity of water and then subjected to distillation. A temperature of approximately 130°C is essential for heating the flask and the distilled essential oil is collected in an oil trap attached to the flask. The process has to be continued till no further increase of oil is observed. The whole process takes usually three hours and after completion, the oil is left undisturbed and dried over the anhydrous sodium sulphate. The oil should be kept in dark and closed bottles to avoid light and oxygen exposure and stored at a temperature of 4°C.

PATCHOULI (*POGOSTEMONCABLIN* BENTH)

Scientific Name: *Pogostemon cablin* Benth
Family: Lamiaceae
Chromosome No.: x=16, 2n=32, 34, 64

Introduction

Patchouli (*Pogostemoncablin* Benth.) belonging to the family Lamiaceae is one of the highly valued aromatic medicinal plant that is in great demand worldwide for its essential oil. The term 'Patchouli' has been derived from Tamil word 'pacchilai' which means 'pacchi' (green) and 'ellai' (leaf). The species name 'cablin' takes after the word 'cablan' which is the vernacular name of the species in Philippines. Patchouli essential oil is widely used in perfume industry, in aromatherapy, flavour and fragrance industries as well as in pharmaceuticals. It blends well with other essential oils and acts as a fixative/binder in perfume and cosmetics industries. Traditionally, patchouli has been used to treat ailments like headache, fever, nausea, vomiting, diarrhoea, abdominal pain, insect and snake bites. The essential oils of patchouli are known to have the properties of antimicrobial, antioxidant, analgesic, anti-inflammatory, ant mutagenic, antithrombotic, antiemetic, cytotoxic and pest repellent. It also finds its use in aromatherapy to calm the nerves, relive depression and stress, control of appetite and to improve sexual interest. Patchouli oil has a characteristic woody, sweet and spicy smell. The value and uniqueness of patchouli oil can be attributed to the fact that no synthetic chemical has been able replace the properties of patchouli oil till date.

Botany

Patchouli is a tropical, aromatic perennial bushy herb that reaches a height of 2-3 ft. Leaves are large, aromatic, ovate to oblong ovate in shape, leathery in texture with dentate margins pale to purplish green in color. Leaves are born opposite along the branching stems. Leaves as well as the axillary and terminal stems and leaves are densely hairy.Inflorescence is a spike and bears small, pale pinkish or mauve tinged white flowers with long stamens.

Flowering and Fruiting Period: March-May

Origin and Distribution

The genus *Pogostemon* comprising of over 130 species is known to be a native of Tropical Asia. It is found growing wildly in Philippines, Malaysia, Indonesia and Singapore. Patchouli is extensively cultivated in China, Brazil, Indonesia, Cambodia, Myanmar, Maldives, Mauritius, Thailand, Vietnam, etc. In India, Patchouli was first introduced in 1941 to Madhya Pradesh, Tamil Nadu, Kerala and Karnataka. At present, the commercial cultivation of Patchouli is taken up in South India, West Bengal, Assam, Karnataka, Madhya Pradesh and coastal regions of Gujarat. *Pogostemon hyeneanus* (Indian Patchouli) is the only indigenous species that has been reported from India and Sri Lanka.

Agro-Techniques

Patchouli thrives well under tropical as well as sub-tropical conditions and can be grown up to an altitude of 800 – 1,000 m above sea level. The crops prefer humid and warm climate and annual rainfall of 150-300 cm. Optimum temperature range for its best growth is 25-35ºC. Patchouli prefers a well-drained, loam soils, rich in organic matter and a pH of 5.5 to 7.5.

Propagation of patchouli is through stem cuttings and can be taken all the year round. Cuttings should be 10-12 cm in length, with 4-5 nodes with a terminal bud and a crown of 2-3 leaves. Cuttings are raised under shade in well prepared nursery beds and starts rooting after 4-5 weeks. Rooted cuttings are ready for transplanting to main field in 9-10 weeks. The main field should be brought to fine tilth by proper ploughing and harrowing. Before planting, FYM @15-20 tonnes per hectare are incorporated with the soil to enrich its fertility. The rooted cuttings are planted in raised beds following a spacing of either 45x45 cm or 60x60 cm. Irrigation should be given frequently until the plants establish and thereafter, given according to the prevailing soil and climatic conditions. Patchouli responds well to application of fertilizers specially nitrogen and potassium. Recommended fertilizer dose is 150 kg N, 50 kg P_2O_5 and 50 kg K_2O/ha with full dose of P_2O_5 and K_2O and ¼ N given as basal dose. The remaining dose of nitrogen should be given in 5 split doses after every harvest. Crop should be kept weed free during the initial stages and can be done manually (2-3 times) or by using wheel hoe. Patchouli is prone to attack by root knot nematodes which causes stunting and wilting of plants. Control measures includes soil application of Furadon @ 25 kg/ha and intercropping with *Tagetes spp*. or *Catharanthus roseus*. Leaf blight (*Cercosporaspp*) is also a common occurrence in Patchouli cultivation which shows symptoms of brown spot at the margin or apical region which later enlarges and coalesce. It can be effectively controlled by spraying of Dithane M-45 @0.5% at every one-month interval.

Patchouli plants are ready for its first harvest after 5-6 months of transplanting. Leaves are the commercial part of the plant that carries the essential oil and should be harvested at the right stage for good yield and better quality of oil. The maturity is judged by change in colour of the branches when it turns slightly brown, foliage becomes pale green to light brownish and the plant begins to emit a characteristic aroma. Harvesting is done with the help of small sharp shear or secateurs. While harvesting, it is advisable to remove a few branches of 40-60 cm in length from the top portion and leave the lower branches for fast regeneration. Depending upon the prevailing environment conditions and goof managements practices, patchouli leaves can be harvested after every 3-4 months and can remain in the field for about 3 years. The leaves should be cured right after its harvest by spreading in thin layers on the ground and turned periodically provided with good air circulation. Proper drying of leaves can take about 3-4 days which can be stored in a cool dry place. Approximate yield of patchouli is 2 tonnes (dried leaves) and 60 kgs of essential oil from one hectare area.

Chemical Constituents Structure of Major Compound(s)

The essential oils of patchouli reveal the presence of more than 140 compounds, including terpenoids, phytosterols, flavonoids, organic acids, lignins, alkaloids, glycosides, alcohols and aldehydes. The main phytochemical compounds are patchouli alcohol, α-patchoulene, β-patchoulene, α-bulnesene, seychellene, norpatchoulenol, pogostone, eugenol and pogostol.

Table 4. Compounds identified in patchouli essential oil

Crop	Chemical compounds
Patchouli essential oil	1-Octen-3-ol, Limonene, Linalool, δ-elemene, γ-patchoulene, β-elemene, β-caryophyllene, γ- elemene, α-guaiene, α-Himachalene, α-patchoulene, Seychellene, 9-Epi-caryophyllene, cis-β-Guaiene, Ledene, α-selinene, δ-Guaiene, β-Curcumene, 7-epi-α-selinene, Longicanfenolene, Caryophyllene oxide, Globulel, Epi-α-cadinel, Patchoulol, δ-Patchoulene - δ-himachalene, Ftalete

Method of Oil Extraction

The essential oils of patchouli are extracted through steam distillation commercially though it can also be extracted through techniques of hydro distillation, microwave distillation, supercritical fluid extraction and ultrasound extraction. For extraction of oil, the dried herbage is tightly packed inside the distillation still and filled with water and boiled. On boiling, the vapors comprising of steam and essential oils are cooled in the condensation tubes and the condensate flows into the receiver. This mixture of essential oil and steam will be condensed back to liquid phase in the water-cooled condenser and the condensate will be collected in the receiver tank. The end product comprises of a liquid distillate which contains the volatile, water soluble parts of the plant materials known as "hydrosol" and the volatile non water-soluble material of the plant constituents known as the "essential oil" (Tannous et al., 2004). The condensate in collected in the receiver should be allowed to stand overnight to allow the oil to separate from the water layer and thereafter, funnel can be used for separation. The oil being lighter than water and insoluble floats on the top of the receiver and only water gets drained out. The oil is further clarified by adding anhydrous sodium sulphate and keeping the distillate mixture for 4–5 h, after which the oil is filtered through a Whatman filter paper to get clear essential oil. The clear essential oil thus obtained should be stored in air-tight aluminum containers or color glass bottles up to the brim and stored in cool dry place, away from light. The time taken for distillation varies from 6- 8 hours.

CITRONELLA (*CYMBOPOGON WINTERIANUS*)

Scientific Name: *Cymbopogon winterianus*
Family: Poaceae
Vernacular name: English: Citronella, Mana grass; **Marathi:** Gavati Chaha
Chromosome No.: 2n=20, 40

Introduction

Citronella (*Cymbopogon spp*.) belongs to the family Poaceae comprising of highly aromatic perennial grasses that has been used for its aromatic and medicinal values across many cultures for centuries. There are nearly 140 species of *Cymbopogon* reported from worldwide. The term *Cymbopogon* has been derived from two Greek words 'kymbe' (boat) and 'pogon' (beard) that refers to its peculiar flower spike arrangement. There are two cultivated types of citronella grass viz. Ceylon citronella, botanically known as *Cymbopogon nardus* and Java type which is *Cymbopogon winterianus*. The famous citronella oil is obtained from *Cymbopogon winterianus* and is of superior type having more commercial importance than *Cymbopogon nardus*. The essential oils extracted from citronella grass are known as natural insect repellent especially against malaria-causing mosquito species, therapeutic properties against various diseases and its anti-fungal property against several species of *Aspergillus, Penicillium* and *Eurotium* due to presence of citronellal and linalool. The oil is extensively used for perfumery, detergents, incense sticks, cosmetics, flavouring agent and in soap industries worldwide. In addition, the oil is reported to have properties of anti-inflammatory, analgesic, anti-septic, disinfectant, antioxidant, anticancer, anticonvulsant, nematicidal, anti-parasitic and anti-bacterial.

Traditionally, it also finds its use for making tea, as massage oil for aching joints and muscles, and in flu control.

Botany

Citronella is an aromatic perennial herb, clump forming with numerous erect culms and fibrous roots. Culms are tufted, robust and up to 2.5 m tall. Plants are erect and reach a height of over 2 m with smooth and glossy leaves. Leaf blades are thin and linear, tapering towards the tip, with 2/3rd of their length drooping, light green surface and apex long acuminate. Leaf sheath is smooth, glabrous, yellow or reddish inside. Inflorescence is a spike, sessile, elliptic lanceolate, lower glume, flat or slightly concave, 2-keeled, 3-veined between keels.

Origin and Distribution

The genus Cymbopogon is native to warm tropical and subtropical regions of Africa, Asia and America. It is cultivated in parts of tropical and subtropical areas of Asia, Africa and America *Cymbopogon winterianus*has its origin in Sri Lanka and was introduced to Java (Indonesia) before 1900s and hence the name Java citronella. It is commercially grown in Indonesia, Vietnam, Java, Haiti, Honduras, Guatemala, Taiwan, Brazil, India, Argentina, Mexico and China.Presently, 300-350 tonnes of oil are produced in the India for the last 6-8 years in the states of Assam, Karnataka, U.P, M.P, Maharashtra, Tamil Nadu, and West Bengal.

Flowering: September-October

Agro-Techniques

Citronella is a perennial grass which performs well under tropical and sub-tropical climatic conditions. The plant prefers to grow under the presence of bright sunlight with a good amount of moisture. An average annual rainfall of 200-250 cm is required for its good growth and development. Optimum day temperature of 22-27°C is essential and low temperatures may retard its growth and reduce the oil content in leaves.A well-drained sandy loam soil with a good amount of organic matter and pH of 6-8 is suitable for citronella. Propagation of citronella grass is through vegetative slips which are separated and grown. At least 1-3 tillers should be present in the slip at the time of separation. The slips are prepared by trimming off the roots and leaves. Best time for planting citronella slips is during the onset of the monsoons. Since the crop is perennial, the land should be prepared by thorough ploughing and harrowing and should be brought to a fine tilth. Spacing adopted is 60x60 cm or in areas which provide the crop with good soil fertility and climatic conditions, a spacing of 90x90 cm can be adopted. Depth of planting should be at least 10 cm. With good soil moisture and irrigation facilities, the crop takes 15-20 days to establish itself well in the field. Weeding should be done from time to time and after every harvest in the inter rows either manually or by mechanical means (cultivator). Citronella is a moisture loving crop and should be regularly irrigated depending on the soil conditions. During drier months, irrigation should be given at an interval of 8-10 days. Recommended dose of fertilizers for North and North East India is 80-120 kg/ha/year of N along with 40 kg/ha/year each of P and K. Frequency of N fertilizer application is 4 times a year split equally beginning from one month after planting and thereafter every harvest. Under South Indian conditions, fertilizers are given at the rate of 120 kg/ha N and 40 kg/ha each of P and K. Full dose of P and K and half dose of N should be given as basal dose and the remaining doses of N in four equal splits after every harvest. Plants of citronella are commonly attached by leaf blight (caused by *Curvulariaandropogonis*) and anthracnose which infects the leaf and thereby causes drastic reductions in oil production. Fungicides like dithiocarbamates, Dithane M-45 or Dithane Z-78 (0.3%) spray at 10-15 days interval is recommended to control the disease. Among the pests, termites are known to damage the plants which can be effectively controlled by soil application of Aldrin@ 25kg/ha at the time of planting (Katiyar et al. 2011).

Leaves are the economical part of citronella grass and can be harvested once it assumes its growth nearly 6-12 months after planting. The maximum oil content is present in the leaf blades of the Java grass. Plant height is taken as a harvest index by most of the growers (Guzman and Reglos, 2016). Leaves are harvested with sharp sickles by leaving 2-3 cm of the plant for further regeneration. Depending on the environmental conditions, the number of harvests per year varies. With good management practices, two harvests can be taken in the first year and thereafter in the preceding years, 3-4 harvests can be taken. The economic life of the crop is for 5-6 years and has to be replanted with slips. Citronella gives a fresh herb yield of 20-25 t/ha/year. The average oil content is about 1% and oil yield is about 100 kg/ha in first year and slightly increases up to 150-200 kg/ha from second year (Kumar 2019; Katiyar et al. 2011).

Chemical Constituents Structure of Major Compound(s)

The major chemical constituents of Citronella oil are citronellal (32-45%), citronellol (11-15%) and geraniol (12-18%) (Kumar 2019). Other components of the oil include elemol, geranyl acetate, limonene, β-elemene, citronellyl acetate, camphene, and eugenol (Gusmand and Reglos 2016; Avoseh et al. 2015).

Method of Oil Extraction

The essential oil of *Citronella winterianus* is extracted using steam distillation method. The distillation unit comprises of a distillation tank, condenser and a separator. Freshly harvested grass should be used for extraction. The leaves are prepared either by chopping them into smaller pieces or as a whole leaf and loaded into the distillation unit along with distilled water. The tank is connected to a condenser and heated. On heating, essential oil mixed with vapor condenses into liquid in the condenser and are collected in the separator. The oil gets separated and collected in amber colored bottles or aluminum containers and stored in a refrigerator at 4°C for further use. The whole process takes nearly 4 hours for recovery of the essential oil (Shetty et al. 2017).

OCIMUM BASILICUM L.

Scientific Name	*Ocimum basilicum* L.
Family	Lamiaceae
Vernacular names	English: Sweet basil
Chromosome No.	2n=48

Introduction

Ocimum basilicum, popular known as Basil or Sweet Basil, is a common herb that belongs to Lamiaceae family. It is sometimes referred to as “the king of herbs,” and may have been derived from the Greek basileus, or king. Basil is well-known for its folk medicinal value and is accepted officially in a number of countries. The leaves and flowers of basil are used in folk medicine as a tonic and vermifuge, and basil tea is good for treating dysentery, nausea and flatulence. The oil of the plant is beneficial for the alleviation of spasm, rhinitis mental fatigue, cold, and as a first aid treatment for wasp stings and snakebites. It has been used as a folk remedy for boredom and convulsion. Basil cures headache, improves digestion and is also good for toothache, earache and for curing epistaxis when used with camphor. Infusion of plant is effective in cephalagia, gouty joints, fever, otitis and snakebite. The plant is effective in treatment of stomach problems, fever, cough, gout and given internally to treat cystitis, nephritis and in internal piles. Infusion of basil seed is used to treat gonorrhoea, chronic diarrhoea and dysentery.

Origin and Distribution

Basil is native to areas in Asia (India, Pakistan, Iran, Thailand, and other countries) and Africa and grows wild as a perennial on some pacific islands. Basil was brought from

India to Europe through the Middle East in the sixteenth century, and subsequently to America in the seventeenth century. It grows in habitats like wastelands and on hills and due to its ornamental and therapeutic significance it is also grown as pot plant.

Agro-Techniques

Sweet basil is cultivated in agro climate between 7 to 27°C, with 0.6 to 4.2 m annual precipitation and soil pH 4.3 to 8.2. While susceptible to frost and cold-temperature injury, the species develops best under long days, in full sun and on well-drained soils. Basil can be directly seeded or transplanted to the field in late spring, after the frost period. The seed is relatively small, and a good friable, well-tilled and uniform seedbed is required for optimum plant establishment. Seeds should be planted only 0.3-0.6 cm deep. About 200-300 g seeds are enough to raise the seedlings for transplanting in one hectare of land. The seeds germinate in 8-12 days and the seedlings are ready for transplanting in about 6 weeks' time at 4-5 leaf stage. Seedlings of six weeks old and having 4-5 leaves are transplanted at different spacings of 40 × 40 cm, 40 × 50 cm and 50 × 30 cm to get high herbage and oil yield. Farm yard manure/compost are to be applied at 10 t/ha before planting. The optimum fertilizer dose recommended for this crop is 120 kg N, 60 kg of P_2O_5 and K_2O per hectare. Half the dose of N and the entire dose of P_2O_5 and K_2O should be given as a basal dose, whereas, the remaining N is applied in two split doses after first and second cuttings. In summer three irrigations per month are necessary whereas, during other seasons it should be done as and when required except in rainy season when no irrigation is required. About 12-15 irrigations are required during the year.

The crop is to be harvested at full bloom stage to obtain maximum essential oil yield and better-quality oil. The first harvest is obtained at 90-95 days of planting. Thereafter, it may be harvested at every 65-75 days interval. Harvesting should be done usually on bright sunny days for high and good quality oil. The crop should be cut at 15-20 cm above the ground level. About 5 tonnes of fresh herbage per hectare can be obtained by two to three harvests in a year. The whole herb contains 0.1-0.23% essential oil and an oil yield of 10-23 kg can be obtained per hectare.

Chemical Constituents

The essential oil composition of *Ocimum basilicum* includes α-pinene, benzaldehyde, sabinene, β-pinene, myrcene, cis-hex-3-enyl acetate, p-cymene, limonene, eucalyptol, cis-beta-ocimene, cis-linalool oxide, trans-linalool oxide, linalool, neo-allo-ocimene, trans-myroxide, menth-2-en-1-ol, pinocarvone, terpinen-4-ol, 3,7-dimethyloct-1,5-dien-3,7-diol, α-terpineol, n-octyl acetate, endo-fenchyl acetate, nerol, neral, geraniol, geranial, carvacrol, bicycloelemene, exo-2-hydroxycineole acetate, α-cubebene, 3,7-

dimethylocta-1,7-dien-3,6-diol, geranyl acetate, α-ylangene, β-bourbonene, β-elemene, β-cubebene, methyl eugenol, β-caryophyllene, β-copaene, trans-alpha-bergamotene, α-guaiene, cadina-3,5-diene, epsilon-muurolene, α-humulene, cis-muurola-4(14),5-diene, β-acoradiene, α-acoradiene, germacrene d and bicylogermacrene.

OCIMUM GRATISSIMUM L.

Scientific Name	*Ocimum gratissimum* L
Family	Lamiaceae
Vernacular names	English: Wild basil, African basil, Clove basil, tree basil
Chromosome No.	2n=40

Introduction

Ocimum gratissimum, also known as clove basil, African basil is a herbaceous plant which belongs to the Lamiacae family. It is known by various names in different parts of the world. In India it is known by its several vernacular names, the most commonly used ones being Vriddhutulsi (Sanskrit), Ram tulsi (Hindi), Nimma tulasi (Kannada). It is used for a variety of reasons. In culinary, it is used in salads, soups, pastas, vinegars and jellies in many parts of the world. The Thai people are popularly known to use it in food flavoring. In traditional medicine, the leaves have been used as a general tonic and anti diarrhoea agent and for the treatment of conjunctivitis by instilling directly into the eyes; the leaf oil when mixed with alcohol is applied as a lotion for skin infections, and taken internally for bronchitis. The dried leaves are snuffed to alleviate headaches and fever among other uses.

Origin and Distribution

The plant is indigenous to tropical areas especially India and it is also in West Africa. It is widely distributed throughout Central America, West African Coast. It is cultivated in Ceylon, South Sea Islands, and also within Nepal, Bengal, Chittagong and Deccan.

Agro-Techniques

Ocimum gratissimum has wider adaptability and can be grown under warm and humid climate. It grows well during summer and monsoon months when the temperature is moderate and with annual rainfall ranging from 500-1200mm. Long days and high temperature have been found to be favourable for plant growth and high oil production. Crop remains in dormant state during winter season. Rich loam to poor laterite, moderately alkaline, saline and acidic soils are well suited for its cultivation. The plantation can be raised either by raising the seedlings in the nursery and then transplanted in the field or direct sowing of seeds in the field. Time of sowing is in February and about 400 gm of seeds are required for 1 hectare area. Seed takes about 10-12 days to germinate and are ready for transplanting after 40-45 days at 5-6 leaf stage. The plants may be spaced at 40x40 cm, 50x50 cm or 40x50 cm. Water requirement of the crop varies according to the season and type of soil. About 10-12 irrigations are required in a year. In the first year of growth, about one hand weeding and two hoeing are required. During successive years, four hoeing one after each harvest is required. Pruning should be done once in a year to maintain the growth and yield at economic level. Pruning is done upto 10 cm from the ground level. This results in the higher herbage, oil and fresh wood yield. Recommended dose of fertilizer is 80 kg/ha N, 40kg/ha each of P2O5 and K2O.

Ocimum gratsissimum becomes ready for first harvest 90-95 days after transplanting. In the first year, 2-3 times and in the subsequent years four harvests may be obtained. The crop should be cut at 15-20 cm from the ground level in the first year, 25-30 in the second year and 35-45 cm in the subsequent years. Oil content is the maximum in the leaves. The oil and eugenol content are the highest at flowering and seed setting stage. On an average 45 tonnes of fresh herb is obtained per hectare in the first year and about 70 tonnes per year in the subsequent years.

Chemical Constituents

Table 5. Chemically active compunds from *Ocimum gratissimum*

Plant Part	Chemical constituent
Plant	Thymol, eugenol, methyl chavical, Gratissimol, Alkaloids, tannins, flavonoids and oligosaccharides, thymol, p-cymene,terpene and trans sabiene hydrate, Eugenol, 1,8 cineole, linalool, methyl chavicol, methyl eugenol
Seed	Pentoses, hexoses, uronic acid and lipids, Thymol and eugenol
Leaves	Eugenol, methyl eugenol, cis-ocimene, trans-ocimene, pinene, camphor, germacrene- D, trans-carypohyllene, farnesene and l-bisabolene, bisaboline, thymol, Citral, ethyl cinnamate, linalool, -terpinene, p-cymene, limonene, terpinolene and 1,8-cineole, oleanolic acid
Aerial Parts	Eugenol, linalool, limonene, methyl eugenol, -caryophyllene, farnesene, -terpineol, - -salinene, methyl isoeugeneol, geraniol, -copaene, bisabolol, -pinene, p-cymene, fenchone, cubenene, camphene, T-cadinol, -eudesmol, sabinene, myrcene, - bisoboline, -humelene and -elemene.

OCIMUM SANCTUM L.

Scientific Name	*Ocimum sanctum* L.
Family	Lamiaceae
Vernacular Name	English: Holy basil, Thai basil
Chromosome No.	2n=32

Introduction

Ocimum sanctum is an annual herb belonging to the mint family with 150 varieties worldwide. *Ocimum sanctum* emits a spicy scent when bruised. It is believed to purify expectorants, and called the "wonder herb." The leaves of the plant are considered to be very holy and often form a consistent part of the Hindu spiritual rituals (Tirtha or Prasada). *Ocimum sanctum* has two varieties i.e., black (Krishna Tulsi) and green (Rama Tulsi), their chemical constituents are similar. Tulsi is also known as "the elixir of life" since it promotes longevity. The roots, leaves and seeds of Tulsi possess several medicinal properties. It has a variety of biological/pharmacological activities such as antibacterial, antiviral, antifungal, anti-protozoal, anti-malarial, anthelmentic, anti diarrhoeal, analgesic, antipyretic, anti-inflammatory, anti-allergic, antihypertensive, cardio protective, central nervous system (CNS) depressant, memory enhancer, antihypercholesterolaemic, hepatoprotective, anti-diabetic, anti-asthmatic, anti thyroidic, antioxidant, anticancer, chemopreventive, radio protective, immunomodulatory, anti-fertility, antiulcer, anti-arthritic, adaptogenic/anti stress, anti-cataract, anti leucodermal and anticoagulant activities. Its leaves are helpful in sharpening memory and in curing fever and common cold.

Origin

Basil is naturally found wild in the tropical and subtropical regions of the world. *Ocimum sanctum* is native to India, Iran and now cultivated in Egypt, France, Hungary, Italy, Morocco, and USA. In India, the plant is grown throughout the country from Andaman and Nicobar Islands to the Himalayas up to 1800 meters above the sea level.

Agro-Techniques

Sacred basil thrives well in rich loams to poor laterites including saline and moderately acidic soils are well suited for its cultivation, it grows well under fairly high rainfall and humid conditions. Long days and high temperatures have been found favorable for plant growth and oil production. It grows well up to an altitude of 900 m. Most species tolerate drought and frost moderately. Sacred basil is propagated through seeds and are sown during February. About 200-300 g seeds are enough to raise the seedling for transplanting in one hectare of land. Seed germinate in 10-12 days and are ready for transplanting in 6 weeks at 4-5 leaf stage. The seedlings are transplanted at 4x40 cm, 50x50 cm and 50x30 cm to get high herbage and oil yield per ha. A light irrigation should be given after planting. Optimum fertilizer dose recommended is 10t/ha of FYM, 120 kg N, 60 kg of P2O5 and K2O per hectare. Half dose of N and the entire dose of P and K should be given at the time of land preparation and the remaining dose of N is applied in two splits after first and second cuttings. Irrigation depends upon the moisture content of soil. In summer 3 irrigations per months is necessary, whereas during remaining period, plants are irrigated, as and when required. Weeding should be done one month after planting and second is done 4 weeks after planting. One hoeing and earthing up should be done two months after planting.

The crop should be harvested at full bloom stage to obtain maximum essential oil yield and better quality. Sacred basil is ready for first harvest in 90-95 days after planting and thereafter, it may be harvested every 65-75 days interval. The crop should be cut at 15-20 cm from the ground level. About 5 tonnes of fresh herbage can be obtained twice or thrice a year per ha.

Chemical Constituents

Fresh leaves and stem of *Ocimum sanctum* extract yielded some phenolic compounds (antioxidants) such as cirsilineol, circimaritin, isothymusin, apigenin and rosameric acid, and appreciable quantities of eugeno. The leaves of *Ocimum sanctum* contain 0.7% volatile oil comprising about 71% eugenol and 20% methyl eugenol. The oil also contains carvacrol and sesquiterpine hydrocarbon caryophyllene. Two flavonoids orientin and andvicenin from aqueous leaf extract of *Ocimum sanctum* have been isolated.

THYME

Scientific Name	*Thymus vulgaris* Linn
Family	Lamiaceae
Chromosome No.	2n=30

Introduction

Thyme is an aromatic shrub with woody stem and dark green small aromatic leaves which releases a pungent aroma when bruised. It is commonly known as "Garden Thyme" and belongs to Lamiaceae family.Mainly the floral parts are harvested and distilled. The essential oil of Thyme is used for flavoring food products, soaps and in many pharmaceutical preparations. Phenol content is high in this oil and that makes the oil spore-killing and antiseptic. It has also insect repellent and anti-microbial properties. Since ancient time it has been used in foods for culinary purposes, preparation herbal tea, etc.

Botany

Thyme is a small, hairy, semi ever green groundcover perennial shrub with upright habit. Reddy P et al., (2014) stated that with age, the stem of the *T. vulgaris* become woody and hard. The plant is of 10 to 25 cm in height and it covered the ground forming dense mats. The leaves sizes are of very tiny with 2.5 to 5 mm long and oval to rectangular shaped.The fleshy aerial plant parts are used for volatile oil production, predominantly by steam distillation methods.

Flowering and Fruiting Period

Flowering and fruiting of Thyme start from April and continue till September. Flowers are polygamous and it blooms pink color flowers.The male flowers are larger in size.

Origin and Distribution

Thyme is native to South Europe. It is grown in USA, Canada, North Africa, Australia and North Asia, In India, it is found in the Western Himalayas from Kashmir to Nepal at altitudes of 1500-4500 m**.** It is reported that thyme plant grows well in hilly region compare to plain area.

Agro-Techniques

Thyme plants grows well in temperate to warm, dry, sunny climate but sensitive to frost.Proper drainage facility should be given to avoid water logged condition.It prefers lightweight soil with slightly acidic to alkaline (pH of 5.0 to 8.0). Thyme plant is commonly propagated by seeds but by cutting and layering can also be done during March to April with a spacing of 35-45 cm x 60 cm. Light irrigation is recommended after planting or sowing. Clean cultivation is a must to avoid pest incidence. Application of vermin compost @ of 5 tonnes per ha and 1.25 tonnes of neem cake per ha is recommended to apply prior to sowing or planting to enhance the crop yield and quality of essential oils. Aphids and spider mites are the important insect of thyme plant. It can be managed by spraying with neem-based insecticide and severely infected plants should be removed and destroy. In case of disease, *Botrytis* rot and *Rhizoctonia* rot are common. To avoid rot disease, disease free planting material should be used with proper drainage system.

Harvesting

In leaves, the essential oil content is more just before flowering stage which consider as the best timing for harvesting of the plant. Harvesting can also be done during flowering stage but there is some problem in harvesting due to bees and other insects which attracts to flowers. The plants are harvested by cutting the aerial parts of about 8 to 10 cm above the ground level.

Chemical Constituents Structure of Major Compound(s)

A number of compounds found in essential oil of *T. vulgaris* were reported by Abdulrahman et al. (2017).

Table 6. Chemical constituents of *T. vulgaris*

Sl. No	Name of the Compounds	Percentage (%)
1	Furan, tetra hydro-3-methyl	12.19
2	Thymol	3.82
3	o-Thymol	38.71
4	α-Terpineol	0.28
5	Terpinen-4-ol	0.31
6	Endo-Borneol	0.90
7	Phenol, 2-methyl-5-(1-methylethyl) acetate	0.34
8	Caryophyllene	0.91
9	Humulene	0.22
10	2-Aminopyrimidine-1-oxide	0.14
11	(−)-Spathulenol	0.13
12	Caryophyllene oxide	0.51
13	Isoaromadendrene epoxide	0.11
14	Cyclo propane carboxamide	0.11
15	1,6-Octadien-3-ol, 3,7-dimethyl-	0.38
16	γ-Terpinene	1.18
17	*o*-Cymene	0.39
18	*p*-Cymene	2.77
19	Carene	0.27

Table 6. (Continued)

Sl. No	Name of the Compounds	Percentage (%)
20	3-Octanol	0.22
21	β-Myrcene12.19	0.15
22	Camphene	0.13
23	α-Pinene	0.18
24	Cyclohexane	0.13

Methods of Oil Extraction

Michalak (2006) reported that the yield and essential oil quality of thyme depends on many factors and can be extracted either through Steam Distillation, Solvent Extraction, Supercritical Fluid Extraction, Pressurized Liquid Extraction, etc.

1) **Steam Distillation**: Steam distillation methods is widely used for extraction of essential oils but this method gives a greater or lesser compounds instability under the influence of high temperature. There are two methods use in steam distillation, Simple Steam Distillation and Clevenger System (Eghdami, 2013).
   Abdulrahman et al. (2017) used a Clevenger apparatus to extract volatile oil from Thyme plant. Thirty (30) grams of coarsely powdered leaves mixed with 750 ml of water in 1000 ml of flask. After heating the flask, the volatile oil extracted and it was evaporated, which were passed through condenser and oil was accumulated. The oil was drained followed by passing over anhydrous sodium sulphate. The oil was filtered through 0.22µmol/L filter paper, and kept at 4°C in sealed vials in dark.
2) **Solvent Extraction**: This is one of the important methods that accepted by most researchers to extract phenolics from leaves. It is designed in such a way to separate soluble compounds by diffusion from a solid matrix using a liquid matrix. The aim of extraction is concentrated antioxidant components of raw material (Michalak 2006).
3) **Supercritical Fluid Extraction**: This method of extraction preserves the properties of antioxidants. It can be also used for the extraction of polyphenol from plant tissue and greatly facilitates the extraction process, takes less time to extract due to low viscosity and relatively high density of supercritical fluid. During operation with the absence of light and air, it minimized the degradation (Topala 2016).
4) **Pressurized Liquid Extraction (PLE)**: This method is based on the use of solvents at temperatures above their usual boiling points and pressures enough to keep the extracting fluid in the liquid state during the extraction process. From

this technique, faster extraction processes result in which typically higher extraction yields are obtained with lower volumes of organic solvents (Villanueva 2015).

ROSEMARY

Scientific Name	*Rosmarinus officinalis*
Family	Lamiaceae
Chromosome No.	2n=20, 24

Introduction

Rosemary is perennial aromatic plants belongs to Lamiaceae family. The name rosemary derived from Latin words meaning "rosmarinus" literally means dew of the sea. It has been named as "The Herb of the Year" in 2001 by the International Herb Association. Rosemary is also being regarded as 'The herb of faithfulness' as Elizabethan sweethearts carried a twig of rosemary as its sign. Nowadays, the market demand of the plant is growing, as the plant is being used in several commercially available products. Rosemary was introduced to Britain by the Romans and it is still loved today particularly by the Italians and the British, who use it in their cooking. In ancient Greece and Rome, it was believed that this plant strengthens the memory, hence it is also being known as 'The Herb of Remembrance and fidelity'. It was introduced in India by the Europeans as a garden plant due to its pleasant fragrant scented leaves. It was one of the earliest plants used in medicine, food, as insect repellent, etc. It has been extensive use in skin and hair care and its ingredient of true *eu de cologne*.On the skin, it helps to ease congestion, puffiness and swelling and can also be used for acne, dermatitis and eczema.It has a pronounced positive effect on the hair and scalp. It increases the circulation to the scalp and is, therefore, also effective for promoting hair growth. The fresh and dried leaves are used frequently in Mediterranean cuisine as an herb. The tender shoots, leaves and flowers are eaten raw or cooked. A fragrant tea also made from the dried leaves. The growing plant is believed to repel insects.

The rosemary plants are intolerant to excessive winter wet and it can be propagated by seeds, cutting and root layering. The volatile oil is obtained by the steam distillation from the twigs and fresh flowering tops of the shrubby perennial. The oil has fresh, minty-herbaceous scent with woody and balsamic undertones. It can be planted as a hedge.

Origin and Distribution

Rosemary is the native of Mediterranean region and is cultivated in Europe and California in US. It is also grown in Algeria, China, Middle East, Morocco, Russia, Romania, Serbia, Tunisia, Turkey, and India.

Botany

It is a polymorphic species that is commonly grown as ornamental and herb. It is an evergreen, woody, shrubby, perennial herb with fragrant, green grey needle like leaves. Guzman, (1999) reported that stem of rosemary is indistinctly quadrangular, finely grey pubescent. Leaves are 2-4 cm long and 2-4 mm broad, opposite, sessile, linear, tufted on the branches, leathery, glossy appearance, aromatically fragrant when crushed. Inflorescences are small cluster in nature situated towards the ends of branches.

Guzman (1999) stated that Seeds of rosemary are germinated only after 21-28 days after sowing. The favorable temperature is below 18°C to enhance the germination of seed. Under favorable environmental conditions and suitable cultural management, rosemary can remain productive for up to 30 years.

Flowering Period

Flowering is started when plants attain two or more years old. Normally it blooms from March to October. The flowers are hermaphrodite and are pollinated by bees. Rosemary flowers are variable in color, white, pink, purple or blue.

Agro Technique

R. officinalis originated in the Mediterranean region with coastal climate, and can tolerate heat, drought, and poor, dry, sandy, and rocky soil types (Floridata, 2014). However, the rosemary plant prefers a hot and sunny climate and slightly alkaline, light dry soil but very heavy soil is not suitable. The plants become smaller but are more fragrant when grown on chalky soils. According to PFAF (2014) report, it can also tolerate maritime exposure and soil types ranging from light sandy to medium loamy, well-drained soil, and pH ranging from acid to basic (alkaline) soils. It has low tolerance for shade and thrives under full sun (PFAF, 2014). Reddy (2016) stated that rosemary plant grows well at 20°Cto 26°C. Though these plants are suitable in dry land condition, light irrigation should be given until the crop is well established. If the annual rainfall is above 450mm then it does not require any irrigation.

It is propagated by seeds, cutting and layering. Propagation by seeds is the most common and seeds are sown during the spring in a cold frame. Usually rooting started within 3 weeks. It can be propagated from an existing plant by clipping a shoot, 10-15 cm long, and planting it directly into the soil. Rooting starts after 3-4 weeks. Layering can be done during summer under sandy soil. Deep ploughing of 3-4 times should be set to get fine tilt stage. Rosemary plants required full sunlight; therefore, the plants should be planted in east-west direction to get the full sunlight with the spacing of 1-to-2-meter beds and 40 cm to 50 cm rows. Weed management is one of the important practices in rosemary cultivation as it affects the quality of the plant. Weeding can be done by manual means, at least 3 to 4 times during the cropping season.

Chemical Composition

The oil sample had following physical properties:

Table 7. Oil sample: physical properties

1	Colour	Colourless to light yellow
2	Specific gravity	0.893
3	Refractive index	1.467
4	Optical rotation	5° at 18°C having fresh woody rosemary odour

Quality profile of the essential oil was evaluated by GC and GC-MS. The major constituents of *R. officinalis* L. oil identified are α-pinene (16.33), 1, 8-cineole (14.33), camphor (22.01), camphene (9.28), β-pinene (5.97), β-phellandrene (5.19), bornyl acetate (4.59), myrcene (4.31), borneol (3.35), (E)-β-caryophyllene (2.88), verbenone (1.39), linalool (1.16), terpinen-4-ol (1.11), α-terpineol (1.02) and γ-terpinene (1.04%).Further variation in the chemical composition of essential oil depends upon number of factors such as environmental conditions, location, elevation, harvesting period, storage conditions etc.

Mechanism for Extraction of Essential Oils

Rosmarinus officinalis L. essential oil is usually extracted by hydro-distillation, steam distillation, or extraction with organic solvents. These techniques cause the loss of certain volatile compounds due to long extraction times and degradation of unsaturated compounds by thermal or hydrolytic effect. It is also reported that this essential oil can also be isolated by Microwave assisted hydro-distillation (MAH) and Clevenger hydro-distillation (CH).The oil should be stored in Aluminium.

PALMAROSA (*CYMBOPOGON MARTINI* [ROXB]WATS. VAR. MOTIA BURK.)

Scientific Name	*Cymbopogon martini*
Family	Poaceae
Vernacular Name	**English name:** Rosha grass, Rusa grass; **Hindi:** Gandhabel, Rusaghas; **Sanskrit:** Dhyamakah
Chromosome No.	2n=20

Table 8. Other Species (Bedi et al. 2008)

Sl. No	Other Species	Vernacular Name
1.	*Cymbopogon caesius*(Nees) Stapf	English: Ginger grass
2.	*Cympobogon citrarus* (DC) Stapf	English: Lemon grass; Hindi: Sugandhrohisha
3.	*Cymbopogon coloratus* Stapf	
4.	*Cymbopogon flexuosus* (Nees ex Steud.)	English: Malabar grass
5.	*Cymbopogon jwarancua* (Jones) Schult.	Hindi: Lamjak
6.	*Cymbopogon nardus* (L.) Rendle	English:Citronella grass; Hindi: Ganjini
7.	*Cymbopogon pendulous* Wata	
8.	*Cymbopogon schoenanthus (L.)*	English: Camel-hay; Hindi: Rousaghas

Introduction

Palmarosa is an aromatic perennial grass belongs to Poaceae family. It yields an essential oil with high geraniol content (60-90%) which is also called as East Indian Geranium Oil or Russa Oil. It is commonly cultivated for aromatic oil purpose. This essential oil smells likerose oil and got the name 'palmarosa'. The best quality essential oil of palmarosa is obtained from the leaves. Floral shoots and above ground parts of the plant are used for distillation of essential oil. Palmarosa oils are used in preparation of soap, perfume and in food industry. It is also useful in vitiated condition of neuralgia, bronchitis, cough, anorexia, cardiac debility, leprosy, skin diseases, epileptic fits in children, pharyngopathy and fever. It can be propagated by seeds and vegetative methods and suitable in slightly alkaline soil with well drainage system.

Botany

The plant is perennial, sweet-scented grass, with 1.5-2.5 m height, leaves are linear, dark green in colour, which are leathery, prominently mid ribbed, roundish at the base and form an obtuse to right angle with the stem; flowers in spikelets, in panicles and turns reddish in colour when it matures. Roots are shallow and fibrous; culms erect and nodes swollen. Leaf sheath is glabrous, ligule membranous and blades linear. Seeds are brown in colour, fine, hairy and easily disposed by air. It is a best natural source of geraniol (75-90%).

Origin and Distribution

Cymbopogon martini is native to India. It is cultivated throughout India such as Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Uttar Pradesh and Odisha.

Agro-Techniques

Palmarosa grows well where the temperature is between 10-4°Cwith annual rainfall of 100 cm and adequate sun light. It is prone to frost area. The sandy loams to black soils are suitable for the cultivation of Palmarosa with soil pH range of 6 to 7. Well drained should be maintain to avoid water stagnation especially during summer. It can be propagated through the seeds and vegetative methods (slips). Two to three kg of seeds required to cover one hectare of land. However, seed propagation is the best method for large scale propagation by raising seedlings and transplanting in the main field. Before sowing seeds are usually mixed with fine sand or soil in a ratio of 1:10 for even distribution in sowing. With the depth of 1-2 cm and 10 cm apart are made and the seeds are uniformly sown in lines and covered with soil and manure mixture and irrigate the beds regularly. After 45 to 50 days when plant attains the height of 15-20 cm, seedlings are ready for transplanting in the main field with spacing 45 x 30 cm. In case of slips propagation, clumps are trimmed from 20-25 cm above ground. The individual slip or a group of 2-3 slips having enough healthy root system are separated to minimize drying and loss of the roots. About 30,000 slips are requiredto cover1 acre of land.

Irrigation should be given at an interval of 20 days during winter right after first cutting (October to November) and 12-15 days interval during summer. It required 2-3 hoeing and weeding activities during the first year.Weeding should be done before they start competing with main crop for soil moisture and nutrient for their growth. Mulching can be practice to inhibit weed growth and it also maintains soil moisture. For better growth of the plant the farm yard manure is applied at 10 t/ha before planting. Nursery bed should be well pulverized and add 2 baskets of cow dung manure, 100 g calcium ammonium nitrate, 150 g super phosphate and 50 g muriate of potash in each bed. The recommended dose of fertilizer is 100:50:50 kg/ha of $N:P_2O_5:K_2O$ for main filed. Phosphate and potash fertilizers are applied in two split doses as basal and after first harvest, while nitrogen is applied in four equal splits as basal dose, one month after transplanting and remaining is equally divided into two parts and may be given one part after the first cutting and second part after the second cutting. Application of NPK should be repeated every year at the time of appearance of fresh leaves. The production of oil in the plant may be increased by adding *Azotobacter* culture @ one kg per acre at the time of root initiation and 1 kg of culture mixed with 20 kg of powdered cow dung manure after transplanting.

The maximum oil content is present in the grove of flowers and leaves. Harvest the crop from10 to 15 cm above the ground when flowers are in bloom stage. Successive harvestscan be done after every 2.5 months for the next 5 years.

Chemical Constituents Structure of Major Compound(s)

The constituents of palmarosa essential oil are geraniol (70-85%), geranyl acetate (8-12%), linalool (2.4%), ß-caryophyllene (1.3%), geranyl formate (1.5%), geranyl butyrate (1%), nerol (0.22%), 6,7 geranyl epoxide (0.5%), 2,3 geranyl epoxide (0.2%), geranyl hexanoate (0.5%), geranyl octanoate (0.5%), limonene (0.5%), prenyl-isovalerance (0.4%), amyl hexanoate (0.3%), neryl formate (0.2%), and trace amounts of ß - pinene, myrcene, D-hexanol, geranial, prenylotonoate, caryophyllene epoxide, p-menthal etc.

Method of Oil Extraction

Palmarosa oil can be extracted either by hydro-distillation or steam distillation methods. Steam distillation results in maximum yield of quality oil. The oil, being lighter than water and insoluble, floats on the top of the separator and is continuously drawn off. The oil is then decanted and filtered. The distilled oil is treated with anhydrous sodium sulphate or common salt at the rate of 20 g per litre to remove the moisture. The oil should be stored in sealed amber colored glass bottles or containers made of stainless steel, galvanized tanks, aluminum containers and stored in a cool and dry place. The yield of palmarosa oil starts decreasing from fourth years onwards, therefore, it is recommended that replantation should be done every after four year.

Table 9. Yield of palmarosa essential oil for the first four years (Himadri and Dharamvir 2013)

1. First year	60 kg/ha
2. Second year	80 kg/ha
3. Third year	80 kg/ha
4. Fourth year	80 kg/ha

MARJORAM

Scientific Name *Origanum majorana*
Family Lamiaceae
Chromosome No. 2n=30

Introduction

The word "Oreganum" is derived from Greek word 'orosganos' means 'joy of the mountain'. Marjoram is perennial herbs, also known as "knotted marjoram" plant and it belongs to Lamiaceae family. Its oil is characterized by warm, slightly spicy smell and is colorless to amber or yellow color. It has been used in medicine, cosmetic, tea and perfumes. It has good muscle relaxant and pain killing properties and also used for headaches, migraines, insomnia, respiratory congestion, digestive problems and menstrual cramps. It is gently fragrant, calming action that does have mild antioxidant, anti-fungal properties, non-toxic, non-irritant and non-sensitizing but should not be recommended during pregnancy.

Origin and Distribution

Marjoram (*Origanum marjorana)* is originated from Mediterranean region. It is widely grown widely in Europe, USA, China, Russia, Morocco, North Africa and India. In India, marjoram plant is cultivated in.

Botany

Marjoram plants are bushy perennial herb with 60 cm in height and it has hairy stem, oval shaped and small pink or white flowers. Leaves are light, greyish green in color with 21 mm in length and 11 mm breadth.

Flowering and Fruiting Period: Summer

Agro Techniques

Marjoram grows well in any well-drained system, fertile garden loam and cultivated as an annual crop. It prefers slightly alkaline soil in nature. It is commonly propagated by cuttings, layers, root divisions and seeds. Seed sowing can be done during March- April in hilly regions and October in the plains. The cultivated field should be free from weeds and weeding can be done manually without giving any injuries to plants.

Chemical Constituents Structure of Major Compound(s)

The main compounds content in marjoram oil are sabinene, a-terpinene, y-terpinene, p-cymene, terpinolene, linalool, cis-sabinenehydrate, linalyl acetate, terpinen-4-ol and y-terpineol. Even though marjoram oil is non-toxic to human but should be keep away from pregnant women.

Method of Oil Extraction

The essential oil of marjoram can be extracted from both the fresh and dried leaves and flowers by steam distillation methods. Drying under shade improve the aroma with lesser broken leaves.

DAVANA (*ARTEMISIA PALLENS* WALL EX. DC)

Scientific Name	*Artemisia pallens*
Family	Asteraceae
Chromosome No.	2n = 16

Introduction

Davana (*Artemisia pallens*) is an annual aromatic plant belongs to ‘Asteraceae’. It is also known as South –Indian aromatic annual herb. In India, it is commonly grown in Southern part. For the extraction of oil, the aerial parts of the plants are cut just before flowering stages and dried under the shade for a week. The oil gives a somewhat brownish viscous liquid. It has a deep, mellow persistent rich fruity odor. It is used for high grade perfumes, cosmetics, flavoring cakes, tobacco and beverages. Davana flowers can also be used in arrangement of dry flowers, bouquet and garlands. It is also reported that it has some anti-bacterial properties. Bail et al. (2008) shows that davana oil from South India has high anti- bacterial activity against the Gram- (+ve) bacterium *S. aureus* and the Gram-(-ve)bacteria *P. aeruginosa* and *Salmonella entericaenterica*, as well as against the yeast *Candida albicans*.

Origin and Distribution

Davana is native to India. It is commercially used in South India, especially in Karnataka, Kerala, Maharashtra, Andhra Pradesh and Tamil Nadu since the ancient time as garlands and in making flower bouquets. The essential oil of davana is first distilled by Mysore based firm and exported to Europe.

Botany

It is an aromatic, annual, erect herb that grows to 50 – 60 cm height. Leaves are alternate, petiolate, and lobed to pinnatisect grey. At the early stage, this plant is difficult to distinguish from weed because its compact herb looks like weed. But after flowering stage it can be easily distinguished as it blooms with yellow color flowers.

Flowering and Fruiting Period: January-February

Agro-Techniques

Davana is moderately cool loving plant. It is a short duration winter season crop but cannot tolerate frost.It can be grown successfully during November to April with temperature of about 20-25°C. During winter season, heavy rains and frost may adversely affect the plant growth. In South India, davana plant is commonly cultivated in red soil area. It grows well in fertile, well drained, loamy soils, etc. It requires full sunlight for vigorous growth. At the time field preparation, FYM @ 6t/ha is incorporated into the soil and later, NPK @ 120kg: 40kg: 40kg is recommended to enhance the plant growth. Nitrogen fertilizer is applied in three (03) equal split doses. The first dose is given at 10 days after transplanting and the remaining two doses at 15 days' intervals, respectively. Phosphorous and Potash fertilizer are given at the time of transplanting.

Davana plant is propagated by seeds at the rate of 1.5 kg per ha of land. Seedling plants are raised in nursery bed. As the seeds are quite small it is advised to mixed with sand before sowing. Seedlings are ready for transplanting after 4 – 5 weeks and when seedlings are about 10 – 12 cm in height. Light irrigation is required after sowing or planting and to avoid water logging area. Planting during October to November give a better performance as compared to December planting. Insect pest incidence in davana field is not so common except the ant problems that carry away the seeds. In nursery field there is a problem of damping off caused by *Rhizoctonia spp* and it can be avoided by maintaining proper drainage system, raised nursery bed, clean cultivation and growing of disease-free planting materials.

Harvesting is done in the month of February to March by cutting the aerial parts of the plant just 10 cm above the ground level. Ratooning is done after two (02) months of first harvesting. It produces 10-12 kg of davana oil / ha from 8 – 10 tonnes of fresh plants per ha.

Chemical Compounds

Stefanie Baila et al. (2008) reported that davana oil collected from India contents some chemical compositionsuchcis-Davanone (45.8%), bicyclogermacrene (9.6%), linalool (2.5%), caryophyllene oxide (2.2%) and phytol (2.1%) that analyzed byusing GC and GC-MS.

Laxmi et al. (1991) found that the volatile components of the essential oil of *Artemisia pallens* contained more than 50 compounds, of which 34 are identified and for the first timeeight (08) components are reported of which five are new. 11-Hydroxy-8-oxo-9,10-dehydro-10,11-dihydronerolidol was also isolated indicating a possible role for this compound in the biogenesis of furano-sesquiterpenes of davana oil.

Extraction Methods

Davana oil can be extracted from partially dried flowering tops by using steam distillation. To complete the process of this method it takes mostly 6 – 8 hours. This method is efficient and gives higher yields. In this process, steam is employed to carry the volatile odorous oil along with its vapors which are subsequently condensed to liquefy the oil and water vapor. The mixture of oil and water can be separated by decantation and the remaining traces of water are removed by adding anhydrous sodium sulphate at the rate of 20-30g/l. Later, the oil is filtered to remove the sodium sulphate and other sediments (Himadri and Dharamvir 2013).

KHUS-KHUS (*VETIVERIA ZIZANIOIDES* L.)

Scientific Name	*Vetiveria zizanioides*
Family	Poaceae
Chromosome No.	2n = 20

Introduction

Vetiveria zizanioides (Khus-Khus) is an interesting perennial grass belongs to Poaceae family and commonly known as Khus-Khus grass, an aroma of tranquility. It can be anticipating as glorious gift from the botanical kingdom to the society. Cultivation of this plant not only prevents soil erosion, it also absorbed hazardous chemical residue from soil, maintain the soil moisture and improves the physical characteristics of the soil. It can be propagated by seeds or tillers and naturally grows best by the riverside. The world production of vetiver oil is about 300 tons per annum of which India contributes about 20-25 tons only. Khus-khus is commercially cultivated in Haiti, India, Java and Reunion. In India it is cultivated in the states of Rajasthan, Uttar Pradesh, Karnataka, Tamil Nadu, Kerala and Andhra Pradesh, with an annual production of about 20 tons of oil (ICAR 2014).

Vetiver plant can be used in many ways such as medicine, food and household items but it is mainly cultivated for fragrant essential oil extracted from its roots by steam distillation technique. The amber colored volatile oil has a characteristic strong, rooty-green, woody odor with lasting notes. During hot summer the oil is applied to the skin to reduce the effects of the external heat. The oil also used to treat flatulence, colic and obstinate vomiting. The dried roots can also be used in making incense sticks, fans, baskets, mats etc. In India, it has been used to cool the air with its special natural perfume. Nowadays, Vetiver products are widely used in making stuff such as men’s colones (Guerlain 1958), facial tonic mist, skin care, perfume, etc. It is reported that vetiver plants have been grown for soil and water conservation as it has extensive finely structured fibrous roots.

Vetiver oil is often used in the food and perfume industry and therefore there is a need to improve the quality of the essential oils extracted. The best methods such as microwave assisted extraction; supercriticalcarbon dioxide extraction (SCE) and subcritical water extraction (SWE) are now being used to improve the quality of end products (Luque de Castro et al. 1999).

Botany

Vetiver is considered as speedily growing variety of perennial grass. It grows vertically up to 1 to 2 meters high with thick clumps. The leave size is of 120-150 cm long with 0.8 cm wide. It has a long fibrous strong root system which is knitted together like a net in the soil. The roots grow vertically, 2-3.0 m deep and horizontally 0.5m only. The root systems hold the soil together and prevent soil erosion, retain soil moisture as well as it has the capability to absorb hazardous chemical residue remain in the soil from fertilizers and other pesticides by which it helps to reduce pollution in the environment.

Origin and Distribution

The Khus-khus plant is widely distributed in many tropical and subtropical countries. It is commercially cultivated in the countries like, Haiti, Brazil, Java, Seychelles, Sri Lanka, Indonesia, Jamaica, Zaire, and Vietnam. In India, vetiver oil is mainly produces from Tamil Nadu, Karnataka and Uttar Pradesh. In India, it is seen growing wild throughout Punjab, Uttar Pradesh and Assam. It is systematically cultivated as a crop in the states of Rajasthan, Uttar Pradesh, Kerala, Karnataka, Madhya Pradesh and Andhra Pradesh. Annually a 20-25 tonne of oil is produced in India. Uttar Pradesh produces the highest quantity of oil, mainly through wild sources. Vetiver oil produced in North India is of premium quality and fetches a very high price in international market.

Agro-Techniques

It grows well in different types of soil but a rich and fairly well drained loam is considered the best. The loamy soils, which are loose in texture, are ideal for root growth and harvesting as well. It is favorable with warm summer and well- distributed rainfall. It can be also cultivated on steep slopes or on flat land. The purpose of vetiver cultivation on flat land is to use the leaves for mulching so as to preserve soil moisture and conserve rainwater in the soil. Well drained sandy loam and red lateritic soils rich in organic matter are favourable for cultivation. It can be grown in wide pH range from 8.5 to 10.It has the capability to absorb dissolved heavy metals from polluted water and can tolerate arsenic, cadmium, chromium, nickel, lead, mercury, selenium and zinc. Growing of vetiver helps to prevent the damage of road shoulders and erosion caused by rain. The row should be parallel to the road shoulders at a distance of 30-50 cm to prevent car accident due to poor visibility. Contour planting of vetiver across the slopes helps to trap silts and filter crop residues, while only letting parts of water of flow through. This effectively reduces soil erosion and prevents surface soil from being washed away. Vetiver is also planted around the base of fruit and perennial trees on the plains, and on dry, deteriorated area in order to preserve rain water in the soil.

It can be propagated by tillers and slips. Slips are better compared with tillers, as it takes more time to germinate. The clumps are divided into slips with 2-3 tillers. These slips are jabbed into ground like seedlings. Slips are separated from the clump with the rhizome portion intact having 15-20 cm of the shoot portion. Cultivated land should be free of any kind of weeds and plant debris. Deep tillering or summer ploughing is recommended before planting to destroy the weeds and other resting structures of pathogens. Before planting, the fibrous roots are removed from the base of the root. Nearly 75,000 slips are required for one hectare land with a spacing of 45 x 30 cm. Only healthy and disease-free slips should be used as planting material. Irrigation should be given right after the planting. In India, the best time for planting is the onset of monsoon, June –August but in South India, the suitable time for planting is February-April. Recommended dose of fertilizer is 100kg of N, 40kg of P_2O_5 and 40 kg of K_2O per hectare. FYM or compost of 10-12 t/ac can be given at the time of planting, supplemented with urea one month after planting, to enhance the plant growth. Weeding is required for 2-3 times at an interval of about a month during the initial period of growth. Application of suitable herbicides like Atrazine @ 0.5 kg/ha as pre-emergence and before transplanting gives weed free condition for three months, after which the crop is able to cover the ground surface. Manual weeding is difficult in commercially grown areas. It is a hardy aromatic crop in nature and report on disease and pest incidence is not serious as compared with other cultivated aromatic plants.The following are the major diseases andpests of vetiver:

Table 10. Major diseases and pests of vetiver

Sl. No	Name of the Pests	Symptoms	Integrated Disease Management
1.	Leaf blight (*Carvularia trifolii*)	Symptoms appear at aerial parts of the plant. Small brown spot is the characteristic symptom and later the spots coalesce and turn blighted symptom and causes premature leaves fall.	• Clean cultivation • Copper oxychloride @ 0.2-0.25%.
2.	*Fusarium* Wilt (*Fusarium sp)*	Symptoms appear at the basal part of the plant and lower leaves turn yellow to brown in colour.	• Field sanitation • Disease free planting material • Proper drainage system • Soil drenching with Carbendazim@ 0.1%
3.	Grubs of beetle *(Phyllophaga serrate)*	Damaged the root portion	• Neem cake @ 5 t/ha before final ploughing
4.	Stem borer *(Chilo sp.)*	Attacks leaves part	• Removal of damaged plant parts • Application of neem based oil @ 5%.
5.	Scale insects	Sucked the sap of the plant and reduces the growth of the plantvigorously	• Application of neem based oil @ 5% • Spraying of Chlorpyriphos @ 2.5 l/ha.
6.	Termites and Ants	Very common in dry areas and it also damaged root portion.	• Clean cultivation
7.	Nematode *(Heterodera zeae)*		• Growing of healthy planting material from nematode free area is recommended. • Application of neem cake @ 5 t/ha

The crop should be harvested during October, after the monsoon period is over so that the roots need dry in the ground before the harvesting. To obtain good quality oil roots should be harvested at 18 months. The average yield is about 25-30 q/ha.

Chemical Constituents Structure of Major Compound(s)

The characteristic feature of khus-khus oil is the presence of the large amount of laevototarykhusilal (a race C-14 class of terpenoid) which is in fact responsible for the strong laevororation of this oil. It is also known for complex oil containing over 100 identified components, mainly sesquiterpenes. The characteristic constituents were vetiverol (45-80%), ß-vetispirene (1.6-4.5%), khusimol (3.4-13.7%), vetiselinenol (1.3-7.8%) and vetivone (2.5- 6.3%). Besides these components trace amounts of benzoic acid, vetivene, furfurol, khusemene, khusimone, ß-humulene, valencene, ß-vetivone, selinine etc. also exist in the oil.

Method of Oil Extraction

The extraction of vetiver oil is mostly done using conventional methods such as hydrodistillation, steam distillation and solvent extraction (Leite, 2012).However, it is reported that, these conventional methods are time taking methods and a lot of solvents and energy is required (Kusuma and Mahfud 2017). Khajeh (2004) stated that losses and degradation of some volatile compounds and degradation of unsaturated or ester compounds through thermal or hydrolytic effects are the principal disadvantages of this extraction method. Kusumaet al. (2017) showed that the extraction of essential oil from vetiver roots (*Vetiveria zizanioides*) by using microwave hydrodistillation method deals important advantages over hydrodistillation method as per the following reasons:

Table 11.Comparative advantages of microwave hydrodistillation over hydrodistillation

Sl. No	Important Practices	Microwave hydrodistillation	Hydrodistillation
1.	Extraction time	3 hours	24 hours
2.	Yields	0.49%	0.46%
3.	Environmental impact	energy cost is considerably lower	energy cost is considerably higher

Therefore, developing an alternative to conventional method like microwave hydrodistillation with the rapid, sensitive, safe and energy conserving extraction method is highly desirable.

Preparation of Raw Material by Martinez et al., (2004)

The harvested plant parts are cleaned and dried properly under shade for 24-48hours to improve the olfactory quality of the essential oil. Prolonged drying in the sun should be avoided as it reduces the oil yield. In case of roots, after harvesting the roots are first soaked and washed to remove dirt particles. The cleaned roots are then dried in a cool dry place or under shade for 2-3 days at room temperature to allow all the low value, non-polar, low boiling components of the oil to evaporate naturally (Danh 2007). The dried roots are grind into smaller sizes in order to increase the surface area for maximum extraction of the oils.

1) **Steam Distillation Methods:** Steam distillation method is one of the most common methods that practice in extraction of essential oils. In this method, the steam is sprayed through the plant material from below. When the steam is cooled down, it transformed into water and essential oils which remain on the top. Then, the essential oils are skimmed off and pour into a separate chamber/ container. The drawback of this method is that, it takes more time to complete the process than others.
2) **Hydrodistillation Methods:** Cleaned and dried vetiver roots are mixed with sufficient amount of distilled water inside the flask and boiled. A live steam also supply into the plant charge. Both hot water and the steam helps in freed the essential oil from the oil glands in the plant tissue. The vapour mixture of water and oil is condensed by indirect cooling with water. From the condenser, distillate flows into a separator, where oil separates automatically from the distillate water.
3) **Microwave Hydrodistillation Methods by Kusuma et al. (2017):** In this method, a domestic microwave oven (maximum delivered power of 800 W) with wave frequency of 2450 MHz can be used. The dimensions of the PTFE-coated cavity of the microwave oven were 48.5 cm x 37.0 cm x 29.25 cm. The microwave oven was adjusted by drilling a hole at the top. A round bottom flask with a capacity of 1000 mL was placed inside the oven and was connected to the Clevenger apparatus through the hole. Then, the hole was closed with PTFE to prevent any loss of the heat inside. Some feed to solvent ratio (0.30; 0.40; 0.50 g/mL) were placed in the reaction flask and heated by microwave irradiation with various power (300; 450; 600 W) and various extraction time (60; 120; 180 min). The different densities and their immiscibility required that the water and vetiver oil be separated from each other by separating funnel and the excess water be refluxed to the extraction vessel in order to provide uniform conditions of feed to solvent ratios for extraction. The vetiver oil collected in amber vials, dried under anhydrous sodium sulphate and stored at 4^{o}C.

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Chapter 7

ESSENTIAL OILS AND THE METHODS OF EXTRACTION

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ABSTRACT

Essential oils are synthesized, collected and deposited as liquid droplets in secretory glandules of aromatic plants. These essential oils have broad biological activities like anti-inflammatory, anticancer, anti-diabetic, anti-aging and anti-microbial activity spectrum like antibacterial, antifungal, anti-moulds, pest control and pests repellents because of which they have many applications in traditional medicines, health care such as pharmaceutics for their potential as therapeutic agents, used in aromatherapy as well as applications in skin care products, detergent, soap and perfume industries. Since time immemorial, many extraction methods have been developed and used for extraction of these essential oils from aromatic plants and these methods are being improved with advancement in technology in recent times. In this chapter, the different methods of extraction of essential oils are categorized into two groups viz., conventional methods and modern/advanced methods of extraction which are being discussed in detail.

Keywords: essential oil, extraction, distillation, supercritical fluid extraction, cold pressing

Basically, essential oil is a storehose of several secondary metabolites produced in response to a physiological stress, pathogen attack and unfavourable environment.

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Essential oils are synthesized, collected and deposited as liquid droplets in secretory glandules (Bruneton 1987).There are two types of secretory glandules one with exogenous secretion (those located on the plant surfaces like, epidermal papillae, the glandular trichomes etc.) and other is endogenous secretion (those located inside the plant in internal organs like secretory canals, schizogenous pockets etc. However, their quantity is very low (roughly 1%), making it extremely valued. Only 10% of the plant species (over 17,000) contain essential oils and are termed aromatic plants (Svoboda and Greenaway 2003). They are placed in a small number of families: Lamiaceae, Lauraceae, Asteraceae, Rutaceae, Myrtaceae, Poaceae, Cupressaceae and Piperaceae (Bruneton 1999; Figueiredo et al. 2008).

Due to the advancement of alternative health practices and the increasing customer appreciation for natural products as substitutes for synthetic flavors and pharmacological medicines, demand for essential oils is rising. Essential oils have been recognized as Generally Recognized As Safe (GRAS) substances by both the United State Food and Drug Administration and the Environmental Protection Agency. Hence, they are generally considered less hazardous substances and thus able to reduce the risks for the environment, animals and human health (Miresmailli and Isman 2014). From a financial point of view, the use of essential oils in skin care products, the detergent, soap and perfume industries are of significant concern. The generation of essential oils for the preparation of perfumes and fragrances has increased dramatically on a global scale and collection of these aromatic plants concurrently. Essential oils are utilized as a part of pharmaceutics for their potential as therapeutic agents. Essential oils have a broad biological activity like anti-inflammatory, anticancer, antimicrobial, anti-diabetic, anti-aging and anti-microbial activity spectrum like antibacterial, antifungal, anti-moulds, pest control, insect repellents (da Silveira et al. 2014; Kfoury et al. 2016; Nazzaro et al. 2013; Raut and Karuppayil 2014 and Asbhani et al. 2015). In pharmaceutical applications, essential oils are used to enhance pharmaceutical drug sensory attributes. Aromatherapy is the primary use of essential oils in pharmaceutics. Specific methods may be used to deliver essential oils. Local application of these oils along with some carrier oils following dilution to a concentration is the most well-known application technique for essential oils. They can also be breathed into the steaming water after a few drops have been added, or by a humidifier or atomizer system. These may also be used as balms, compresses, and creams. In any case, the oral use of essential oils by encapsulation or other customized discharge techniques was presented as a successful strategy for obtaining the beneficial effects of these essences (Boehm et al. 2012). Essential oils are utilized as seasoning material in wide range of food products, for example, confectionery sodas, and alcoholic drinks. Even though numbers of essential oils are labelled as GRAS, their uses in food as preservative are often restricted due to taste, because effective antimicrobial doses can surpass sensory appropriation levels. Their use as additives in foodstuffs requires a detailed knowledge of their properties, including target inhibition of

Table 1. Variety of essential oil from different plants

Common Name	Species	Parts used	Extraction process	Reference
Abies alba oil	*Abies alba*	Cone, leaf, needle, young branch	Steam Distillation, Hydrodynamic cavitation	Yang et al. 2009; Albanese et al. 2019
Angelica root oil	*Angelica archangelica*	Root, seed	Steam Distillation, Hydrodistillation, supercritical fluid extraction	Sowndharajan et al. 2017
Anise oil	*Pimpinella anisum*	Seed	Steam Distillation	Wong et al. 2014
Avacado oil	*Persea gratissima*	fruit	Cold press extraction	Costagli and Betti 2015
Benzoin oil	*Styrax tonkinensis*	Resin	Solvent extraction	Anonymous 2020d
Bergamot oil	*Citrus bergamia*	Peel	Pervaporation	Figoli et al. 2006
Black cumin oil	*Nigella sativa*	Seed	Solvent extraction, cold pressing	Subratti et al. 2019
Black pepper oil	*Piper nigrum*	Fruit, seed	Hydrodistillation, steam distillation, solvent extraction, supercritical CO_2 extraction and microwave extraction	Tran et al. 2019
Bitter orange oil	*Citrus aurantium*	Peel	Steam distillation, hydro distillation, supercritical fluid extraction	Golmohammadi et al. 2018
Cajuput oil	*Melaleuca leucadendron cajuputi*	Leaf	Supercritical fluid extraction, microwave exraction	Jajaei et al. 2010; Ismanto et al. 2018
Calamus oil	*Acorus calamus*	Rhizome	Steam distillation, super critical fluid extraction	Shreelaxmi et al. 2017
Cananga oil	*Cananga genuine*	Flower	Solvent free microwave extraction	Putri et al. 2019
Cedarwood oil	*Cedrus atlantica*	Wood	Steam distillation	Eller and Taylor 2004
Chamomile oil	*Anthemis nobilis*	Flower	Steam distillation	Gawde et al. 2014
Cherry pit oil	*Prunus avium*	Seed	Super critical fluid extraction, Solvent extraction	Straccia et al. 2012
Citronella oil	*Cymbopogon nardus*	Herb	Ohmic-heated Hydro-distillation, Hydrodistillation, Steam distillation	Hazwan et al. 2014
Clove oil	*Eugenia caryophyllus*	Bud	Solvent extraction, super critical CO_2 extraction, Microwave-Assisted, Ultrasound assisted extraction	Khalil et al. 2017
Coriander oil	*Coriandrum sativum*	Fruit, herb, seed	Semi-continuous supercritical carbon dioxide extraction,	Pavlicet al. 2015
Costus oil	*Saussurea lappa*	Root	Steam distillation	Abdelwahab et al. 2019
Cypress oil	*Cupressus sempervirens*	Leaf	Solvent extraction, hydrodistillation	Selim et al. 2014
Eucalyptus oil	*Eucalyptus species (citriodorata, globulus, radiata)*	Flower, stem, leaf	steam distillation, Organic solvent extraction, Supercritical CO2	Anonymous, 2020e

Table 1. (Continued)

Common Name	Species	Parts used	Extraction process	Reference
French marigold oil	*Tagetes species (erecta, patula)*	Flower	Solvent extraction, Supercritical CO2	Daghero et al. 1999
Geranium oil	*Pelargonium roseum*	Leaf	Supercritical CO2	Peterson et al. 2006
Ginger oil	*Zingiber officinale*	Root	Microwave-Assisted Hydrodistillation, steam distillation	Mathialagan 2012
Grapeseed oil	*Vitis vinifera*	Seed	supercritical fluid extraction, gas-assisted mechanical extraction	Rombaut et al. 2004
Hyssop oil	*Hyssopus officinalis*	Herb, leaf	Hydrodistillation, ultrasound assisted extraction	Rashidi et al. 2018
Jasmine oil	*Jasminum officinale*	Flower	Hydrodistiillation	Phuc et al. 2019
Juniper oil	Juniperus species *(communis, mexicana, oxycedrus, phoenicea, scopulorum, virginiana)*	Wood, fruits	Steam distillation, solvent extraction, supercritical fluid extraction	Naji et al. 2008
Laurel oil	*Laurus nobilis*	Leaves	Solvent free microwave assisted extraction	Bayramoglu et al. 2009
Lavender oil	*Lavandula officinalis*	Flower	Steam distillation, Solvent extraction	Sadathian et al. 2013
Litseacubeba oil	*Litsea cubeba*	Fruit	Microwave assisted water method	Lai et al. 2019
Lovage oil	*Levisticum officinale*	Leaf, root	supercritical CO2	Dauksas et al. 1998
Melissa oil	*Cymbopogon citrates*	Leaf	Supercritical fluid extraction, hydrodistillation	Rehman et al. 2017
Myrrh oil	*Commiphora* species *(abyssinica, myrrha, schimperi)*	Gum	Steam distillation, supercritical CO2	Anonymous 2020f; Marongiu et al. 2005
Neem oil (oil of margosa)	*Melia azadirachta*	Seed	supercritical CO2, solvent extraction	Liauw et al. 2008
Nutmeg oil (myristica oil)	*Myristica fragrans*	Kernel	Steam distillation, Microwave assisted extraction	Anonymous, 2020f; Novak et al. 2016
Olibanum oil (frankincense oil)	*Boswellia carterii*	Gum	Steam distillation	Adhari said et al. 2019
Origanum oil	*Origanum vulgare*	herb	Hydrodistillation, supercritical CO2	Moghrovyan et al. 2019 Veenstra et al. 2019
Patchouli oil	*Pogostemon cablin*	Leaf	Steam distillation, supercritical CO2, microwave oven distillation	Donelian et al. 2009
Pine needle oil	*Pinus species*	Needle	Solvent extraction, microwave-assisted extraction, ultrasound-assisted extraction, accelerated solvent extraction, solvent-free microwave extraction, microwave hydro-diffusion and gravity, supercritical fluid extraction,	Silori et al. 2019

Common Name	**Species**	**Parts used**	**Extraction process**	**Reference**
Rosemary oil	*Rosmarinus officinalis*	Flower	Steam distillation, hydrodistillation	Boutekedjiret et al. 2003
Rosewood oil	*Anibarosae odora*	wood	Steam distillation, microwave hydrodistillation,	Amusant et al. 2018
Sage oil	*Salvia* species *(e.g., officinalis, sclarea, hispanica, lavandulifolia)*	Herb, seed, flower	Steam distillation	Anonymous, 2020f
Sandalwood oil	*Santalum album*	Wood, seed	Microwave-air hydro distillation	Kusuma and mahfud, 2016
Sweet orange oil	*Citrus* species *(aurantium, sinensis)*	Flower, peel, seed	Steam distillation, supercritical fluid extraction,	Mercy et al. 2015
Tangerine oil	*Citrus tangerina*	peels	Cold pressing, CO2 supercritical extraction	Anonymous 2020f; Dong et al. 2014
Tea tree oil	*Melaleuca alternifolia*	Leaf	Steam distillation,CO2 supercritical extraction, and solvent extraction	Huyhn et al. 2012
Thuja oil	*Thuja species (occidentalis, plicata)*	Stem, Leaf	Hydrodistillation	Aniqa et al. 2020
Thyme oil	*Thymus* species *(vulgaris, zygis)*	Herb	Steam distillation, solvent extraction	Eqbal et al. 2017
Valerian oil	*Valeriana officinalis*	Root	Solvent extraction	Boyadzhiev et al. 2004
Vetiver oil	*Vetiveria zizanoides*	Root	Hydrodistillation	Kasuma et al. 2017
Violet leaves absolute	*Viola odorata*	Leaves	Hydrodistllation and solvent extraction	Akhbari 2012
Ylang-ylang oil	*Canangaodorata macrophylla*	Flower	Steam distillation, solvent extraction	Tan et al. 2015
Zdrawetz oil	*Geranium macrorrhizum*	Leaves, Rhizome	Steam distillation	Anonymous 2020e

microorganisms, specific methods of activity, their antibacterial efficacy and possible interactions with their antibacterial attributes (Hyldgaard et al. 2012). The demand for essential oils is rapidly expanding, moving tens of millions of dollars yearly. In 2018 the overall demand for essential oils on the market was 226.9 kilotons. It is expected to grow from 2019 to 2025 at a compound annual growth rate of 8.6 per cent (Anonymous 2020g).

Different Extraction Method of Essential Oils

Several plant species produce essential oils which have many applications be it food preparation, manufacture of cosmetic products besides their medicinal properties such as antibacterial, antifungal, anticancer, antioxidant, etc., which found their uses in traditional medicines and pharmaceuticals (Valgimigli 2012;Teixeira et al. 2013). Essential oils are volatile aromatic compounds which can be extracted using different methods. One of the oldest methods to recover these essential oils from plant materials are the hydro-distillation and steam distillation methods. However, they are limited by temperature as high temperature can damage or alter the action or the quality of the essential oil (Burt 2004). Hence, numerous innovative methods have been developed to extract these molecules from the plant materials. Exploiting the microwave and ultrasound technologies have also led to the development of new methods which are more efficient in recovering the essential oils (Vinatoru 2001; Cardos-Ugarte et al. 2013). Therefore, the different extraction methods can be categorized into two groups – conventional methods and modern/advanced methods.

Conventional Methods

1. Distillation

a. Hydro-Distillation

It is a very old and simple method of essential oil extraction from the plant material. In this method, the plant material is completely immersed in water followed by boiling, which means the plant material is in direct contact with boiling water. Upon coming in contact with boiling water, the plant material releases their essential oils. The water-essential oil vapour mixture is then passed through a condenser which further flows into a separator where the essential oil and water are separated by simple decantation (Figure 1) (Janardhanan and Thoppil 2004). The advantage of this method is that majority of the essential oils are immiscible in water and after their extraction the essential oils can be easily separated from water. The third edition of the European Pharmacopoeia has recommended the Clevenger system for determining the yield of essential oil. The duration of extraction in this method may be from three to several hours depending on the plant material. This method is effective for those herbs and spice that contains essential oil that are non-soluble in water, heat stable molecules that have high boiling point. This method also has several disadvantages such as: 1) long extraction time (3-6 hours per sample; 24 hours in rose petals), 2) Hydrolysis of unsaturated or ester compounds due to prolonged exposure in boiling water, polymerisation of aldehydes or thermal degradation of heat sensitive molecules that would decrease the quality of the essential oil (Gavahian et al. 2012). Examples of plants that can hydro-distilled are osmium, dill, caraways, geranium, sage, etc. The yield and quality of essential oils obtained varies with plant varieties, crop growth stages, season of cultivation, post-harvest treatment prior to distillation and time distillation duration. With slight modification of hydro distillation extraction efficiency can be increased and extraction time can be reduced.

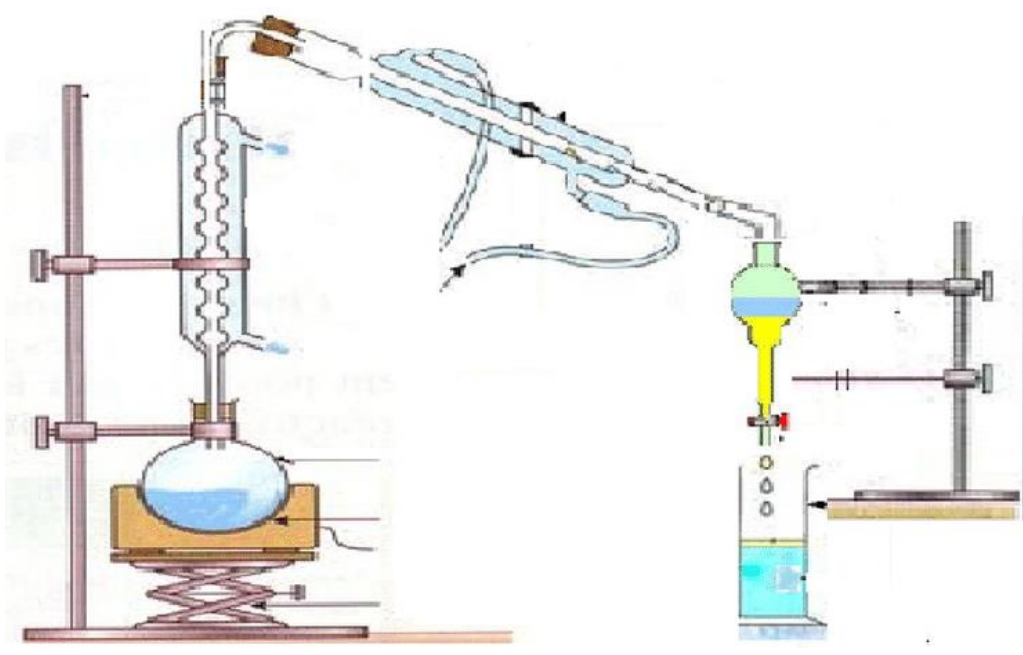

Figure 1. Hydro-distillation method-Clevenger apparatus (Mehani et al. 2016).

i) Turbo-hydrodistillation: In this technique, the extractor in the Clevenger system is replaced with a stainless-steel stirrer which helps accelerate the process of extraction of essential oils. The stirrer may also be equipped with sharp razors blades which cuts the plant materials into smaller pieces thus increasing the exposure area of the plant material which increased the extraction of essential oils. This technique have been used to extract essential oils of Alliaceae family and lavender (Filly et al. 2016).

ii) Addition of salt to the water helps to increase the boiling point of water and thus increase the chance of higher yield of essential oil as in the case of lavender oil where addition of salt increases the yield of essential oil (Filly et al. 2016). However, in case of rosemary, adding salt to the boiling water doesn't increase the oil yield (Fazlali et al. 2015).

(iii) Enzyme-mediated hydrodistillation: Before the distillation process, the plant materials are pre-treated with enzymes which assist the release of more essential oils during the extraction process. Enzymes such as cellulase, hemicellulase, xylanase, pectinase or protease help to break down the cell wall faster and releases the oil (Kashyap et al. 2001). This technique helps to reduce the extraction time as well as increase the yield of essential oils.

b. Steam Distillation

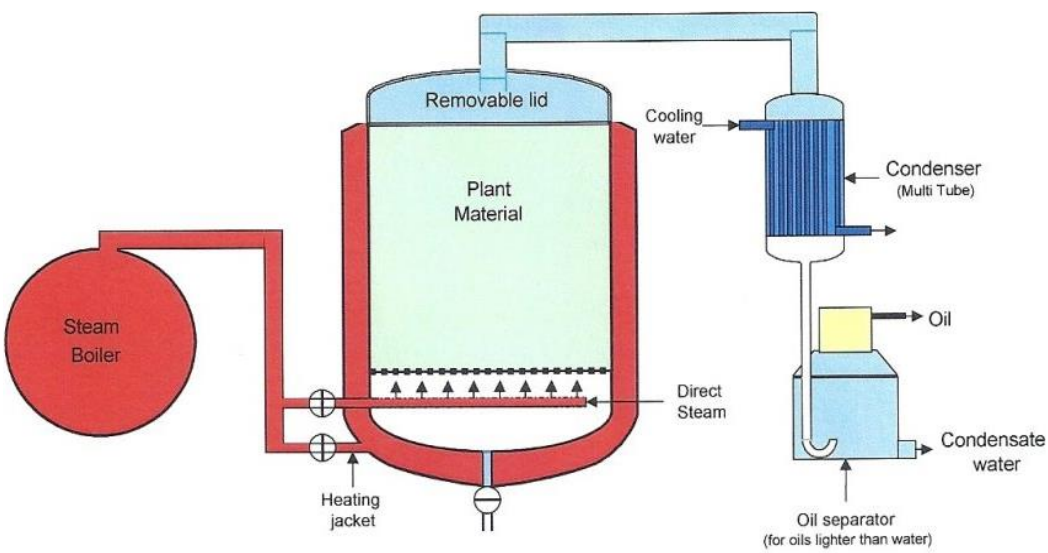

Figure 2. Steam distillation method.

Steam distillation is one of the oldest and popular methods used for essential oil extraction (Figure 2). For several decades, this has been the best method to obtain high quality essential oils (Burt 2004). In this method, the plant material is placed on a perforated tray in the extractor and is not in direct contact with the boiling water. The steam is generated in a boiler which is then introduced to the bottom of the extractor through a pipe. The steam passes through the plant material from the bottom to the top during which the volatile components (essential oils) are released from the plant cells due to the heat which destroys the cell structure. The oil vapour mixture is then passed through a cooling system/condenser where the oil-vapour mixture is condensed into liquid form. The liquid mixture of oil and water is then passed to a separator where the essential oil and water are separated by decantation (as these two liquids have different densities). As this method also involves high temperature, degradation of heat sensitive components is unavoidable (Pecorino-Issartier et al. 2013). Therefore, the quality of the essential oil obtained greatly depends on the time duration of steam distillation and boiling point of targeted essential oils. It is suggested that for low boiling point essential oils, the duration of steam distillation should be short whereas, for high boiling point essential oils the duration of steam distillation should be longer. Although the yield and quality of essential oils also depends on the type of plant materials, species or varieties, harvesting time, season, etc. Pre-treatments of the plant materials by maceration, addition of cell wall degrading enzymes and by heating have been reported to be promising in enhancing the release of more essential oils which increases the yield and quality (Sahraoui and Boutekedjiret 2015; Sowbhagya et al. 2011), besides, increasing the efficiency of the extraction method and decreases the energy requirement.

c. Water/Steam Distillation

This method is similar to steam distillation except that the steam is generated in the extractor itself but below the plant materials. In this case, the plant material is kept on a perforated tray above the water level and the plant material is not in direct contact with the boiling water. As the heat is applied, the water boils and steam is generated. The steam penetrates the plant materials and release the essential oils. The oil vapour mixture is then passed though a condenser which condensed the mixture into liquid. The oil-water mixture is then passed to a separator and the essential oils and water are separated by decantation process (Figure 3).

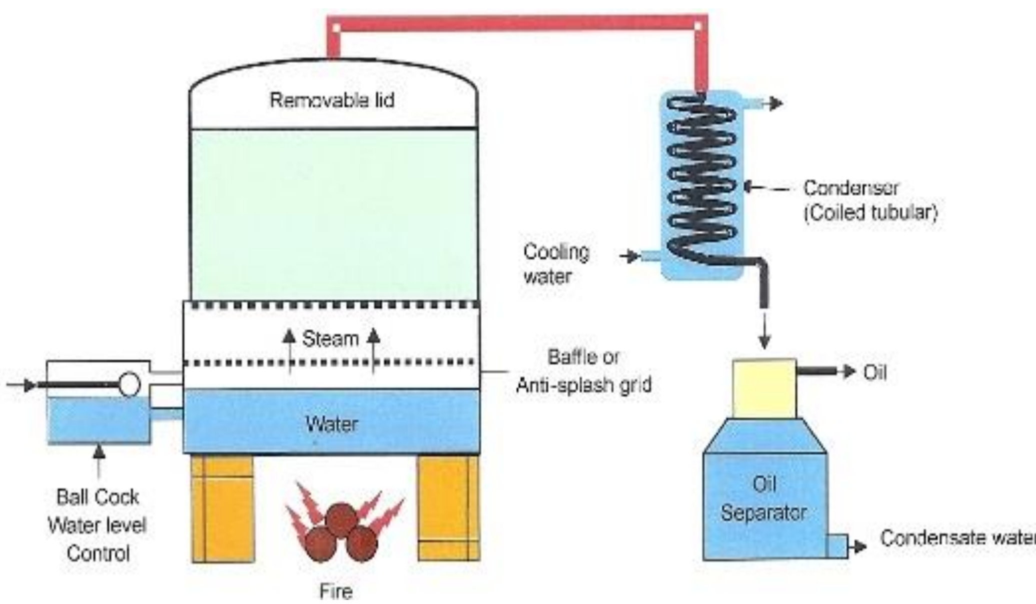

Figure 3. Water-Steam distillation method.

2. Solvent Extraction

In this method, the plant materials containing essential oil are dissolved in a solvent. This is possible because the essential oils are hydrophobic and have non-polar characteristics. The solvent essential oil mixture can be separated by evaporation. Solvents such as hexane, benzene, and acetone are commonly used in dissolving the essential oils from plant materials (Dai and Mumper 2010). These solvents have high volatility event at room temperature, so application of slight heat to the extracted solvent-oil mixture easily evaporates the solvents leaving behind the essential oils.

The simplest solvent extraction method is percolation. A percolator has wide opening at the top, to facilitate removal or addition of samples, and a regulator at the base to facilitate removal of the solvent. The solvent passed through the plant materials continuously and the saturated solvent is replaced constantly by fresh or less saturated solvent. The dried plant material is first grounded into powder form and is placed into the percolator with the valve at the bottom in closed position. A suitable solvent is added at the top covering the powdered samples and allow soaking for several hours or overnight. Using the valve at the bottom, the saturated solvent is removed at a controlled rate and fresh solvent is added from the top (Jones and Kinghorn 2005).

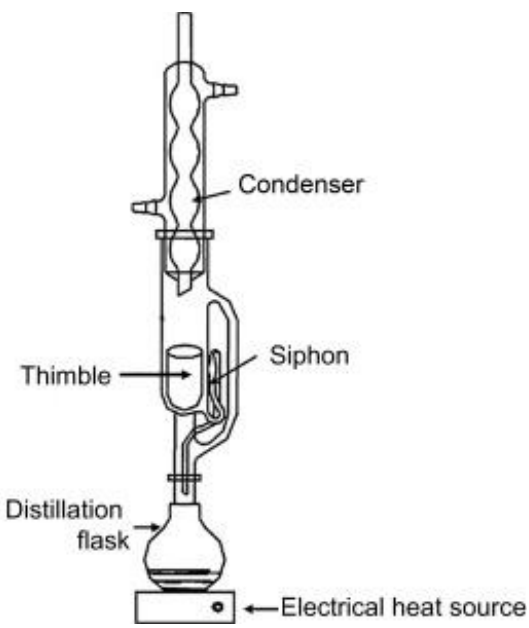

Figure 4. Soxhlet's apparatus.

Another common method of solvent extraction is the use of Soxhlet extraction apparatus (Figure 4). The Soxhlet extractor consists of a distillation flask, an extractor, and a condenser. As the solvent is heated, it evaporates into a vapour that passes through the condenser and is condensed into a liquid form. The condensed solvent is then passed to a thimble-holder (extractor) holding the sample to be extracted. The solvent dissolves the essential oils from the sample and when the solvent in the extractor reaches the overflow level, a siphon system releases the solvent-oil mixture from the extractor back into the distillation flask. Given the high volatility of the solvent, the extracted essential oil is retained in the distillation flask whereas the solvent is evaporated, condensed and returned to the extractor (Tandon and Rane 2008). This process is repeated several times during which the sample is extracted multiple times until the extraction is complete.

3. Cold Pressing

Cold pressing is the old-style method to extract essential oils from citrus fruit skin by mechanically pressing the materials. Due to the force, the oil sacs start breaking and release volatile oils which are present in the skin yielding a watery emulsion. The watery emulsion of oil and water is separated by centrifugation (Ferhat et al. 2007). This recovered oil has various applications such as in food industries, pharmaceutical industries as well as a flavouring ingredient.

Modern Innovative Methods

1. Microwave-Assisted Extraction

In this method, the heat produced by the microwave radiation is used in heating the mixture of plant materials and solvent. Heating with microwave causes dipole rotation of the molecules which disrupts weak hydrogen bonds and changes the cell structure helping in very fast extraction of the essential oil. The heat caused by the microwave is instantaneous and occurs in the interior of the plant materials helping in fast extractions. Utilizing microwave technology helps in reducing the extraction time by more than half as well as the solvent requirement when compared with the conventional methods like steam distillation or solvent extraction methods without compromising the quality of the essential oil (Flamini et al. 2007; Bendahou et al. 2008). With the development of the green extraction concept and to reduce energy inputs in the extraction of essential oils, more emphasis has been given to the exploitation of microwave technology which has led to the development of several methods such as solvent-free microwave extraction (Lucchesi et al. 2004 a,b), vacuum microwave hydro-distillation (Huma et al. 2011), microwave assisted solvent extraction (Tomaniova et al. 1998), microwave hydro-diffusion and gravity (Vian et al. 2008) and microwave assisted simultaneous distillation-solvent extraction (Ferhat et al. 2007).

2. Ultrasound Assisted Extraction

The use of ultrasound technology in combination with other extraction techniques such as hydrodistillation or solvent extraction has proven to be useful in accelerating the extraction of essential oil from plant materials. In this process, the plant material is submerged in water (hydrodistillation) or solvent, while being introduced to ultrasound activity at the very same time. The ultrasonic waves have a frequency of 20 kHz–1 MH (Cravotto et al. 2008), but their intensity at low frequencies (18–40 kHz) is substantially greater. Ultrasound causes mechanical vibration of cell walls and plant cell membranes to facilitate rapid release of essential oil droplets. This technique was developed primarily for the extraction of some therapeutically important targeted molecules. With the use of ultrasound, these volatile compounds can be isolated at room temperature with organic solvents, shortening the extraction time, reduce the requirement of solvents and increasing the yield of essential oil when compared with conventional methods (Alissandrakis et al. 2003). Plant tissues containing essential oils have very thin outer covering which can be easily rupture by sonication. Therefore, application of ultrasound enhances the release of essential oil thereby increasing the extraction efficiency and recovery of essential oil (Toma et al. 2001). The efficiency of ultrasound assisted extraction depends on many factors such as particle size and moisture content of the plant materials, type of solvent used, temperature, pressure and the time duration of sonication. This technique is particularly suitable to plant materials sensitive to high temperature. Another added advantage of this technique is that the equipments are relatively simple and inexpensive compared to other novel techniques such supercritical fluid extraction or microwave assisted extraction.

3. Supercritical Fluid Extraction (SFE)

Supercritical Fluid Extraction is similar to Soxhlet extraction method, but the solvent used is supercritical fluid. SFE is one of the emerging extraction techniques, which is usually faster and more selective in extraction of the compounds from plant materials (Figure 5). As well as it is ‘green’ technologies which means the resultant waste materials can be easily recycled and reused. Thus, SFE may be defined as separation and extraction of chemical compound of interest from samples or products such as tea, herbs, and spices etc. using supercritical fluid as an extracting solvent. When the extraction mixtures are subjected to temperature and pressure above their critical points the state obtain is SF state. Supercritical fluid exhibits physico-chemical properties which are intermediate between liquid and gas. These fluids can diffuse through solid like a gas and dissolve material like a liquid (Mendiola et al. 2013). Additionally, small changes close to the critical point in temperature or pressures results in greater changes in the densities allowing many properties of SCF to be fined tuned. Thus, supercritical fluids (SCF) are preferably a substitute for organic solvent in the many industrial and laboratory processes. The supercritical solvent of choice for the extraction of plants compounds is carbon-di-oxide, since it is odourless, nontoxic, inflammable and inexpensive. Carbon dioxide facilitates supercritical activity at relatively low pressure and close to ambient temperatures (Knez et al. 2010; Zizovic et al. 2007). The critical temperature for CO2 is 31.1°C and 72 bar. The SFE method consists of extraction of the soluble components in supercritical solvent and isolation of the solutes from solvent. The segregation of soluble solutes from the solvent may be executed by simply changing the temperature and pressure of the system thus changing the thermodynamics of supercritical solvent. The desired effect in these cases is a reduction of a solvent power (Pereda et al. 2007). A standard SFE unit includes a high-pressure pump that supplies the SCF and an extraction tank with sample which is held at the specified temperature and pressure. The selectivity of a SCF can be modified by adjusting temperature and pressure, allowing access for selective extraction from a mixture of different compounds. Examples of procedures for selectively extracting or separating different compounds with SFE are the fractional extraction process (FEP), single stage extraction (SSE), and sequential depressurisation (SD) (Shi et al. 2006; Zizovic et al. 2007).

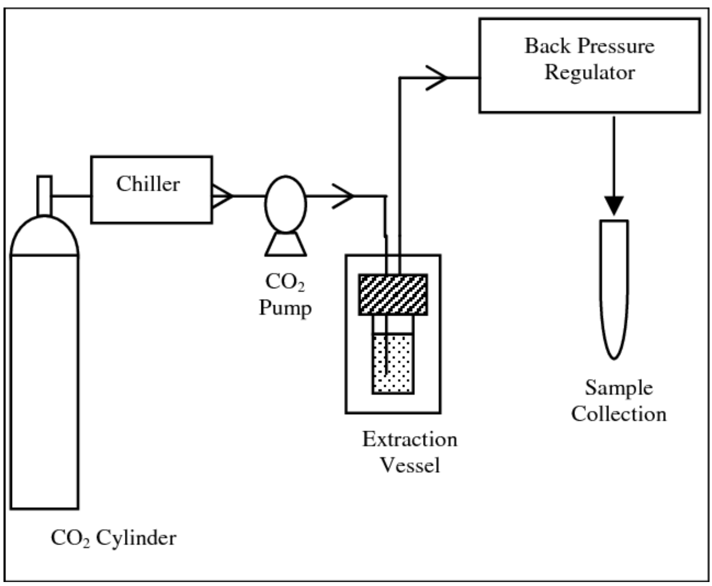

Figure 5. Flow diagram of SCF (Puah et al. 2005).

4. Ohmic-Assisted Hydrodistillation

Ohmic heating is an advanced method of extraction using electricity to increase the heat uniformly in plant materials. As electricity passes through the plant materials, the ohmic/electric energy is converted to heat by resistor constituting in plant material. The bulk of plant material can be quickly and uniformly heated using ohmic heating without affecting the material quality. Conventionally heating the plant material by conduction reduces the quality owing to slow heating rate and un-even heating. Ohmic-assisted extraction can provide faster extraction kinetics at lower cost. Conventionally plant materials are by conduction, which involves slow heating rate and causes a non-uniform temperature in the materials. These gradients in temperature decrease the extraction efficiency and destroy the quality of the product. The extraction time can be decreased by a factor of two as compared to the conventional extraction process (Gavahian et al. 2012).

5. Pulsed Electrical-Assisted Extraction

Pulsed electric field (PEF) is a non-thermal technique of processing food and plant materials. It involves changes in cell membrane structure and other local structural alteration by applying the short and intense electric pulses. Increasing permeabilization of cell membranes by electroporation is currently gaining interest. PEF impact on the cell in various ways, like by formation of possible transmembrane in the cytoplasmic membrane, formation of pores and changing the size and number of the pores of the cell membrane (Roohinejad et al. 2014). Depending on the field strength applied, the electroporation may be reversible or permanent.

6. Vacuum Microwave Hydrodistillation (VMHD)

Archimex Corporation licensed Essential oils extraction from plant materials through VMHD for the first time. The process is done in two steps (Figure 6): First, heating the plant material with MW (the matrix is humidified if used in dry state), and second, creating vacuum (0.1–0.2 bar) in the system, enabling the water-essential oils mixture to be extracted azeotropic. The thermo-sensitive compounds are kept intake as the usual working temperature is below 100°C. In addition, compared with the traditional method of hydrodistillation, the operating time can be reduced by five to ten times (Li et al. 2012), thus decreasing the power utilization.

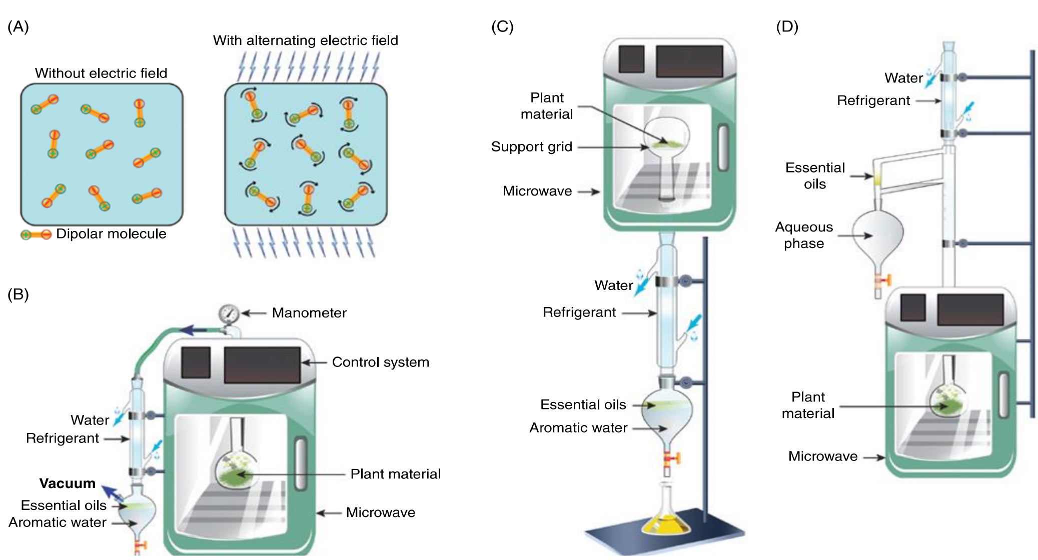

Figure 6. Vacuum Microwave Hydrodistillationset-up at laboratory scale. A. Dipolar molecules under electromagnetic field. B. Vacuum microwave hydrodistillation. C. Microwave hydrodiffusion and gravity. D. Solvent-free microwave extraction (Roohinejad et al. 2018).

7. Microwave Hydrodiffusion and Gravity (MHG)

Another green technique used for the extraction of essential oils from plant matrices, proposed in 2008 is MHG (Figure 7) (Vian et al. 2008). The advantage of the process is that it allows essential oils to be extracted without distillation and evaporation, which is very helpful because it saves the energy used for heating (Huma 2010). It is designed for both laboratory and industrial applications, involves MW heating and earth gravity at atmospheric pressure. Inside the MW equipment, plant material is first placed without additional water. Essential oils are released in situ due to the internal heating by MW, a phenomenon called as hydrodiffusion (which allows the diffusion of the extract outside the cells and its recovery by gravity). The extract obtained by a cooling system is composed of two phases. Using separatory funnel' or 'Florentine flask', light phase-in the top collects essential oils, and heavy phase in the bottom collects aromatic water, which are then separated.

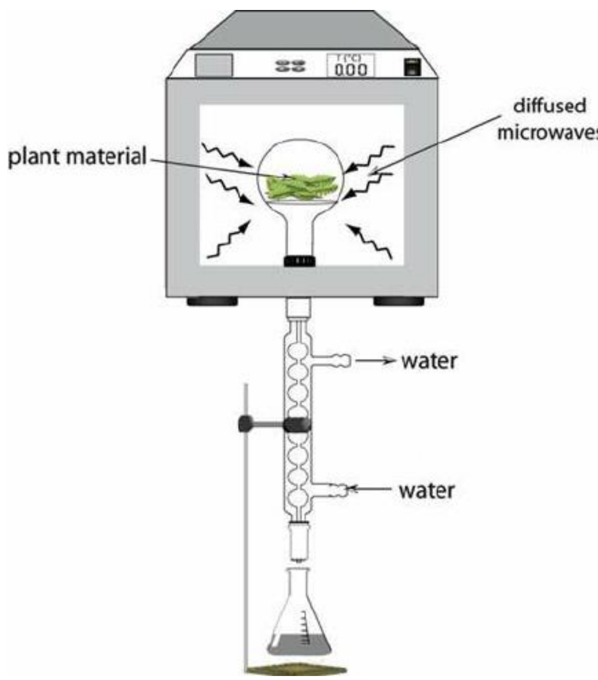

Figure 7. Microwave Hydrodiffusion and Gravity (MHG) (Li et al. 2012).

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Chapter 8

THE ROLE AND EFFECTS OF AROMA: STATUS AND TRENDS

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ABSTRACT

Aromatic plants have been utilized since antiquity as peoples' medication and as additives in nourishments. The most popular aromatic plants, for example, oregano, rosemary, sage, anise, basil, citronella, peppermint and so on, begin from the Mediterranean zone. They contain biologically active compounds, for the most part, polyphenolic, which have been found to have antimicrobial, cancer preventing, antiparasitic, antiprotozoal, antifungal, and mitigating properties. As of now, the interest of these plants and their derivatives has expanded in light of the fact that they are natural, eco-friendly and generally perceived as safe items. Hence, aromatic plants and their extract can possibly turn out to be new-age substances for human and animal nutrition and health. Today, an assortment of accessible herbs is utilized all through the world and kept on advancing good human health. The advantages of restorative and aromatic plants are perceived, which may be proven as unique role for mankind health.

Keywords: aromatic plant, pharmaceuticals, herbs, bioactive compounds, antimicrobials

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INTRODUCTION

Natural goods from plants are well recognized since time immemorial. Global markets have been utilizing products from herbs for several decades. The majority of the Asian region has a magnificent custom on a plant-dependent healthcare system. The herbal method of medication gives rise to small expenditure on treatment of different frequent diseases and numerous chronic ailments by protection and effectiveness. The wealthy assortments of therapeutic and aromatic plants (TAP) remain a vital resource of livelihood for common of the forest-dependent communities and acquire the prosperity of information as native habitual awareness. Out of 8,000 species of ethnobotanical significance accessible in Asia, 2,500 species are mainly useful in diverse conventional remedy methods. The present pharmacopeia as well as 25 per cent constituent of plant origin medicine. At present, 134 species are under farming, 160 species are moderately cultivated and more than 250 medicinal and aromatics plants (MAPs) species are traded in huge volumes. This huge source has produced the basis of unprocessed material provide to industries for medicinal formulations, perfumery, food flavoring, dietary applications, cosmetics, etc. The global marketplace of herbal goods is expected approximately to be the US $ 62 billion and hovering to grow at a rate of 7% per annum to the US $ 5-7 trillion latest by 2050. The improved requirement of plant-dependent raw resources has required the overexploitation and unscientific assortment of natural populations from the untamed and mainly of the Asia-Pacific countries are experiencing the defeat of assortment of MAP. The Asia-Pacific region is also wealthy in native conventional knowledge (ITK) and efforts are essential to file and revalidate prior to it gets worn continuously. The WHO has built up the rules for good agricultural and assortment rehearses. The development of restorative and aromatic plant species gives an additional bit of flexibility by delivering uniform and predictable quality crude material. The endeavors are needed to produce eco-friendly agro-innovation to help business development under the natural conditions with repurchase courses of action with client industry (Paroda et al. 2013; ASEAN 2013). Presently the significance of the development of therapeutic and aromatic plants is expanding consistently because of the reactions of the compound and artificial drugs that are making mindfulness among individuals around the world. It has rich potential for the protection and development of restorative plants. The administration of India has started endeavors to save the genetic stock of restorative plants accessible in forests (Devi et al. 2017).

India is probably one of the leading countries in the world that has perceived the significance of herbal products for disease management, nourishment, and magnificence improvement. With the disclosure of a few new particles from herbs for dealing with feared infections like cancer and the overall wellbeing of these items, the worldwide interest for therapeutic plant items has expanded in recent years. Likewise, customers are favoring beautifiers with fragrant items from plants bringing about more popularity for the crude material. India is perched on a fortune of 8000 medicinal and aromatic plants ranging from 1200-2500. Over the most recent 50 years, Central and State Government research associations have built up a few advancements for using therapeutic and aromatic plants. Little and medium endeavors have just been set up by numerous business visionaries and openings exist for new ventures in this field (Rajeswara 1999a; Rajeswara 1999b). Nepal is the fortune of the geographical, organic, and social assorted variety. At present, the forest involves 5828000 hectares of absolute land (M.O.A.D 2015). Nepal has higher plant species of 6,973 out of which 10% offer on the assorted varieties of such important MAPs (Boeckel 2017). Just because, Pandey (1961) revealed 73 therapeutic and aromatic plants (MAPs). At that point, the Department of Medicinal Plants (DMP 1970) discovered 483 species; a report given by Malla and Shyaka (1984) detailed about 690 types of MAPs from Nepal. Further, Manandhar (2002) has detailed ethnobotanical data of 1,500 plant species; most of them have therapeutic worth (Dharmendra and Arati 2018). China is a multi-ethnic nation, where ethnic medication is the primary name for the conventional prescriptions of Chinese ethnic minorities in light of the boundaries created by the distinctive clinical frameworks, language, culture, and species qualities (Zhao et al. 2017). China, the beginning of and greatest focus of creation for some, medicinal and aromatic plant (MAP) materials utilized in customary Chinese medication (TCM), produces a wide assortment of plant-based natural drugs and fixings that are expended inside China and around the world. However, wild TCM plant assets in China, as in different parts of the world, are in danger. Populations are declining the nation over, in huge part as a result of overharvesting to satisfy the towering need from the TCM and natural items industry (Brinckmann 2017).

THE STATUS OF AROMATIC PLANTS

The worldwide significance of the item drug plants is tremendous. During the 1990s, it's detailed yearly generally importation produced on normal to 400,000 t estimated at USD 1,224 million3. Worldwide exchange is overwhelmed by just a couple of nations: 82% of the overall produce was directed to only 12 nations and 12 nations were liable for 80% of the common world's exportation. The part of calm Europe and Asia in this exchange is predominant, as the nations of mild Asia are answerable for 42% of the yearly worldwide import and Europe for 33%. As to nations, the import portion of the Germany 11% and USA is 13%. The rundown of the world's best 12 nations of import shows that Hong Kong is the most significant merchant of medicinal and aromatic plants with a yearly normal of around 67,000 t. It is trailed by Japan with a normal import of around 51,350 and the USA with 49,600 t a year. Germany follows on fourth spot bringing in on normal 45,350 t for each year. No less than five European nations, every one of them European Union Member States, are among the best 12 nations of import.

On the fare side, China heads the rundown of the world's best 12 nations of fare. It traded on normal around 147,000 t of medicinal and aromatic plants. This figure is twofold as high as the quantity sent out from Hong Kong, during multiple occasions than amounts traded from India, and multiple times than Germany and the USA. Further significant exporters are Mexico, Egypt, Chile, and Bulgaria. Three nations, to be specific the USA, Germany, and Hong Kong, are among the 12 driving nations of fare and the 12 driving nations of import. Each of the three nations stand apart as significant exchange places for botanicals, indicating both high import and high fare amounts, which are, on account of Hong Kong, generally re-trades. The net imports of all nations feature the shopper and the source nations of botanicals. In like manner, Japan is by a long shot the most significant shopper nation, trailed by the USA, Germany and the Republic of Korea, and by four further European nations, France, Italy, the United Kingdom and Spain. In these nations, the crude material is principally prepared in every nation's huge industry and afterward sold as completed items either on the homegrown market or traded accordingly. On the opposite side, uncovers China as most significant provider of the crude material to the world's medicinal and aromatic plants market, trailed by India on second spot. Inside Europe, Bulgaria and Albania are significant source nations for drug plants, inside North America, Mexico, Africa, Egypt and Morocco. European nations are significant entertainers in the overall plant's exchange (Lange 1998, 2002). All European nations together imported every year on normal 127,230 t of drug plants in the period 1991-2000. Around 85% of them were bound to European Union nations. Then again, the yearly European fare normal added up to 75,900 t. During this period, the fares have been bound to in excess of 150 nations everywhere on over the world, at the same time, just a little portion of the general European fare, just 20% was coordinated to non-European objections, most importantly to North America. The fares were overwhelmed by eastern and south-eastern European nations which represent at any rate 50% of the general fares with respect to amounts, however just to 33% on account of significant worth. The vast majority of these nations, similar to Bulgaria, Albania, Poland, and Hungary, predominantly previous Eastern Bloc nations, are significant gracefully nations of botanicals inside Europe (Lange 1998, 2001, 2002).

The predominance of Germany in the intra-European medication exchange is clear: (1) 33% of the general amounts of medicinal plants brought into Europe are bound to Germany (2) the portion of the nation's fares is roughly one fifth as far as amounts; (3) besides, Germany goes about as a connection between the business sectors of eastern and south-eastern Europe and those of west and focal Europe: It imports two third of the plant material sent out from south and southeast European nations (Lange 1998), and sends out it most importantly to focal and western European nations, Lange 1998). Other than Germany, there are two further significant exchange places for botanicals (see above). Like Germany, the USA imports the product medicinal plants from everywhere the world, however, the fundamental objections of the fares are Canada, United Kingdom, Germany, Saudi Arabia, Hong Kong, and Kuwait. Hong Kong is the third significant exchange community assuming an essential function in the east and Southeast Asian exchange. Rather than Germany and the USA, 95% of the imports of Hong Kong are re-sent out. Further, 80-90% of the nation's imports are from a solitary nation, in particular China, the staying from Indonesia, the Republic of Korea, Australia, Thailand, and Macau (=China MC SAR). The fares have been bound to numerous nations everywhere on over the world with inclination to east and Southeast Asian nations. As it may have significance declined during the 1990s, as the fares and imports of Hong Kong diminished from around 80,000 t in 1991 to 38,000 t in 2000. India has a long, sheltered and ceaseless use of plentiful home-grown medications in the formally perceived elective frameworks of wellbeing such as AYUSH. These frameworks have legitimately existed beside each other with Allopath and they are not in 'the space of indefinite quality', as articulated by Venkat (2003). A large number of Indians utilize homegrown medications routinely, as flavor's, home-cures, wellbeing nourishments in the form of over-the-counter (OTC) as self-medicine or additionally as medications recommended in the case of non-allopathic frameworks (Gautam et al. 2003). The in excess of 500,000 non-allopathic specialists are prepared in the clinical schools (>400) of their separate frameworks of wellbeing and are enrolled with the official committees which screen polished methodology.

Current Status of Medicinal and Aromatic Plants in India

India is a place where there are different climatic, ethnic, social, and phonetic zones with a populace contacting one billion. The nation is separated into ten bio-geographic zones: Trans-Himalayan, Himalayan, semi-dry territories, Indian deserts, Western Ghats, Gangetic fields, upper east India, islands, and coasts. All scopes of the atmosphere (high to tropical) and height (ocean level to 6,000 m) are accessible in the nation. The recorded forest territory of the nation is about 63.73 mn hectares, which is 19.39% of its absolute region. The district is likewise one of the spots of most punctual developments known to man. From the old-time, India has been known for its rich assets that have achieved various intrusions and prompted its riches and information to various pieces of the world. The yearly per capita utilization of medications in the nation is around US$ 3, which is the least on the planet, predominantly in light of the fact that customary drugs dependent on the sound old arrangement of medication are as yet pervasive in the nation with regards to developing public and the worldwide market for therapeutic and aromatic plants, India is very much aware of the protection and practical utilization of its regular assets. These medicinal plants are likewise significant wellspring of another sort of advantageous mixes including the elements for useful nourishments. These practical nourishments elevate better wellbeing to forestall incessant sickness. A few fixings that make food useful are dietary strands, nutrients, minerals, cell reinforcements, oligosaccharides, fundamental unsaturated fats, lactic corrosive microscopic organism's societies, and lignin's. A large number of these are available in restorative plants. Indian frameworks of medication accept that perplexing ailments can be treated with a complex mix of botanicals not at all like in the West, with single medications. Entire nourishments are henceforth utilized in India as utilitarian food sources. Some therapeutic plants having dietary constituents utilized in the form of flavors (garlic, onion, red bean stew, mustard, clove, cinnamon, curry leaf, turmeric, saffron, ginger and fenugreek). A few spices, such as Bixa orellana, vegetables (wheatgrass, soybean, Cambogia, Alma, Garcinia have antitumor properties. Some more medicinal plants with such properties including, *Azadirachta indica* (neem), *Andrographis paniculata* (green chiretta), *Aegle marmelos* (bael), Aloe vera, and Brassica juncea (mustard), *Allium cepa* (onion) (Tilak and Devasagayam 2006).

Present Status of Medicinal and Aromatic Plants in Nepal

Customary medication is far-reaching all through the world and Nepal conveys the immense potential for investigating medicinal plants from the logical point of view, since it is wealthy in biodiversity and endogenous information on ethno therapeutic plants. Nepal covering 750 plants in detail (IUCN Nepal 2004). Work done by Banerji (1955) is the earliest distributed work dependent on therapeutic plants in East Nepal (Banerji 1995). About 80% of the Nepalese populace is contingent on the customary plant-dependent drugs for their essential medical service's needs (Kunwar et al. 2006). Nepal comprises 1624 plant species as having medicinal and aromatic qualities, while for Sri Lanka it is about 1400, for India around 2500 and for China, it is around 5000 (Shrestha et al. 2000; Chaudhary 1998). It appreciates all the atmospheres of the elevated, mild, and tropical marsh. It has a biodiversity of 10 bioclimatic zones, 6 phytogeographical areas, 75 vegetation types, 35 forest types. Majesty of the biological system of Nepal inside an extremely tiny separation around 200 km, which offers bulky tropical rainstorm forest (mainly Terai in the south), and high fields and snow-secured Himalayas (in the north). Forest accounts for essentially in the economy of what is else probably the least fortunate country of the world. Approximately 7,000 types of blossoming plants have been accounted for the nation and out of which 246 are endemic. On a worldwide scale, the nation stands 27th in the quantity of blossoming plants. The list of recorded distinguished therapeutic plants utilized in Nepal has developed from 70 species during the studies report of 1968 and 1,463 in the 1997 report. This increasing number for the period of the years obviously mirrors that still the absolute number of species utilized as medication in the nation isn't known. A land region of 14% is under assurance in Nepal (Shrestha and Pandey 2018).

Present Status of Medicinal and Aromatic Plants in Laos

Laos is wealthy in an assorted variety of therapeutic and aromatic plants. Concurrently, no organization in the nation attempts the business on Materia medica. Just a little scope industrial facility in the Southern aspect of the nation produces crude material for medication from plants, and another in the middle produces turpentine oil from pine (*Pinus* spp.). There are some drug production lines in the capital (of which three have a place with the administration segment, one is a joint-adventure with China and the rest are exclusive), which produces just a little number of plant-based medicines. The industrial facilities in the private sectors produce to a great extent current prescription and just a little segment from plant material. Most customary medication industrial facilities in the private area produce just conventional cures comprised of at least one restorative plant. The crude material is pre-treated and handled, (for example, cleaning, slashing, blending, dose detailing and bundling) for both homegrown deal and fare purposes. Through the subjective overview, the Institute has gathered data in surplus of 200 types of therapeutic worth. Despite the fact that it is as yet a little entity that needs experience, to be considered as the base camp of the therapeutic and aromatic plants innovative work in Laos. For the commercial productions in Laos, it has one pilot plant for the mining of therapeutic plants, which has delivered the antimalarial drug (artemisinin) through the extraction and sanitization (Kraisintu 2003).

Current Status of Medicinal and Aromatic Plants in Philippines

Since the establishment of the Asian Network on Medicinal and Aromatic Plants (ANMAP) in 1993, momentous advancement happened in the area of medicinal and aromatic plants in Philippines. This is mainly because of the improving economy and the dynamic support of both administrative and private segment, to incorporate medicinal and aromatic plants development in to existing cultivating framework in country regions. The restorative plants recorded in the year 1993 from the country report and numerous others keep on giving fundamental and elective medical services to the people groups of The Philippines, particularly in the distantly islands, which need current clinical offices. The innovative work endeavors on medicinal and aromatic plants that flourish the nation have achieved significant changes in medical care industry. Several drug organizations have ventured into assembling of natural medications and body-care items. The EOs industry has become massively contrasted with certain years prior. Numerous herbal items, particularly natural teas and makeup, are traded from the nation. There is a solid development from people medication to drugs, and herbal meds are at present viewed as a solid accomplice in the medical services conveyance framework. Therapeutic plants, which were prior, viewed as decoctions and poultices administered by cultivators, are currently accessible in dose structures like tablets, syrups, cases, liniments, creams, treatments, capsules and colors. Among body-care items, natural cleansers, skin and body creams, shampoos, powders and colognes are main stream on the market (Farnsworth et al. 1985; WRI 2001).

Current Status of Medicinal and Aromatic Plants in Thailand

Thailand is offered with rich normal assets and has assorted natural conditions furthermore, ethnic decent variety including old human advancements. There are excessive of 10,000 types of plants out of which around 1,400 recorded as indigenous plants used in the Thai Materia Medica. Plant-based crude material is created and utilized universally in drug, perfumery, beauty care products, smell synthetic compounds, and related businesses. A few therapeutic and aromatic plants are utilized in domestic and export as crude materials or chemical agents to different counties such as Europe, USA and Japan (Kraisintu 2003).

Current Scenario of Medicinal and Aromatic Plants in Vietnam

Vietnam is a tropical nation with broadly shifting climatic and topographical highlights. It has a plenitude of different normal assets of medicinal and aromatic plants. The greater part (80%) of its populace living in the open country and an enormous number of ethnic minority bunches dissipated in the good countries don’t approach current drugs. In any case, Vietnam has a well-established customary arrangement of medication which has been passed on from age to age. The utilization of customary drugs is profoundly established in the general public. Medicinal and aromatic plants and herbal medications have made a gigantic commitment to public wellbeing and advancement. The Vietnam government has given extraordinary consideration to medical services since its autonomy: the medical services framework has coordinated customary drugs with present-day ones. For a nation that not long after its freedom needed to confront 30 years of frightful war, the best way to give medical care to everything was to prepare its own assets to create medications from indigenous crude materials, since the import of medications was restricted. Because of this arrangement and remodeling endeavors, in twenty years of the after-war period, the state drug manufacturing plants and privately owned businesses have served viably the interest for drugs in Vietnam (Kraisintu 2003).

Current Scenario of Medicinal and Aromatic Plants in China

China is a bound together multi-ethnic nation, where ethnic medication is the authority brought together name for the customary prescriptions of Chinese ethnic minorities in view of the obstructions created by the distinctive clinical frameworks, language, culture and species qualities. Exploration dependent on ethnic medicinal assets is uncommon (Li et al. 2006). In some ethnic minority regions, the creation innovation of conventional ethnic medication and clinically normal and key ethnic therapeutic remedies is confronting the danger of serious misfortune, without being given to the people to come (Vandebroek and Balick 2012). There are numerous fragrant plants remembered for records on preparing and use in the old writing of China. Individuals have regularly utilized aromatic plants for seasoning, medical care, in wine and beautifiers, as moth anti-agents and reviving substances, and for cleaning air. During the previous thirty years, conventional Chinese medication, in view of on fragrant plant materials, has been embraced all through an important part of the Western world and become one of the quickest developing medical care decisions in the United States (Darrin, pers. commun.). Proof of development in the act of Chinese medication is presumably best shown by the extension in number of authorized Chinese medication suppliers in the US, from 5,525 out of 1992, to currently 14,228 (Mitchell, pers. commun.). This expansion in customary Chinese medication specialists has expanded the interest for therapeutic plant material, essentially the whole plant material (developed or wild crafted) utilized in the act of conventional Chinese medication in the US which was imported from China (Darrin, pers. commune.). Domestic manufacture of these botanicals would help guarantee the security, newness, and nature of the material. In fact, some Chinese medicinal plants, those are legendary perceived as adaptogens (Astragalus membranaceous root, Lycium Chinese natural product, and Schisandra Chinensis berries), are as of now in nutraceutical items in the US, including herbal teas, soda pops, soups, and trail blends. (Strategy and redesign endeavors, in twenty years of the after-war period, the state drug processing plants and privately owned businesses have served adequately the interest for drugs in Vietnam (Lyle and Jean 2002).

CURRENT SCENARIO OF AROMATICS PLANTS

Natural medication is the outcome of helpful encounters picked up for over hundreds of years by ages of rehearsing doctors of indigenous medication framework. They are known to be the most seasoned medical services items that have been utilized by humankind everywhere on over the world. The medicinal utilization of herbal drugs is increasing significant energy on the planet during the past few decades. The WHO assess that herbal medication is as yet the main backbone of around 75%–80% of the total populace, mainly creating nations, for essential medical care as a result of better social worthiness, and lesser reactions. In India, the estimated botanicals-related exchange of 10 billion US$ for every annum with yearly fare of 1.1 billion US$. In India it is hovering on the goldmine of all around recorded and very much rehearsed information on conventional home-grown medication and it has a rich legacy of MAPs (in excess of 8000 therapeutic plant species). China has effectively misused its natural medication information by advancing its utilization in the created world medication framework, in contrast to China, India has no alternative option to gain by these herbal riches due to the non-accessibility of normalized natural medications. Significant commitments of MAPs over the Himalayan region identified on the basis of documentation of inventories, further data for the rundown of species, or part(s) utilized and dispersion runs. A comprehensive abridgment of medicinal plants for the nation and also for their organic movement is accessible as per report given by the researchers (Rastogi and Mehrotra 1991). India has been explored through *in vitro* engendered and preservation of some endangered therapeutic types of pants (Bhojwani and Arumugam 1993). Lately, through the *In vitro* cultured conventions of Himalayan therapeutic valued plants have been normalized. Which incorporate *N. jatamansii, Valeriana wallichii, P. hexandrum, A. heterophyllum and Rheum emodi*. According to evaluations of Exim Bank, yearly worldwide business through the therapeutic plants is greater than US$ 60 billion, and every year development pace of about 7%, among which 2300 crore is the India's turnover per year (Sharma 2005). Nations, such as France, Germany, Italy, Spain, China, UK, Japan, and US accounted main worldwide exchange places for the MAPs (Laird 1999). As per the detailed report of WHO, current worldwide interest of therapeutic plant items is roughly 14 billion US$ each year which is further required to go beyond the 5 trillion US$ continuously by 2050 and the worldwide interest for MAPs items expanding with pace of the 15%–25% every year. Nutraceutical part comprising of natural prescriptions, which are included along with dietary enhancements to meet FDA standards effortlessly, is presently assessed to India which is among the 17 super biodiversity nation over planet, along with more than 45,000 types of the plants, and 7,500 species from them assessed from which 4,635 to be utilized for the healthcare as well as for the veterinary purposes. Unknown trade earned through the plant-based medication from India and exported during 1994–95 valued for 53,219 million US$ and 13,250 million US$ earned from basic oils (Lambert et al. 1997). Trades by India through the natural material and medicines are of Rs. 3,000 crores, and it is expected to be 15,000 crores by 2015. Therapeutic plants have great extent unexplored wellspring of medication store (Dar et al. 2013). Numerous literatures demonstrating the increasing patterns of the antimutagenic effect which concentrates with plant extricate reported by the groups of researchers (Khader et al. 2010; Chen et al. 2011; El-Sayed and Hussin 2013). Therapeutic spices/plants or herbal medications allude to the utilization of plant and plant-based items for the administration of basic infirmities. World Health Organization has characterized herbal medications as a completed marked medicinal item that contains a functioning fixing, elevated, or underground pieces of the plant or other plant material or mixes. In India, over 70% of the populace utilizes herbal medication for their health-related issues. A significant lot of the establishments embrace the "converse pharmacology" way to deal with study the clinical adequacy of medicinal plants and their business-like utility in medical care. In addition, the herbal therapeutics establishes a significant portion of all the convincingly perceived Indian frameworks of medication, for example, AYUSH. Nonetheless, there is proof of deceptive medications, unreasonable use, and antagonistic medication responses of natural medications which ought to surely be observed with legislative patronization. Besides to be acknowledged as a feasible option in contrast to present day medication energetic techniques for logical and clinical approval must be applied to demonstrate the wellbeing and adequacy of these natural items. Nonetheless, the clinical preliminary of natural medications is troublesome inferable from a portion of the conspicuous reasons. Around 20,000 restorative plants have been distinguished for their therapeutic properties; despite just 7000–7500 therapeutic plants are being utilized by conventional practitioners (Samal 2020). MAPs are widely utilized in Traditional Chinese medication framework, Ayurveda, Unani, Sidhha about 3000 types of MAPs exchanged universally, from which 2000 are especially exchanged through the European nation like German, Switzerland and France (Schippmann et al. 2006). Therapeutic and aromatic plants are offered in a wide assortment of items available. Approximately each fourth blossoming plant is utilized. The colossal interest in botanicals brings about a tremendous exchange from nearby to global level. During the 1990s, the revealed yearly overall importation of drug plants produced on normal to 400,000 t esteemed at USD 1,224 million. Global exchange is overwhelmed by just a couple of nations. As of recently, the creation of botanicals depends to a huge degree on wild assortment. In spite of, usage and business of wild plant assets are not inconvenient in themselves, be that as it may, for instance, the expanding business assortment, generally unmonitored exchange, and natural surroundings misfortune lead to a superlatively developing weight on plant populaces in nature. Worldwide an expected 9,000 restorative plant species are undermined.

SCOPE AND TRENDS OF AROMA

Universally 72000-11000 plants at present utilized for medicinal purpose. Worldwide imports and fares (2004-2008) of medicinal plants were worth US$ 1.59 and l.44 billion/year, separately with >40Va development rate per annum. Out of the 3000 therapeutic plants exchanged globally, just 900 are under development and lion's share of the traded biomass is reaped from nature. Loss of living space, over reaping, an Earth-wide temperature boost and environmental change are seriously influencing therapeutic plant populaces, undermining (15000 species) their future presence. To monitor the worldwide abundance of medicinal and aromatic plants and their biodiversity, development is rising as a monetarily suitable choice. Many sending out countries are practicing this alternative as developed plant material is acknowledged by organizations managing spices. Future holds guarantee for developed therapeutic plants as worldwide item of trade. India with an abundance of 8000 therapeutic plants, accessibility of development and handling advancements, can possibly saddle the monetary intensity of these plants (Rajeswara and Raiput 2010). Chinese baijiu (alcohol) is probably the most established distillate on the planet and can be arranged into 11 classes as indicated by their fragrance qualities. Ethyl hexanoate was the key aromatic compound in aroma and flavor type baijiu. Unsaturated fats were significant aromas for Chinese baijiu. Sulfur-containing compound were significant aromatic compounds. A large number of the unpredictable compounds additionally influence the severe taste and astringent mouth feel. The information acquired in the previous decade about fragrances and kinds of baijius has given a heading to baijiu quality improvement and new innovation execution in industry (Fan et al. 2019).

Aroma assumes a predominant part in the multisensory impression of flavor. It is itself a develop apparent in light of incitement of the olfactory framework by unstable synthetics and blends thereof, with blends being ordinarily experienced in regular daily existence as food, wine, plants, aroma, and so forth. While our comprehension of the neurobiological and mental components that make an interpretation of volatiles into smell discernments has progressed essentially lately (Buck 2004; Axel 2004) explanatory methodologies for portraying the impression of these fragrance blends are as yet restricted. The connection between synthetic structure of a blend of volatiles and its apparent fragrance or flavor is perplexing and hard to anticipate based on concoction information or straightforward tactile information alone. Diagnostic science describing flavors or aromas based on chromatographic strategies for evaluating aromatic quality of individual compounds present in a mixture, which is reflected as either the fixation present in the blend and extracted by deliberate tactile limit focus (Odor Activity Value, OAV) (Guadagni et al. 1966) Chromatographic procedures just survey the aromatic nature of individual mixes, instead of mixture of compounds. In any case, the aroma of mixture is habitually perceptually unmistakable from that of its individual segments (Wilson and Stevenson 2006) and may have characteristics not found in any of these parts (Berre et al. 2008). The blending subordinate nature of aromatic quality is proven by the general absence of aromatic compounds, or those aggravates that are independently answerable for the general aromatic impression of a food or drink. Then again, oversight tests depend on a supposition that all sensorially significant mixes have been accurately recognized and measured and that any compound happening at a fixation underneath its putative tangible edge isn't critical to the general aroma as of late distributed outcomes recommend this isn't the case (Pineau et al. 2007). Regardless of having indistinguishable fixation profiles of supra-edge odorants, the aroma of a reconstitution in some cases actually smells unique in relation to the first mixture (Steinhaus et al. 2009); a wonder alluded to as "reconstitution disparity". Some ongoing oversight tests have included sub-limit parts in the reconstitution (Bult et al. 2001), however this is certainly not a general practice, and can incredibly muddle and amplify the test plan.

Medicinal Importance of Aromatic Plants

The compound of therapeutic value from aromatic plants continues sparing human health until the present, for example, medication, food, recuperating, and entertainment. One of the tremendous advantages from therapeutic and aromatic plants was to beaten numerous troublesome ailments, for example, infectious illness, AIDS/HIV, and malignant growth. National Cancer Institute (NCI) screen plants having chance of new medications and dynamic plant synthetic concoctions for disease and AIDS/HIV in a few continuous collective projects (Taylor 2000). As of late, individuals concern wellbeing of body and psyche, anticipation illnesses, detox, and life span. Subsequently, incorporated medication or preventive medication is engaged and acknowledged in present day medication and day by day life. Some restorative and sweet-smelling plant starting points of Asia are every day utilized on the planet in view of the fame and assortment. Every day utilize restorative plants were listed cry. Drug industry is developing each year, particularly the business in United States added an expected $790 billion to the economy in 2014 (U.S. Department of Commerce International Trade Administration Industry & Analysis 2016). Natural compound of plant materials will give a clue to make another medication including the degree of family, plant species, and cultivars. Today, at any rate 120 particular synthetic substances got from plants are considered as significant medications (Taylor 2000). The structure of compound and constituent shows interesting therapeutic activity (Pengelly 2004) and information and practices of conventional medicinal and aromatic plants demonstrated the suitable uses for the manifestation. The data will turn into a sign to build up another medication. Herbal medication is utilized by 75–80% of the total populace, essentially in creating nations for essential wellbeing care. Moreover, the natural medications are accepted to have no side effects, modest, and locally the utilization of natural medication in Indian, Chinese, Egyptian, Greek, Roman, and Syrian writings go back to around 5000 years. The old-style compositions of India, for example, Rig-Veda, Atharvaveda, Charak Samhita, and Sushruta Samhita depict the use of therapeutic plants. This demonstrates the herbal prescriptions or the conventional medicaments have been gotten from the rich customs of old developments and logical inheritance (Kamboj 2000) In India, natural therapeutics establishes a significant portion of all the formally perceived Indian frameworks of medication, for example, Ayurveda, Yoga and Naturopathy, Unani, Siddha, and Homeopathy (AYUSH) (Vaidya and Devasagayam 2007). In India, 17,000–18,000 types of blooming plants are found of which 6000–7000 is assessed to have medicinal properties. The utilization of these medicinal and aromatic plants is found in numerous Indian societies and is recorded in Indian frameworks of medication, for example, Ayurveda, Siddha, Unani, and Homeopathy. An expected 960 types of medicinal and aromatic plants are in exchange of which 178 species have yearly utilization levels in excess of 100 metric tons. These therapeutic and aromatic plants not just establish a significant asset base for the conventional medication and herbal industry yet in addition give employment and wellbeing security to a huge segment of Indian populace (National Medicinal Plant Board of India 2015). The TCM, the conventional medication of eastern Asia, depends by and large on indigenous plant species. Conventional healers in numerous African nations depend on nearby or at most territorial plant material. In Bulgaria, around 750 local plant species, or 20% of the absolute greenery, are utilized in people's medication. Of these, 200-300 species are most generally utilized. Further, in Albania, 205 local plant species are utilized as wellsprings of botanicals (Lange 1998). In Hungary, approximately 270 local restorative and fragrant plant taxa are utilized, 180-200 of which are authoritatively perceived by the Hungarian Pharmacopeia list an aggregate of 337 local taxa that have been monetarily exchanged Turkey since at any rate 1990 (Lange 2001). From the French pharmacopeia and arrangements of prescriptions Goi et al. (1997) and Lange (1998) noticed nearly 900 taxa, of which practically half are local to Europe. This implies numerous nations depend on a significant part of their own plant assorted variety. A significant number of them can't stand to import unfamiliar botanicals, completed natural items or even phytopharmaceuticals and the nation's own "biodiversity" is principally offered in an unrefined structure or at most as meagre prepared items available. Traditional natural medication is being drilled all through the globe as indigenous medication. The utilization of therapeutic plant assets to recuperate human diseases goes with the advancement of human development and structures the premise of the source of present-day medicine (Pal and Shukla 2003). Recognition of the rising use of herbal drugs and other elective integral medication prompted the establishment of the workplace of elective medication by the National Institute of Health, USA, in 1992. The natural medication got an overall lift when the World Health Organization urged creating nations to utilize customary plant-based medication to satisfy needs neglected by current frameworks (Winslow and Kroll 1998).

Impacts of Aromatic Plants on Human Health

Therapeutic and aromatic plants (MAPs) add to human nourishment and medicinal treatment for a very long time (Gahukar 2018). Numerous plants effectively affect the human body (Hao and Xiao 2018), giving a wide range of advantages, accordingly adding to the wellbeing of the general public. Regardless of broad exploration led on herbal items and regular MAPs, shockingly, fewer than 10% out of 250,000 species on the planet have been utilized for any organic application (Omidbaigi 2007). Right now, 25% of drugs are gotten from plants and 12% are produced using microbial assets. There is an ever-developing requirement for MAPs in creating nations, yet it shows up recently that individuals in created nations show a propensity to restorative spices as opposed to current medications (Kumar 2008). The explanations behind this inclination could be that concoction prescriptions have been demonstrated to have hurtful reactions, from one perspective, and furthermore they add to natural contamination, then again. As indicated by current insights, practically 80% of the total populace addresses drug issues by utilizing therapeutic spices (Karki 2003). Guides are known to be an indistinguishable piece of regular assets all around the world. With appeal for regular wellbeing items and auxiliary metabolites of MAPs, the utilization of these plants is developing rapidly all through the world. Be that as it may, a few animal types face the danger of termination from unpredictable assortment and natural surroundings misfortune (Jeelani et al. 2018), while certain wild assets are seriously debilitated with raising human populace and plant overconsumption (Ross 2011). This leads in elimination, however puts biodiversity at high danger (Aslam et al. 2017). Guides' creation by means of development can limit the high weight on populaces of wild MAPs and keep up consistency underway. Additionally, expanded development can diminish the collect volume of MAPs, accordingly profiting the reclamation of their wild assets and diminishing costs (Larsen and Olsen 2007). This methodology will limit ecological harm and the demolition of hereditary sources (Kala 2005). Urging ranchers to develop MAPs through enhancement of their trimming design for these harvests the usage of medicinal and aromatic plants is known since days of yore. The world market incorporates home grown medications, drugs, scents, flavors, colors and different fixings and their advertising surpasses a few billion dollars for every year. Basic essential oils (EOs), extricated from fragrant plants, are intriguing common items and speak to a significant aspect of the conventional pharmacopeia. The utilization of some EOs as elective antimicrobial and drug operators has pulled in impressive intrigue as of late. The vast majority of the EOs and their single constituents have been accounted for to repress a few phytopathogens, human microorganisms, and creepy crawlies just as their successful uses in food and drug enterprises. Plants are essential for humans since from the earliest starting point. Plants and their concentrates are predominantly utilized therapeutic purposes both for the counteraction and treatment of human maladies in numerous nations. As of late, contemplates are directed to exhibit the significance of normal cancer prevention agents in human wellbeing. The reason for these investigations is to distinguish the significant plants and concentrate structure them to show the impact of these concentrate on human and natural wellbeing. Manufactured items are delivered to address the issues of expanding the total populace for food and medication. Notwithstanding, genuine wellbeing and ecological issues are expanded by utilizing these manufactured items. One of the most significant issues on the planet is to give enough safe food to individuals. Cancer prevention agent expansion is important so as to protect the flavor, shading and nutrient substance of the food. A portion of these sources are containing regular cell reinforcements, (for example, flavors), in any case, enterprises are broadly added engineered cancer prevention agents to the handled nourishments. Butylated hydroxy anisole and butylated hydroxy toluene, tertiary butyl hydroquinone and gallates are instances of manufactured cell reinforcements. These days, particularly in created nations, public mindfulness moved to human-ecological wellbeing and common item came about to safe food creation and option in contrast to engineered cancer prevention agent items (Çoban and Patır 2010). Level of wellbeing shows monetary advancement of the general public. The least expensive approach to determine this issue is that directing exploration on plants that have high cancer prevention agent compound. Shopper's ought to be educated about the examination results on constant ailments and urged to expend nourishments that have high cell reinforcement properties. Responsive oxygen species are created metabolic and physiological cycles where these biomolecules have profoundly harming impacts. Creatures may cause unsafe oxidative responses during indispensable exercises and the expulsion of these oxidative items is practiced through enzymatic and non-enzymatic cell reinforcement systems. An expansion in oxygen creation and diminishing on cell reinforcements can't be forestalled in certain circumstance. After effect of oxidative pressure chiefly causes malignancy, cardiovascular illness, waterfalls, joint pain and numerous neurodegenerative issues (Tsala et al. 2013). Cell reinforcements could forestall the beginning of these unsafe responses or could stop them. Common items with high cancer prevention agent properties contain pharmacologically successful flavonoid gatherings (flavones, flavanols, and flavanones), different phenolic and sweet-smelling mixes. Numerous plants including such segments are expended as regular defensive specialists because of potential cell reinforcement exercises. The consequences of investigates on normal items utilized for cancer prevention agent treatment are indicated that this action seriously because of phenolic segments. Phenolic mixes are aromatic compounds containing more than one hydroxyl bunches that are glycosylated or methylated. Numerous sweet-smelling plant seeds, natural products, leave or roots contain diverse dynamic synthetic segment that are utilized different zone in light of their distinctive activity components. Additionally, the pace of dynamic substances of the aromatic plants shows changes relying upon where the plant source or part. Scientists underline that with different mixes of these dynamic compound may display synergistic impact.

INTEGRATED MEDICINE

Integrated medication is a medication to play out a satisfiable living and improve the personal satisfaction (QOL). Coordinated medication is acknowledged in the treatment of ailment as well as in the treatment of the presymptomatic state, anticipation of sickness, or upkeep of wellbeing. Integrated medication incorporates, for instance, western and eastern medication and conventional prescriptions. Each medication has solid and powerless point, the upside of western medication is brisk activity by activity and medication and assessment, frail point is symptom. Then again, the upside of eastern medication is that it can make a parity of entire body, with respect to deep rooted and chronicity infection, and for newborn child, matured, and pregnant lady, and frail point may be the time utilization for fix. Tolerant picks the most fitting treatment relying upon the conditions; in any case, the most significant reasoning with respect to "fix" is self-recuperating power that could fix you utilizing therapeutic assistance, not simply the medication that fixes. The utilization of common items as prescriptions must, obviously, have introduced a colossal test to early people. It is profoundly likely that when looking for food, early people frequently devoured toxic plants, which prompted retching, loose bowels, unconsciousness, or other harmful responses maybe even demise. Nonetheless, thusly, early people had the option to create information about palatable materials and characteristic drugs (Gao et al. 2007). Therefore, people concocted fire, figured out how to make liquor, created religions, and made mechanical achievements, and they figured out how to grow new medications. Conventional prescriptions utilize regular items and are critical. Such types of medication as customary Chinese medication, Kampo, Ayurveda, conventional Korean medication, and Unani utilize common items and have been polished everywhere on over the world for more than 100 years, and they have bloomed into efficient managed frameworks of medication. In their different structures, they may have certain deformities, yet they are as yet an important storehouse of human information (Alves and Rosa 2007). In view of past examinations in such territories as union, toxicology, pharmacokinetics, pharmacology, arrangement, and QC, scientists confirmed that the new anti-hepatitis drug bicyclol offered noteworthy hepatoprotective impacts, antihepatitic infection movement, and less unfavorable responses (Yang et al. 2009). Bicyclol has been endorsed for the therapy of interminable viral hepatitis in China since 2004 (Sun et al. 2012). The medication is one of the mitigating and hepatoprotective medications suggested by the "Rules on Liver Disease Clinical Diagnosis and Treatment" in China, and it has been sent out to numerous nations (Yang et al. 2009).

Aromatic Plants in Asia

The overall enthusiasm for the utilization of therapeutic plants (MP) has been developing, and its advantageous impacts being rediscovered for the advancement of new medications. In light of their tremendous ethno pharmacological applications, which roused present examination in drug revelation, common items can give new and significant leads against various pharmacological targets. Plants can be utilized as medicinal assets as an herbal mixture, drug arrangements, for example, concentrates, tablets, or containers by removing and filtering dynamic compounds (Mohamed et al. 2012). In another study Schippmann et al. (2006) characterized the plants which are utilized for medical purposes in both allopathic and conventional medication frameworks, and spreads a wide scope of animal varieties utilized including toppings, food, sweet-smelling and makeup (Schippmann et al. 2006). Conventional therapeutic practices in Asia have existed from days of yore; old-style models are Ayurveda (Himalaya, 4500–1600 BC), Jammu (Indonesia, 800 AD), Traditional Chinese Medicine/TCM (China, 3000 BC), Sowa Rigpa (Bhutan, 700 AD), Kampo (Japan, 500 AD), Thai medication (Thailand, 1200 AD), and Herbal Medicine (Bangladesh, 4500–1600 BC and 900 AD) (Kunwar et al. 2006). About 70% of the populaces of the creating scene legitimately depend on conventional medication for essential medical services (Jeelani et al. 2018). Nine nations, China, Korea, India, Indonesia, Malaysia, Myanmar, Sri Lanka, Thailand, and Vietnam, have archived their National Monographs for home-grown medications, while Pharmacopeia is found in Bangladesh, India, Indonesia, Sri Lanka, Thailand, and Vietnam (Sahoo et al. 2010). An expected 25% of present-day pharmacopeia and 18% of 150 top doctor prescribed medications are plant-based (Vasisht et al. 2016). China and India are two significant worldwide players from Asia in such a manner. Asian therapeutic plants represent about half of the fare amount and 45% of worldwide income from customary meds.

Oregano

In addition to the above-alluded concentrates on the polyphenol's constituents, oregano was recently examined particularly for its essential oil. The synthetic examination has demonstrated its constituents to be chiefly carvacrol and thymol (Dzamic et al. 2008). Vokou et al. (1993) inspecting fundamental oils of *O. Vulgare* sp. hirtum from 23 regions dissipated all over Greece, discovered that despite the high changeability of individual mixes in the essential oil, the total of thymol, carvacrol, p-cymene, and γ-terpinene was steady. Carvacrol and thymol give off an impression of being the primary parts of all *O. Vulgare* sp. (Menaker et al. 2004). *O. Vulgare* has a high substance of sugars, Phlobatannins, flavonoids, alkaloids, and terpenoids. Alkaloids are normally happening synthetic mixes containing essential nitrogen particles. Alkaloids are among the most indispensable dynamic constituents in common spices, and a portion of these edifices have recently been viably industrialized into chemotherapeutic drugs (Packyanathan et al. 2016). It is an ordinary defensive reaction to tissue injury brought about by physical injury and poisonous substance or microbial operators. Tannin has been accounted for to specifically block HIV replication (Ezeonu and Ejikeme 2016). Amongst the synthetic compounds adding to the flavor are pinene, ocimene, caryophyllenes, carvacrol, thymol, and limonene (Adam et al. 2010). Oregano has a wonderful aromatic fragrance. The spice is utilized to treat respiratory plot problems, gastrointestinal (GI) messes, feminine issues, and urinary parcel issues.

Carvacrol is a monoterpenoid phenol has a trademark sharp, warm smell of oregano. Carvacrol restrains the development of a few microscopic organisms' strains, for example *Escherichia coli* and *Bacillus cereus*. It is a strong activator of the human particle channels transient receptor. The spice is utilized to treat respiratory parcel issues, gastrointestinal (GI) messes, feminine issues, and urinary plot issues.

Thymol (2-isopropyl-5-methylphenol) is a distinctive monoterpenes phenol subsidiary of cymene, $C_{10}H_{14}O$, isomeric with phenolic compound carvacrol which occurs in oil. Thymol is important for a normally happening class of mixes known as biocides, with solid antimicrobial credits when utilized alone or with different biocides, for example, carvacrol.

Limonene is a dry fluid hydrocarbon named a cyclic terpene; limonene has additionally been considered as a biofuel.

Pinene (C10H16) is a bicyclic moneterpene substance compound. There are two basic isomers of pinene found in nature: α-pinene and β-pinene, α-pinene is the most broadly experienced terpenoids in nature and is profoundly repellent to bugs.

Ocimenes are a gathering of isomeric hydrocarbons; α-ocimene and the two β-ocimenes vary in the situation of the confined twofold bond: it is terminal in the alpha isomer. They are utilized in perfumery for their sweet natural fragrance, and are accepted to go about as plant safeguard and have against contagious properties.

Caryophyllenes or β-caryophyllenes is a characteristic bicyclic sesquiterpene that is a constituent of numerous basic oils. It is normally found as a blend with is caryophyllenes (the cis two-fold bond isomer) and α-humulene (outdated name: α-caryophyllene), a ring-opened isomer. Antinociceptive, neuroprotective, anxiolytic, and energizer and hostile to liquor abuse movement in-vitro consider and in rat models have been accounted for.

The *terpinenes* are a gathering of isomeric hydrocarbons that are delegated terpenes. They each have a similar sub-atomic equation and carbon structure, yet they vary in the situation of carbon-carbon twofold bonds. Terpinene is a scent and enhancing substance utilized in the beautifying agents and food enterprises. Its utilization in both the drug and the hardware semi-conductor fabricating enterprises has additionally demonstrated to be significant.

Rosemary

The Phytochemical of *R. Officinalis* plant extricate, are mainly rosmarinic acid, caffeic acid, camphor, betulinic acid, ursolic acid, carnosic acid, and carnosol (Begum et al. 2013). Consequently, R. Officinalis is predominantly made out of phenolic mixes, essential oils and di-and triterpenes. Polyphenols are cell reinforcement synthetic compound basically liable for the natural product shading, which are delegate flavonoids and non-flavonoids and phenolic acids. In case of *R. officinalis*, the mainly well-known polyphenols are diosmin, apigenin, luteolin, phenolic acids, and genkwanina particularly chlorogenic acid, rosmarinic acid, and caffeic acid (Sereiti et al. 1999). Proanthocyanidine was available in an extremely high fixation in leaves. HPLC based studies approved the event of cancer prevention by phenolic agent mainly through the chlorogenic acid and caffeic acid. EOs from *H. officinalis* airborne parts having some primary constituents such as terpenoids (β-pinene, pinocamphone and isopinocamphone) (Fathiazad et al. 2011). The β-pinene, camphor, pinocamphone in addition to 15 different terpenes were present in essential oils at three phases of improvement in GCMS based investigation, among which were myrtenol subsidiaries, α-phellandrene and β-phellandrene, isopinocamphone, germacrene D. It already demonstrated the event of glycosidically bound volatiles similarly in low fixation such as bicyclic terpenes, myrtenol and verbenol present in leaves (Schulz and Stahl 1991).

CONCLUSION

Medicinal and Aromatic plants actually have obscure and uncountable potential; however, long tradition for uses since ancient occasions. To free hereditary assets drives a profound misfortune later on; subsequently, the conjunction stability among plants, creatures, and humans ought not to be disturbed. The function of aromatic and therapeutic plants is modifying persistently in grant to an interval and the job grows, for example, fix of infection to the anticipation of sickness. They amassed enormous information, data, and materials ought to be partaken in the entire world and move down to age to age. The gifts of therapeutic and aroma plants are valuable that have a place with all lives. Notwithstanding, human enduring and improvement of new medications is because of the presence of aromatic and therapeutic plants. Continuing the plant variety and protection of hereditary assets is the highly needed part of human interchanging with the conditions of world. Environmental alteration as of now causes a genuine state for plants all through the world.

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Chapter 9

THE BIOLOGY AND CHEMISTRY OF ESSENTIAL OILS

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ABSTRACT

Essential oils are a mixture of volatile constituents produced by various living organisms. Volatile components are of terpenoid and non-terpenoid origin. Monoterpenes, sesquiterpenes and diterpenes are major constituents of volatile oils. There are different sources of essential oils like microbes, plants and animals. Among all sources, essential oils are mainly extracted from aromatic plants via steam or hydro distillation techniques for commercial purposes. Majority of essential oils are colourless liquids at room temperature. They are insoluble in water but are soluble in alcohol, ether and other lipids. They can exist in any of the chemical form like alcohols, aldehydes, ketones, esters, amines, acids, epoxides, and sulphides; some even contain nitrogen and sulphur. It is this chemical composition of essential oils that provides particular odour to specific essential oil. Essential oils are widely used as flavours and fragrances in different products like food articles, perfumes, pharmaceutical formulations, cosmetics and toiletries. Other than these applications essential oils serve as chemical signals in plants that allow plants to regulate its environment, attract pollinating agents, repel predators, and to inhibit seed germination, etc. Moreover, essential oils are often used as anti-microbials in insecticide, pesticides and repellent sprays. Owing to their wide applications, essential oils never go out of demand.

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INTRODUCTION

The word essential oil for the first time was defined by Paracelsus von Hohenheim in the 16thcentury, referring to it as '*Quinta essential*' (Pichersky et al. 2006). Essential oils (EOs) are a mixture of volatile constituents produced by the secondary metabolism of aromatic and other variety of plants (Bassolé and Juliani 2012). Volatile metabolites are usually isolated from plant material through steam or hydro distillation methods and the fragrant compounds obtained is referred to as an essential oil (Thierry et al. 2012). Volatile constituents are biosynthesised by living organisms. Such constituents are also known as essence, volatile oil, etheric oil or aetheroleum. Aromatic oily liquids can be extracted from different parts of plants viz., leaves, stems, flowers, barks, roots, seeds and peels (Tongnuanchan and Benjakul 2014). They can be obtained from their matrix by expression, fermentation, effleurage or extraction. However, steam distillation and hydro-distillation are most commonly used techniques in production of essential oils for commercial purpose (Burt 2004; Tajkarimi et al. 2010). Essential oils are utilized as flavours and fragrances in food, perfumery, cosmetics and toiletries, pharmaceutical industries and they are used as such or in diluted forms in the aromatherapy. Essential oils in plants are mainly reserved in the oil ducts, resin ducts, glands, or trichomes (Raut and Karrupayil 2014). They are a complex mixture of volatile compounds of low molecular weight compounds, mainly hydrocarbons i.e., monoterpenes and sesquiterpenes, and also their oxygenated derivatives. Essential oils may also comprise volatile compounds that are of terpenoid or non-terpenoid origin. However, some may also contain nitrogen or sulphur derivatives. They exist in the form of alcohols, esters, acids, aldehydes, epoxides, ketones, amines, sulphides, etc. In the composition of many essential oils there are monoterpenes, sesquiterpenes and even diterpenes. In addition, phenylpropanoids, fatty acids and their esters, or their decomposition products are also encountered as volatiles. However, in case of fixed oils or fatty oils, their composition is generally of a naturally occurring mixture of lipids which may not necessarily be volatile. Therefore, essential oils and fatty oils differ entirely from each other both in their chemical and physical properties. These are soluble in alcohol, ether, and fixed oils, however, insoluble in water. These essential/volatile oils are generally liquid and usually colourless at room temperature. They have a characteristic odour due to their particular chemical composition.

Essential oil when dropped on filter paper evaporates completely however, fixed oil does not evaporate and leaves a permanent stain. Major source of essential oils are aromatic plants; especially higher plants (with about 17,500 known species). But essential oils (EOs) are distributed in a limited number of families in good amount. The families of plant kingdom which are rich in essential oil bearing species *Myrtaceae, Myristicaceae, Oleaceae, Rosaceae, Acoraceae, Cupressaceae, Lauraceae, Compositae, Rutaceae, Lamiaceae, Asteraceae, Umbelliferae, Apiaceae, Poaceae, Zingiberaceae,* etc.

Not only plants, EO are also found in animal sources, e.g., musk, civet and sperm whale, or are also produced by some microorganisms (Ebadollahi 2013; Butnariu and Sarac 2018; Nieto 2017).

BIOLOGY OF ESSENTIAL OILS

Essential oils present in various parts of the plants serve as chemical signals allowing the plant to regulate its environment (ecological role), attract pollinating agents like insect-pests and birds etc., repel predators, inhibit seed germination, etc. Moreover, EOs also possess various anti-microbial i.e., antifungal or insecticide and repellent activities. Essential oils are found in tissues of aerial parts like flowers, leaves, stems, seeds and underground parts like roots, bulbs, rhizomes etc. EOs are obtained by the method of distillation or pressing the secretory organs. For example, the EO from citrus peel extracted when it is cold pressed, and from various other parts of the plant (stem, leaves, flowers, root, wood) are distilled. Essential oils in plants are produced by several differentiated structures and the number and characteristics of which are vastly variable. Presence of essential oils is generally restricted in the cytoplasm of certain plant cell secretions, which exists in one or more organs of the plant; viz. epidermal cells, internal secretory cells, and the secretory pockets and trichomes or the secretory hairs. Presence of essential oils in plant parts varies from species to species. Almost all parts of aromatic plants contain essential oils as follows:

- *Flower parts:* Citrus, Jasmine, Kewda, Lavender, Rose, Rosemary and Tuberose.
- *Leaves:* Eucalyptus, Mint, Thyme, Bay leaf, Savory, Sage, Pine needles, Tea tree, Lemon grass, Citronella, Basil and Lemon balm.
- *Underground parts*: like roots of Vetiver, rhizomes in Ginger, Sweet flag and Turmeric.
- *Seeds:* Cumin, Coriander, Black pepper, Cardamom, Fennel and Anise.
- *Wood and bark:* Cinnamon bark, Cedar, Rosewood and Sandalwood.

ESSENTIAL OIL-SECRETING CELLS IN AROMATIC PLANTS

The mechanism of essential oil production in plants is generally related with the presence of special type of secretory structures. After the formation of essential oils within the plant cells, these are also released by secreting cells like conical-papillate cells, cavities, ducts, grandular trichomes, osmophores and occasionally via non-specialized cells into the atmosphere (Caissard et al. 2004).

OSMOPHORES

The term osmophore, comes from words “osmo” meaning “odour” and “phore” meaning “bearing”, was established in 1962 to describe an enclosed area of floral tissue that is specialized in scent emission. Osmophores are also called floral fragrance glands. These are specialized clusters of cells in flowers which are distributed on their petals and sepals that attract insect pollinators (Anton et al. 2012). Osmophoresgenerally consist of a multi-layered glandular epithelium with homogeneous layers of cells with exceptional case in about 18 species of Stanhopeaand Sievekingia. In these species osmophores have morphologically different epidermal cells from the subjacent cells (Curry 1991; Affmert et al. 2005). These cells usually contain dense cytoplasm, have large deposits of starch, or other storage compounds within the mesophyll. However, these deposits in epidermal cells are usually missing. This creates a distinction between the site of production and the emission layer of the flower cells (Affmert et al. 2005).

GLANDULAR TRICHOMES

Most plants have hairs on their surface called trichomes that serve various functions like protection against insect-pests to heat and conservation of moisture (Peter and Shanower 1998). Occurrence of trichomes in plants is in a great variety of forms and are sometimes found to be very structurally complex (Weryszko and Chernetskyy 2005). Two main types of trichomes are there in plants and can be distinguished i.e., non-glandular and glandular trichomes GTs (Osman 2012).

Glandular trichomes are hairs which are present on the epidermal portion or epidermis and have specific cells for the biosynthesis and emission of specific secretory products like acyl lipids, digestive enzymes, essential oils, nectar and mucilage. Generally, these types of secreting trichomes are plenty and have very different morphologies (Lange and Turner 2013). Grandular trichomes are composed of or secrete a mixture of chemicals that have vast uses in the pesticides, pharmaceuticals, and flavour or fragrance industries.

DUCTS AND CAVITIES

Secreting cells such as ducts and cavities are generally found to excrete gums, resins, paste or glue. For example, in case of conifers, presence of diterpenoid resin acids is in ducts and is dissolved in volatile turpentine. The turpentine usually evaporates by injury, and there is formation of crystalline mass of resin that may trap pathogens and insects (Philips and Croteau 1999).

CHEMISTRY OF ESSENTIAL OILS

These oils are complex mixtures which may contain over 300 different compounds. EOs are a complex mixture of polar and non-polar compounds (Masango 2005). The essential oil composition depends on the species of the extracted plant, the geographic location of the plant, time of harvesting and techniques of extraction (Dima and Dima 2015). EOs can be classified into the four main groups (Shukla et al. 2009 and Schmidt 2010) as following:

1. Terpenes, related to isoprene
2. Straight-chain compounds not containing any side chain
3. Phenylpropanoids
4. Miscellaneous group (not included in first three groups and having varied structures i.e., sulphuror nitrogen containing compounds)

1. Terpenes, Related to Isoprene or Isopentene

Essential oils constituents belonging to this group can be divided into two major groups i.e., terpene hydrocarbons and oxygenated compounds (Mohamed et al. 2010).

(i) Terpene Hydrocarbons

Terpenes are the largest class of compounds found in essential oils and are also called isoprenoids. Terpenes are composed of isoprene molecules. Each isoprene molecule or sometimes called isoprene unit contains five carbon atoms having double bonds. Synthesis of terpenes is in the cytoplasm of plant cells, through the mevalonic acid pathway (Hyldgaard et al. 2012). Terpenes are secondary metabolites which have been regarded as polymers of isoprene (C_5H_8) joined in a repetitive head to tail manner (Croteau et al. 2000). The structure is shown in Figure 1.

According to the fusion of the isoprene units or to the number of the rings, terpenes are classified into different types. Terpenes on the basis of number of isoprene units can be classified into hemiterpenes (C5, 1 isoprene unit), monoterpenes (C10,2 isoprene units), sesquiterpenes (C15, 3 isoprene units), diterpenes (C20, 4 isoprene units), sesterterpenes (C25, 5 isoprene units), triterpenes (C30,6 isoprene units) and polyterpenes (many isoprene units).

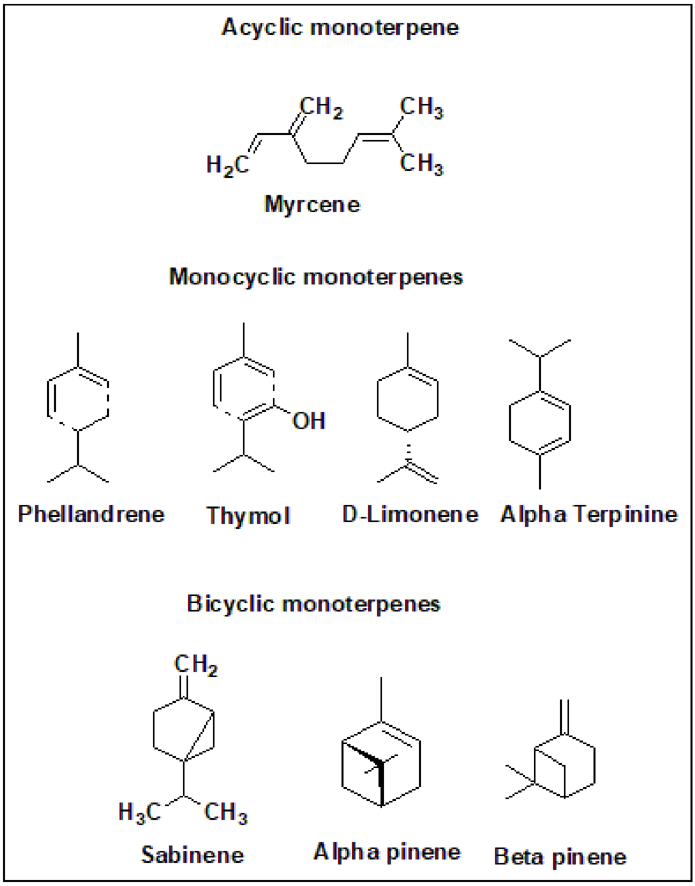

Figure 1. Monoterpenes found in essential oils.

Terpenes are further subdivided into groups i.e., *acyclic* or *cyclic* which denotes their structure. Acyclic types of terpenes are linear, like the monoterpene β-myrcene. However, cyclic terpenes form a ring for example the monoterpene *p*-cymene. Monocyclic, bicyclic, and tricyclic type of monoterpenes (meaning one, two, or three non-aromatic rings) generally occur in essential oils (Baser and Demirci 2007).

a) Monoterpenes

Monoterpenes ($C_{10}H_{16}$) are formed by the attachment of two isoprene units (at least one double bond). These are light molecules that evaporate rapidly and by the perfume industry these are called as "top notes". These terpenes have a hydrocarbon skeleton which can be rearranged into acyclic, cyclic, or aromatic. According to their ring size cyclic monoterpenes can be classified into sub-groups such as monocyclic monoterpenes, bicyclic monoterpenes and tricyclic monoterpenes (Figure 1). Because of their rapid reactions to air and heat sources these compounds oxidize easily.

Table 1. Acyclic, cyclic and bicylic terpenes

Molecular structure	Name	Example
Chain, no ring	Acyclic	α-Myrcene
One ring	Cyclic	D-Limonene
Two rings	Bicyclic	Thujane

Different Monoterpenes Found in Essential Oils of Various Plants

Limonene (Citrus, Mint, Fennel), α and β- pinene (Citrus, Coriander, Cypress), Sabinene, Myrcene, Carene, α-Terpinene (Melaleuca, Mace, Marjorum, Pine, Chamomile), γ-terpinene (Savory, Ajowan, Cumin, Mandarin leaf, Tea tree, Narcissus absolute, Mandarin, Tangelo) and Phellandrene.

b) Sesquiterpenes

Sesquiterpenes ($C_{15}H_{24}$) are the second important group to the dominant monoterpenes. They are generally less volatile than terpenes, have a more potential for stereochemical diversity and have stronger odours. These are formed from the combination of three isoprene units (Croteau et al. 2000). Sesquiterpenes are unsaturated compounds. These are further classified into linear, branched, or cyclic sesquiterpene. Like monoterpenes, according to rings cyclic sesquiterpenes can be classified into monocyclic, bicyclic, or tricyclic.

Different Sequiterpenes Found in Essential Oils of Various Plants

Caryophyllene (Lavender, Sage), Azulene and Chamazulene (Chamomile), Cadinene (Citrus, Cedarwood, Patchouli) (Figure 2).

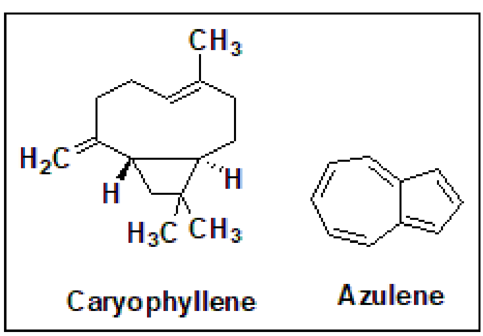

Figure 2. Caryophyllene and Azulene that is found in various essential oils.

c) Diterpenes

Diterpenes are formed by four isoprene units by their head-to-tail combinations followed by rearrangement and/or substitutions (Figure 6).They are important components of plant resins. Diterpenes are generally found in resins (Baser and Demirci

2007). However, the concentration of diterpenes, triterpenes and tetraterpenes is very low in essential oils (Mohamed et al. 2010).Recovery of these compounds increases with increasing time of steam distillation (Baser and Demirci 2007) and is also influenced by the method of extraction. An example is α-camphorene (Cambray-Smith 2013).

(ii)Oxygenated Compounds (Terpenoids)

The oxygenated compounds or terpenoids are highly scented (Darjazi 2011). Terpenoids are volatile secondary metabolites which give plants their fragrance (Srividya et al. 2015). Terpenoids can be subdivided into aldehydes, alcohols, esters, ketones, phenols and epoxides (Hyldgaard et al. 2012).

a) Alcohols (Terpenols)

Terpenicalcohols orterpenols are present in many essential oils. Their names end in *'ol'*. Structurally, they have a hydroxyl group attached to one of their carbon atoms (Figure 3). Common terpenols found in essential oils of different plants are as following:

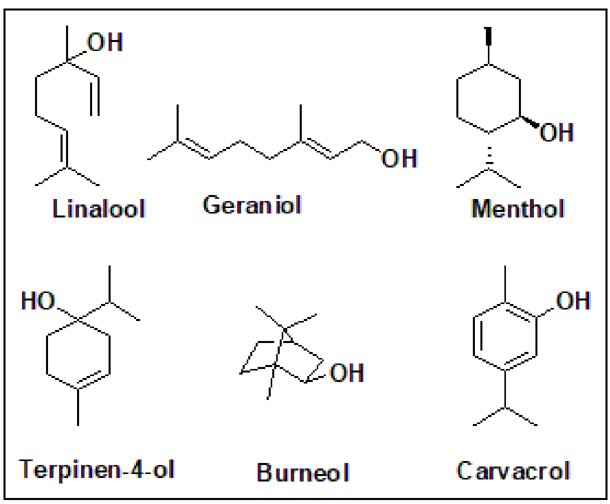

Figure 3. Different terpenols present in essential oils.

- *Geraniol:*Geraniol, an acyclic monoterpene (C_{10}) alcohol which gives a characteristic rose-like odour to essential oils. Geraniol like citral is one of the widely used chemicals in perfumery, in soaps, detergents and cosmetics for its characteristic rose like smell. It is found in essential oils of Bergamot mint, Geranium and Palma rosa.
- *Menthol:* Menthol is found in Lavender, Peppermint.
- *Linalool:*Linalool occurs in many species like Basil (*Ocimum* sp.), Bergamot mint, Lavender, Thyme, Oregano.

- *Burneol:* Borneol occurs in camphor, rosemary, Juniper and lavender oils. It has a camphor-like odour, with a slightly peppery note (Lafhal et al. 2016).
- *Terpinen-4-ol:* It is found in essential oil of *Melaleuca alternifolia* (tea tree oil), Marjorum, Basil, Kewda, Gandhi root (*Homalomenaaromatica*), Mace (East Indian).
- *α-Terpineol:* Orange flower and water absolute, Cedarwood, *Eucalyptus radiata.*
- *Carvacrol:* Carvacrol is found in oregano and thyme oils (Siroli et al. 2015).

b) Aldehydes

An aldehyde is a partially oxidized primary alcohol (Tisserand and Young 2013). Structurally, aldehyde has an oxygen atom which is double bonded to a carbon atom at the end of a carbon chain. The fourth bond in the structure is always a hydrogen atom (Bowles 2000). Aldehydes usually end in *-al* and often have properties like calming effects, sedative etc. Aldehydes are very reactive molecules and combine with oxygen or oxidize to form organic acids called carboxylic acids. If not stored properly this may cause them to be skin irritants and skin sensitizers. The examples of aldehydes present in different essential oils are:

Citral

Citral is a naturally occurring acyclic monoterpene aldehyde and is an isomeric mixture of geranial (α-citral; the *trans* form) and neral (β-citral; the *cis* form) (Figure 4). It is the main component of lemongrass oil, which is responsible for pungent lemon-like aroma of essential oils of *Cymbopogon* spp. Geranial is present in Citrus, *Eucalyptus citriodora*, Lemongrass, Lemon balm (*Melissa officinalis*). Neral is present in lemon verbena *(Aloysia triphylla).*

Other Aldehydes Found in Essential Oils

Cinnamaldehyde (Cinnamon bark, Patchouli), Anisaldehyde (Anise oil), Benzaldehyde (Bitter almond oil), Citronellal (Lemongrass, Lemon balm).

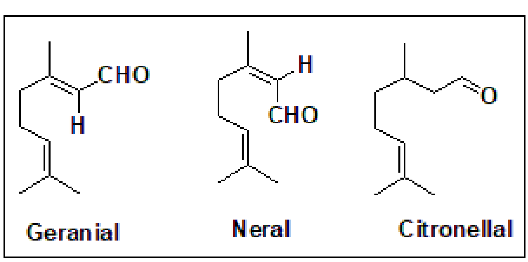

Figure 4. Structure of some aldehydes that occur in essential oils.

c) Esters

Esters are a combination of an acid and an alcohol and named by the acid and alcohol. For example, acetic acid and linalool produce linalyl acetate. Esters end in *–ate* and have antispasmodic (Ou et al. 2012) and calming properties (Igarashi 2013).

Linaly acetate: It occurs in Lavender, Bergamot mint, Clary sage, Geranium, Jasmine.
Benzyl benzoate: It is found in Jasmine.
Geranyl Acetate: It is present in Palmorosa, Lemon grass, Geranium, Sweet marjoram (Figure 5).
Borneol Acetate: It generally occurs in Rosemary, Pine, Juniper.
α-Terpinyl acetate: It is found in Lovage leaf, Sage (Spanish), Betel, Himoki leaf and roots, Laurel leaf, Cypress.

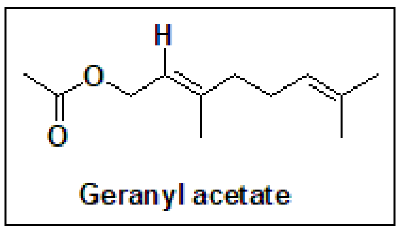

Figure 5. Structure of Geranyl acetate present in essential oils.

d) Ketones

Ketones in their structure contain the carbonyl group (–C=O) and hence are related to the aldehydes. A ketone is derived from an alcohol by oxygenation and it has an oxygen atom which is double bonded to a carbon atom that again is bonded to two other carbon atoms (Bowles 2000). Ketones end in *-one*, for example isomenthone, carvone, fenchone, verbenone etc. (Figure 6). However, there is a single exception that does not end with *–one* i.e., camphor.

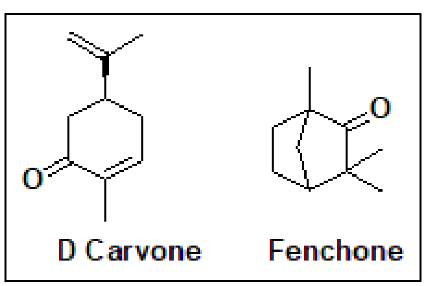

Figure 6. Ketones present in essential oils.

Ketones that are found to be beneficial to the skin are jasmone found in jasmine *(Jasminum officinale)* and isomenthone in scented geranium *(Pelargonium graveolens).* Examples of other useful ketones are d-carvone found in spearmint *(Mentha spicata),* fenchone in fennel (*Foeniculum vulgare* var. *dulce*) and verbenone in rosemary *(Rosmarinus officinalis).*

2. Straight-Chain Compounds, not Containing any Side Branches

In this group, only straight chain non-terpenoid hydrocarbons and their oxygen derivatives are there like alcohols, aldehydes, ketones, acids, ethers and esters. In this group the hydrocarbons range from n-heptane, to 35 carbon atoms compounds. In the wood volatile oils of *Pinus jeffreyi* and *Pinus sabiniana*, the heptane content is around 3.8% and 36.8% respectively (Adams and Wright 2012).

3. Ethers (Phenolic) or Phenylpropenoids

Ethers found in essential oils are phenylmethyl ethers or phenolic ethers or alkenylbenzenes. Ethers occur when a methyl or ethyl group is attached to a benzene ring via an oxygen molecule. Examples of ethers are anethole, apiol, estragole, eugenol, myristicin (found in nutmeg), phenyl ethyl methyl ether (found in kewda), safrole and vanillin (found in vanilla) (Figure 7). Estragole is sometimes called methyl-chavicol.

In the flavour and fragrance industry these compounds are an important group, though in essential oils it constitutes a relatively small part. However, ethers are not widely distributed and are present is some common essential oils like anise, basil, cinnamon leaf, and fennel. Their main characteristic is that they have a chain of three carbon atoms attached to a benzene ring. This group of non-terpenoid compoundsincludes constituents derived from n-propyl benzene. The aromatic ring may have hydroxy, methoxy and methylene dioxy groups; the propyl side chain may have hydroxyl or carboxyl group (Shukla et al. 2009). Phenylpropenes further constitute a subfamily of phenylpropanoids which are synthesized from the amino acid phenylalanine and l-tyrosine by the shikimic acid pathway (Vogt 2010). Phenylpropanoids found in essential oils of different plants are:

Anethole: It occurs in Fennel, *Pimpinella* spp.
Apiole: It is found in essential oil of Dill seeds (Indian), Parsley seeds and leaf.
Eugenol: It occurs in Clove bud, Clove leaf, Cinnamon leaf, Cinnamon bark, Bay leaf, Basil etc.

Estragole: It is present in Basil, Fennel, Marigold (Mexican), Ravensara bark, Terragon, Pine (Ponderosa).

Myristicin: It is found in Nutmeg and Parsnip.

Safrole: It occurs in *Cinnamomum porrectum*, *C. rigidissimum*, Camphor, Nutmeg, *Sassafras albidum* etc.

*Thymol:*It is found in *Thymus* spp., Oregano, Ajowan etc.

Vanillin: It occurs in vanilla

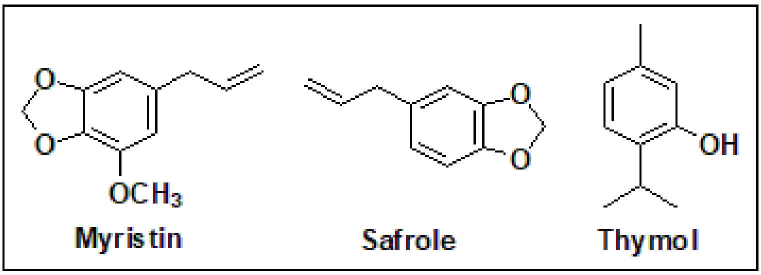

Figure 7. Some ethers present in essential oils.

4. Miscellaneous Group (Sulphur and Nitrogen-Containing Compounds)

The compounds which are not included in above mentioned groups are the representatives of this group (Shukla et al. 2009).These are different products originating from degradation of unsaturated fatty acids, lactones, terpenes, glycosides and sulphurand nitrogencontaining compounds (Caballero et al. 2003).

These sulphurand nitrogen-containing compoundsmainly occur as aglycones or glucosinolates, or, include isothiocyanates their breakdown products (Mastelic et al. 2006). The family which is important source of glucosinolates and isothiocyanates is Brassicaceae (Fahey et al. 2001). Sulphur containing compounds, namely allyl sulfide, dimethyl sulfide, diallyl disulfide and dimethylthiophene are mainly found in garlic, onion, leek and shallots (Iranshahi, 2012). Other compounds like dimethyl trisulphide (18.2%), myristicin (8.9%) and dimethyl tetrasulphide (7.6%) are found in*Ferula persica*Willd. var. *persica* root (Asafoetida) essential oil (Iranshahi 2006).

Nitrogen-containing compounds are present only in few essential oils. Examples include methyl anthranilate, indole, pyridine and pyrazine. Methyl anthranilate is present in orange, lemon and bergamot oils (Baser and Dimirci 2007) and jasmine oil (Rath et al. 2008). Indole occurs in neroli oil of bitter orange tree and some citrus fruit oils. Pyridines and pyrazines are found essential oils extracted from black pepper, sweet orange and vetiver (Baser and Dimirci 2007).

Table 2. Major chemical compounds of essential oils of some plants

Plants	Parts used	Major chemical compound	Reference
Ambrette seed or Muskseed (*Abelmoschus moschatus*)	Seeds	Farnesyl acetate (30.0-65.3%), Farnesol (3.4-39%), Ambrettolide (7.6-14.7%), Farnesyl acetate (2.6-5.8%)	Lawrence 1993
Bergamot mint (*Mentha aquatica*)	Aerial parts	Linayl acetate (34-57.3%), Linalool (24.9-55.2%), β- terpineol (1-2.8%)	Lawrence 1979
Cedar wood (*Cedrus deodara*)	Wood	α- himachalane (20-30%), α- Cedrene (12-16%), β- himachalane (8-13%), α- atlantone (5-7%), Deodarone (4-6%)	Lawrence 2012
Cinnamon bark (*Cinnamomum verum*)	Dried inner bark of young trees	Cinnamaldehyde (63.1-75.7%), Eugenol (2-13.3%), Cinnamyl acetate (0.3-10.5%), Linalool (0.2-7.0%), β- Caryophyllene (1.3-5.8%)	Lawrence 1995
Citronella (*Cymbopogon winterianus*)	Leaves	Citronellal (34.8-42.8%), Geraniol (22.1-25.4%), Limonene (2.6-5.5%), Geranyl acetate (2.9-5.1%)	Rao et al. 1998
Clove (*Syzygium aromaticum*)	Dried flower buds	Eugenol (73.5-96.9%), β-Caryophyllene (0.6-12.4%), Eugenyl acetate (0.5-10.7%), α- Caryophyllene (0.4-1.4%)	Kubeczka2002
Damask Rose (*Rosa damascena*)	Flowers	Citronellol (13.51-30.44%), Geraniol (19.48-31.74%), Nerol (7.54-12.91%), n-heneicosane (4.56-6.78%), n-nonadecane (5.90-11.43%), Farnesol (1.05-2.23%), Geranyl acetate (0.36-4.16%) and Linalool (0.28-1.80%)	Ahmad et al. 2009
Eucalyptus (*Eucalyptus citrodora*)	Leaves	Citronellal (29.31%), Geraniol (27.63%), β-citronellol (14.88%) and δ-cadinene (6.32%).	Adilson et al. 2015
Holy basil (*Ocimum sanctum*)	Leaves, flowers and stems	Linalyl acetate (53.89%) and Linalool (22.52%), Other minor constituents were α- terpineol (4.57%), Eucalyptol (3.29%), Terpinyl acetate (2.95%), Geranyl acetate (2.53%)	Dris et al. 2017
Kewda (*Pandanus odoratissimus*)	Flowers	2-phenyl ethyl methyl ether (37.7%),terpinen-4-ol (18.6%), *α*-terpineol (8.3%)and 2-phenyl ethyl alcohol (7.5%)	Raina et al. 2004
Lemon grass (*Cymbopogon citratus*)	Leaves and stems	Geranial or β-citral (37.58 – 43.95%), Neralor α- citral(29.44 – 31.13%), β-Myrcene(3.18-7.68%), Nerol (3.14-3.73%),Geranyl acetate (1.06-2.16%)	Tajidinet al. 2012
Lemon balm (*Melissa officinalis)*	Leaves, stems and flowers	Citronellal (36.62 to43.78%), Citral (10.10 to 17.43%), Thymol(0.40 to 11.94%), and β-caryophyllene (5.91to 7.27%)	Cosge 2009
Lavender (*Lavandula angustifolia, Lavandula intermedia*)	Leaves and flowers	Linalyl acetate (46.887–29.098) andLinalool (36.8%–28.1%) in *L.angustifolia* and Linalool(28.49%)and Eucalyptol (15.65%) in *L. x intermedia*	Kivrak 2018

Table 2. (Continued)

Plants	**Parts used**	**Major chemical compound**	**Reference**
Pepper mint (*Mentha piperata*)	Leaves, flowers and stems	Menthol (36.02%), Menthone (24.56%),Menthyl acetate (8.95%), Menthofuran(6.88%), 1,8-cineole (5.13%), cis-carveol(3.49%)	Reddy 2019
Scented geranium (*Pelargonium graveolens*)	Leaves, flowers and stems	Citronellol (37.5%), Geraniol (6.0%), Caryophyllene oxide (3.7%), Menthone(3.1%), Linalool (3.0%), β-bourbonene(2.7%), iso-menthone (2.1%) and Geranylformate (2.0%).	Sharopov et al. 2014
Vetiver/Khus grass (*Chrysopogonzizanioides*)	Roots	Khusimol (16.25%), Khusinol (10.28%), Germacrene-D (9.73%), Junipene (5.54%)and γ-muurolene (4.56%) (North Indianvetiver oil) and Khusimol (15.77%), Bicyclovetivenol (10.76%) and Viridiflorene (4.64%) (South Indian vetiver oil)	Dubey et al. 2010
Spanish Jasmine (*Jasminum grandiflorum*)	Flowers	Benzyl acetate (23.7%), Benzyl benzoate(20.7%), Phytol (10.9%), Linalool (8.2%), Isophytol (5.5%), Geranyl linalool (3.0%),Methyl linoleate (2.8%) and Eugenol (2.5%)	Leopold et al. 2007

Conclusion

Essential oils have been used since ages for their flavours and fragrances. The charm of essential oils has increased many folds as they are being widely utilized in different industries like food industry, perfumeries, pharmaceutical industries, cosmetic industries and various other miscellaneous industries. Different types of essential oils have been extracted till date from different biological sources via steam or hydro distillation techniques for commercial purposes. Chemistry and biology of essential oils varies from one another and so is their use. In this chapter we have discussed in brief the chemical properties, biological properties of various components of essential oils and their uses. Overall this chapter contains the gist of information on chemistry and biology of essential oils.

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Chapter 10

ATTRIBUTES INFLUENCING BIOSYNTHESIS OF SECONDARY METABOLITE AND AROMA VOLATILES IN PLANTS, ON AND OFF THE FIELD

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ABSTRACT

There is a wide array or diversified varieties of plants present in the Mother Nature. Among them, a major group is plants which are capable of producing and biosynthesizing secondary metabolites, aromatic in nature or responsible for the development of essential oil. These are precisely very unique in their type as the active output provided by them in the form of volatiles cannot be produced by other group of plants and are of great use to the human race. We are very much aware about the utility of the yield from these plants having exceptional demand in multiple destinations particularly which deals with firms and industries producing medicines, perfumes or other high value herbal products. Furthermore, the demand is not isolated within a region and within a country but it is omnipresent all across the globe. The quantity and quality of these aromatic constituents are influenced by majority of living and nonliving factors which affects them in as well as outside the field. In some cases, factors elevate the development of secondary metabolites and volatiles in the plants, whereas on some other conditions, attributes cause quantitative deterioration in the amount and brings change in the make-up of the metabolites. So, considering the importance of plant secondary metabolites, the present

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chapter is focused to prove an idea that how the various factors are related to the production and alteration in the quantity and the constituents of the volatiles. The chapter also explains that why a better understanding is required about these factors to get a desirable standard output.

Keywords: aroma, metabolites, volatiles, factors, influence, quality

INTRODUCTION

Plants are omnipresent in the Mother Nature and are famous for their aesthetic capability. Apart from this, they help the human beings and the animals as well in providing with supplements of minerals and nutrients from food, supporting the textiles for development of garments, giving the substances for construction, providing with different types of aromatic volatiles used in perfume industries and, most importantly, continuously supplying the ecosystem with uninterrupted stock of oxygen, so vital for our existence (Figueiredo et al. 2008). But these elements as mentioned above are not the sole and only components present inside the system of plants. They are also the great reservoir of other type of elements, called as the secondary metabolites. These groups of compounds are immensely essential in various pharmaceutical, cosmeceutical and therapeutic fields having towering applications with sky-scrapping demands in national and international markets (Figueiredo et al. 2008).

The secondary metabolites of the plants are said to be those substances which do not have a direct influence in catering to various growth and development phenomenon of the plant. But in spite of this, the compounds of the secondary type are still very much essential by the plant for their existence. They essentially help the plant to interrelate with the surrounding atmosphere so that the plant itself can make several adaptive modifications in it which is vital for its survival to cope up with the changing environmental situation (Akula and Ravishankar 2011). The secondary metabolites of the plants have many characteristic attributes. Also, these substances are sometimes developed by the metabolites of the plant which are of primary in origin. Furthermore, their presence and activity are often restricted to a particular genus, or within a species of that genus in a taxonomic classification (Figueiredo et al. 2008). There is a wide variation in the constitution or elemental set up of the secondary metabolites of the plants and this alteration is visible between two species of plants of a given genus or even between two plants which belong to the same species under the same genus, but their area of development may be different (Barton and Koricheva 2010; Verma and Shukla 2015). The plant secondary metabolites assist in defence mechanisms and developing strategies against unwanted foreign endeavours. Scientists today have started to know more about these secondary groups of metabolites, their importance as integral elements of the plant towards continuation of growth (Akula and Ravishankar 2011).

The development and production of secondary metabolites also varies as there is a constant fluctuation in their source area of synthesis and place of congregation after the production. Often the metabolites get deposited in the empty vacuoles of the plant in the form of glycosides and, in some cases, in ducts, trichomes, lacifers or cannals which are considered as the distinctive type of structure of the plant responsible for secretions (Figueiredo et al. 2008). They are frequently produced or biosynthesized in very low quantities which ranges even below 1% of the total dry matter weight. Furthermore their production in the plant is hugely influenced by the growth and developmental stage in which the particular plant is present (Rao and Ravishankar 2002; Akula and Ravishankar 2011).

Secondary metabolites of the plants help in providing support and benefit to the plant in many ways. They provide a strong shield from the attack of various plant-eating animals, undesirable and harmful activities of pests and pathogens and from various types of abnormal atmospheric abnormalities and stresses of the environment (Akula and Ravishankar 2011). The secondary metabolites of the plants, however, will not always show good and positive effects, but they can also demonstrate poisonous effect and may provide a biotic influence in other categories of living beings (Figueiredo et al. 2008). After development of the secondary metabolites through biosynthesis they are being shipped and being accumulated or gathered in a given area or space of the plant which is affected by several biochemicals and plant-based attributes. Not only this, various growth factors of the plants are responsible for commencement and distinction of cell-based anatomies of the plant which helps in the production and storage of the secondary metabolites of the plants (Broun et al. 2006; Verma and Shukla 2015).

The odoriferous elements of the plant (often said as the essence of the plant) are actually the combination or the concoction received from the plant containing both the constituents of essential oil as well as the volatile aromatic components. The extracts of these types of plants which are aromatic and odoriferous in nature are of high utility to the growers. This volatile output of the plant has been utilized from the ancient times for their profound effectiveness in the therapeutic world in preparing various medicines and drugs. Of course they are widely recognized for their natural capability in imparting flavours and highly recommended in the cosmetic arena for the development of perfumes in domestic as well as global export. Aromatic and volatile components extracted from different plant or plant parts are not the same. Each individual component has unique synthetic and physical characteristic and compounds when mixed together in different proportions help in providing the attribute to the final oil and volatile accordingly.

Therefore, the ultimate output obtained from them as perfume or some oils or drugs have the variability in fragrance or mode of action. Different types of plant have different type of aroma due to the variation in the proportion of the amount of the synthetic compound present in their oil. Plants synthesize volatile compounds in which the major categories are terpenes (viz., mono terpenes, sesqui terpenoids and di terpenes), steroids (viz., digoxin, digitoxin or diosgenin), phenols, alkaloids, flavonoids, phenylpropanoids, etc. (Akula and Ravishankar 2011). A knowledge regarding the most suitable harvesting period of the plant is essential so that the maximum amounts of oil and aromatic components with exceptional quality can be obtained from them. It is equally essential to have an insight regarding the major factors and attributes which effect the development of the secondary metabolites of the plants. The extent and the ambience of the factors to produce the maximum aroma yield are also required to be known (Figueiredo et al. 2008).

How these factors precisely play their role in determining the production of the secondary components from the plant has not been studied and or understood clearly. Furthermore, whatever studies have been carried out, are limited to certain number and few groups of taxonomy of plant species only (Neto and Lopes 2007). So, it is required now to conduct further research in this area to get more information and valuable insight. Among the factors responsible for bringing changes in the contents of the secondary metabolites, some are grossly interrelated with each other and cannot show their consequent effects independently or in groups. Examples of such types are changes in seasonal pattern associated with the development of the plant or fluctuation in the temperature to the pluviometric index (Neto and Lopes 2007).

ENVIRONMENTAL FACTORS

Plants communicate or interact to their surroundings which helps in their growth and development and also to their existence. They are very much affected to the various living and non-living condition around them which help synchronizing the formation and synthesis of various secondary metabolites associated to them (Zhi-lin et al. 2007; Verma and Shukla 2015). The production and development of essential oil and various secondary metabolites is related to the type of weather and environment condition in which the particular plant is being grown upon (Figueiredo et al. 2008). However, if a particular species belonging to the common mother plant develops in variable surroundings then there may be alteration in the amount of a distinct essence or a secondary metabolite (Radusiene et al. 2012; Verma and Shukla, 2015). A change in the season is associated with the change in the environment condition subsequently resulting in fluctuations of desirable units in the plant. In few plant types or species, the amount and concentration of the essential oil or other important components vary as per the change in the seasonal pattern of the year. Therefore, it is very important to harvest plants at an ideally suited time to get the maximum and highest output.

In *Crithmum maritimum,* Barroso et al. (1992) found that a particular component, sabine was very profuse during the reproductive or the flowering time. But during other times, another component, γ-terpinene was very much dominant. In *Achillea millefolium,* it was seen that during the non-sexual growth, the essential oil was rich with the sesquiterpene hydrocarbons. But during the reproductive phase of the plant, the essential oil was mainly comprised with different hydrocarbon, the monoterpenes. The abnormalities associated with the nature viz., floods, hurricanes and cyclones can also affect the aroma constituents in the plant and thus affect the industries connected to it (Figueiredo et al. 2008).

The geographical situation amongst the plant also brings down the alteration to the chemical constituents. The changes in the topographical condition throughout the planet cause variation in the atmospheric regime and ultimately cause alterations in the aromatic constituents in the plants. In *Thymus caespititius*, the plants which were obtained from the regions of Portugal and Maderia have the essential oils principally influenced by the chemical components viz. terpineol. However, the plants from the areas of Azorea islands have the essential oils with higher amounts of thymol and carvacrol as the principal influencing component in them (Figueiredo et al. 2008). There are many living and non-living factors present in the environment and if any undesirable change occurs to these factors, then it causes development of stress in the plants which may be again of living and non-living type. But to cope up or counteract these stresses the plant results in synthesis of targeted components which falls in the category of secondary metabolites. Therefore, environmental factors play a very important role in development of the aromatic or secondary metabolite components in the plants (Verma and Shukla 2015).

BIOTIC FACTORS

There are many living factors which greatly effects or determines the presence of aromatic constituents and amount of essential oil. Biotic factors or agents are the living constituents of the nature including the fungi, bacteria, insects, nematode etc. which trigger a particular type of stress in the aromatic plants known as the biotic stress (Verma and Shukla 2015). For example, when a new type of plant is introduced and cultivated rather than the existing plant in a given area then the plant may be prone to attacked by many biotic organisms (Figueiredo et al. 2008). All plants being fixed in soil at a fixed place cannot shift themselves to overcome these stresses. Also, their internal defence mechanism is not very much developed as animals. For example, in case of pepper plant, almost 30-40 percent of the crops can get damaged as a result of infestation from flea beetle (*Longitarsus nigripennis*). The apical and the shoot portion of the plant also gets severely infected (up to 50%) by *Laspeyresia hemidoxa* commonly called as the top-shoot borer (Figueiredo et al. 2008). So, in order to fight against these stresses they chiefly use their secondary metabolites (Verma and Shukla 2015).

Taiz and Zeiger (2006) reported that phtyoalexins, a secondary metabolite of plant, has the ability to fight against the microbial infection and is being used as a component of the counteracting system to wrestle with the harmful pathogens. Thus, in the fight with these biotic organisms, a good amount of secondary metabolites are required by the plant which automatically initiates their further multiplication (Verma and Shukla 2015). In some situations, the damage due to these pathogens is much more pronounced during the time of excessive precipitation which also causes difficulty in carrying out the control measures. Furthermore, problems caused by virus like the cucumber mosaic virus (CMV), which is disseminated by the help of aphids, has been found to cause problem of all sorts in MAPs (Figueiredo et al. 2008). In lupin (*Lupinus angustifolius*) it has been observed that at the time of fungal infection by *Colletotrichum lupini*, there is considerable amount of transformation in the plant secondary metabolite, especially the phenolic content (Verma and Shukla, 2015). For the plant *Agastache anethiodora* popularly known as giant hyssop plant, the CMV attack results in lowering down of 88% of the total essential oil content and alteration in its key constituents (Figueiredo et al. 2008).

ABIOTIC FACTORS

Plants come across various forms of non-living components viz. temperature, moisture, light, drought and salinity. All these constituents are very crucial and are required in an optimum amount for the proper build-out and existence of the plant as a whole. But as and when these abiotic elements are in higher or lower proportions compared to their actual requirement, then it causes in the development of stress in plants which finally results in consequent changes in the bio synthesis of the secondary metabolites of the plants (Verma and Shukla 2015).

TEMPERATURE STRESS

Temperature is one of the very crucial factors required by plants for the proper and sound progress in their growth and development. But the optimality of the temperature is also very essential. Fluctuation of the temperature to the undesirable higher or lower regimes will result in movement of the plant to zones of heat and cold stress aggregating disagreeable consequences (Yadav 2010; Verma and Shukla 2015).Thus, temperature of both high and lower ranges is not good for the plant and considering the scenario of the production of secondary metabolites the variation of the factor bring variation in them. When the temperature is very high (outside the range of its requirement), then it causes heat stress. Subsequently stomatal conductivity is reduced, which causes lowering down of the photosynthesis and ultimately it arrests the development in the plant. It is very much evident that temperature at higher ranges ramifies the biosynthesis of the secondary metabolites of the plants. Apart from these changes in the plant internal process as mentioned above, there are many other biochemical alterations which take place due to high temperature. Because of unwanted elevated temperature, the photochemical productivity of the photosystem-II gets reduced which causes escalation of the stress in the crop. Therefore, the rate of the production of the secondary metabolites of the plants is directly proportional to the temperature. Whereas, few studies have demonstrated an inverse relation of the secondary metabolite constituents with the temperature.

Jochum et al. (2007) in their study have obtained that in *Panax quinquefolius,* the concentration of ginsenosides in the roots is increased with the increase of the atmospheric temperature. Likewise, when the temperature is very low beyond the tolerance range of the plant, then it very much hampers the development process of the plant. Also, the yield per unit area is severely affected. Due to this low temperature adversity, the plant cannot express its genetic attributes completely, and, the biochemical and metabolic reactions in the plants are also negatively influenced. The water absorption power of the plant gets declined due to unwanted low temperature which results in dehydration in the cells and lowers their activity (Chinnusamy et al. 2007). Apart from the above-mentioned problems, due to continuous persistence of low temperature the amount of photosynthesis preformed by the plant also gets diminished and in case of certain plants like *Capsicum annuum,* it directly influences the final output (Verma and Shukla 2015).

However, not only the yield and physical parameters of the plant are affected due to low temperature but, the internal cellular attributes of the plants are also influenced by high temperature stress. In certain cases, it has been seen that the presence of low temperature results in bringing down certain types of alteration in plant with respect to the biochemical, molecular and physiological phenomenon's which renders the plant more capable to deal with the cold situation. This process is known as the cold acclimation by which the resistant power of the plant is elevated against the odd cold temperature. In the report of Aliabandi et al. (2008), it was found that the stress due to temperature brought down a noteworthy effect on the yield of flowering amount and the concentration of the essential oils. It was documented through the study that attributes related to the plant were very good when the plant was not subjected to any kind of stress condition but the concentration of the essential oil was encouraging in a situation of temperature stress to the plant (Abdelmajeed et al. 2013).

According to Koc et al. (2010), the low temperature creates a cold stress in the plants. As a result, the concentration of the appolastics present in the leaf and also the total soluble protein present in it get escalated. But contrary to this, the pigments specifically the chlorophyll a and the total chlorophyll get lower. In *Artemisia annuna,* it was observed that prevalence of low frost condition during plant growth, causes shifting of the plant towards metabolic stress. Due to this, the final yield of artemisin amount gets increased by around 60% (Neto and Lopes 2007).Artemisin is an important secondary chemical component present in this plant which shows very effective activity against the resistant and permitting strains of the principle malaria causing organism *Plasmodium falciparum*. However, the low temperature in the mentioned plant causes declination of dihydroartemisinic acid which is a precursor of biosynthetic origin for artemisin explaining how an expeditious movement takes place to get changed into the chemical component (Wallaart et al. 2000; Neto and Lopes 2007).

WATER STRESS

Water is an important and crucial component essential for the progress of plant growth and development. The combined molecule of hydrogen and oxygen plays a supreme role with respect to various physiological processes taking place inside the plant. The water molecule acts as a universal solvent which provides a forum for carrying different types of supplements and secondary metabolites of the plant from one place to another (Verma and Shukla 2015). Therefore, water is one such component of the nature which is required by each and every living being and it plays some crucial aspects in several ontogenic attributes of the plants. Whenever the situation arises and the plant is received with very low amounts of water compared to its required optimum or if the process of transpiration increases significantly, it causes loss of the plant moisture and the plant moves to a condition of stress called as the water stress. It may be of two types i.e., salinity stress and drought stress (Verma and Shukla 2015). These mentioned types of water stresses influencing the secondary metabolite production in the plants are explained below in brief.

DROUGHT STRESS

When the plants receive very low or stunted amount of water from the surrounding atmosphere then they move to the phase of drought stress. This leads to declining of the water potential, diminished turgor pressure and severely affected physiological processes (Tippmann et al. 2006; Lisar et al. 2012; Verma and Shukla 2015). It is very much obvious that the stress situation created in the plant often accompany certain biochemical modifications in the plants. The condition of insufficient water also changes in activities like closing of stomatas, altered activities related to enzymes and impairment to the membranes, influences the overall process of photosynthesis and causes the alteration in various biochemical attributes in the plant (Zobayed et al. 2007; Aimar et al. 2011; Azhar et al. 2011;Verma and Shukla 2015). Therefore, as the plant moves into these unwanted situations, the plant system tries to overcome that by means of many secondary metabolites. In *Hypericum perforatum* and *Artemisia annua*, there has been an elevated development of the secondary metabolites when situation of stress due to drought prevails (Verma and Shukla 2015).

In the experiment conducted by Razmjoo et al. (2008), it was concluded that in Chamomilla (*Matricaria chamomilla*), attributes like number of flowers in a plant, length of the peduncle and number of branches in plant etc., got lowered by salinity and drought stress (Verma and Shukla 2015). In a different study, it was observed that in the flowers of *Hypericum perforatum*, there was a good amount of elevation in the amounts of chlorogenic acid, flavonoids and hypericins when the plant was in a situation of water stress. But the amount of hyperforins got lowered in the plant due to this prevailing situation (Gray et al. 2003; Neto and Lopes 2007). Also, in Artemisia, the important secondary metabolite called the artemisin rises when the plant is exposed to a prevailing situation of low moisture condition. Furthermore, raised levels of quercitin, rutinin and betulinic acid was observed in *Hypericum brasiliense* (Verma and Shukla 2015). Farahani et al. (2009) have reported that the condition of low moisture situation causes a decrease in the attributes related to the growth and also the amount of essential oil content in plant of *Mentha piperita* L. (Abdelmajeed et al. 2013). According to Zobayed et al. (2007), low levels of moisture in the plant reduces the bulk of photosynthesis in the leaves, amount of some secondary metabolites like pseudohypericin and hypericin also gets lowered. However, another type of the metabolite called hyperforin is elevated in the situation of stress caused by low water (Verma and Shukla 2015). In a study by Belaqziz et al. (2009), the consequence of lower levels of moisture in the different attributes of *Salvia officinalis* like fatty acids, essential oil and vegetative growth were studied. The water stress condition due to drought caused decrease in the fatty acids and various attributes related to development of the plant as well (Abdelmajeed et al. 2013).

It can, therefore, be inferred that the situation of stress caused by reduced water has a notable impact to different types of secondary metabolites of the plants. The situation of stress due to drought leads to higher levels to biosynthesis of various types of secondary metabolites (Waterman and Mole 1989; Gershenzon, 1984; Neto and Lopes 2007). Different types of synthetic components behaving as secondary metabolites are there which gets modified to their volumes. Some of the metabolites whose concentration gets increased as a result of this condition are anthocyanins (Jung 2004), alkaloids (Hoft et al. 1996; Briske and Camp 1982) cyanogenic glycosides, glucosinolates (Blua et al. 1988) and few types of terpenoids (Lokar et al. 1987; Neto and Lopes, 2007). In American basil (*Ocimum americanum*) and sweet basil (*Ocimum basilicum*), the low levels of moisture cause repercussions in various plant parameters. Due to scarcity of water, it causes undesirable effects to the nitrogen, phosphorous and potassium content and ramification of the amount of total carbohydrates and content of essential oil (Verma and Shukla 2015).

Undesirable consequences may also happen due to plant stress. The lower water level causes elevation in the amount of essential oil and reduction to the levels of nitrogen, phosphorous and potassium. (Khalid 2006; Verma and Shukla 2015). The degree of influence of the situation of water stress with respect to alteration in the amount of secondary metabolites is often conditional to the extent of the low moisture situation and the time of its occurrence (Neto and Lopes 2007). Many scientists have reported that when the plants are exposed to the condition of drought stress for a lesser period, the synthesis of these secondary metabolites gets increased. But when the same is for a prolonged and extended period, then a negative effect has been seen in the concentration of the metabolites (Waterman and Mole 1989; Horner 1990; Mattson and Haack 1987; Waterman and Mole 1994; Medina et al. 1986; Neto and Lopes 2007).

SALINITY STRESS

If the range of ions viz., sodium (Na) gets elevated in the soil, then it can result in lowering of absorption of moisture and other minerals and supplements by the plants from the soil. The rate of photosynthesis also gets reduced. Furthermore, due to the situation, the moisture can get drained out from the cytoplasmic region of the cells rendering the cells and plant dehydrated and creating a condition of osmotic stress (Tippmann et al. 2006; Verma and Shukla 2015).

The salt stress may ultimately lead to the elevation or reduction in the secondary metabolite content (Ramakrishna and Ravishankar 2011). Studies have shown that the amount of alkaloids like vincristine and reserpine is elevated in the plants of *Catharanthus roseus* and *Rauvolfiatetraphylla* during condition of salt stress (Verma and Shukla 2015). In *Ricinus communis*, the amount of ricinine alkaloid becomes higher in the shoot region, whereas its concentration lowers down in the root portion due to salinity stress (Said-Al Ahl and Omer 2011; Verma and Shukla 2015). Elements like α-bisabolonoxide A, α-bisabolol oxide A, α-bisabolol, trans- β –farnesene, chamazulene, α-bisabololoxide B are the principle components of the plant *Matricariarecutita* and all of them shows an elevating trend in their concentration when the plant is exposed to a high salinity environment (Baghalian et al. 2008; Abdelmajeed et al. 2013). Also, in *Solanum nigrum*, the alkaloid solasodine and in *Catharanthus roseus,* the indole group of alkaloid shows a good amount of rise in their levels when the plant gets subjected to a situation of stress. It was also observed that in *Achillea fragrantissima*, the amount of phenolic acid got increased when the salinity levels in the soil become high (Verma and Shukla 2015).

In the experiment with *Origanum vulgare* carried out by Said-Al Ahl and Hussein (2010), the component carvacrol which is a major element of the essential oil, gets lowered down in the situation of salt stress. Whereas other elements like p-cymene and γ–terpinene becomes higher in their amount when some treatments were provided with an environment free from soil stress (Abdelmajeed et al. 2013). *Matricaria chamomilla* demonstrated gaining of chlorogenic acid, protocatechuic and caffeic acids which are all types of acids of phenolic group, with higher levels of salinity (Abd EL-Azim and Ahmed 2009; Said-Al Ahl and Omer 2011; Cik et al. 2009; Verma and Shukla 2015). Also in case of some other medicinal plants like *Thymus maroccanus* (Belaqziz et al. 2009), basil (Said-Al Ahl and Mahmoud 2010), Mentha piperita (Tabatabaie and Nazari 2007), peppermint, pennyroyal, and apple mint (Aziz et al. 2008), the increase in the amount of essential oil is inversely proportional to the salinity stress (Abdelmajeed et al. 2013).

In case of different types of plants, like *Mentha piperita*, *Majorana hortensis, Salvia officinalis*, *Origanum vulgare*, *Matricaria chamomilla*, *Thymus maroccanus*, *Mentha suaveolens* etc., a lower level of accumulation of the essential oils was evident under the situation of salt stress (Verma and Shukla 2015). Said-Al Ahl et al. (2010) in their experiment with similar stress have mentioned about elevated amount of linalool and eugenol in essential oil for basil (*Ocimum basilicum* var. *purpurascens*). It was seen that when the amount of salinity in the soil was at 1500 and 4500 mg per kilograms then the concentration of linalool was increased, but at the same range of soil salinity level the amount of eugenol concentration got lowered (Abdelmajeed et al. 2013). In *Satureja hortensis*, *Matricaria recutita* and *Salvia officinalis,*the condition of stress due to salt, shows a higher gain of the essential oil contents (Said-Al Ahl and Omer 2011). In the earlier work of Ashraf and Orooj (2006), it was seen that in the situation of salt stress the amount of essential oil got declined in *Trachyspermumammi*. (Abdelmajeed et al. 2013). According to Jaleel (2009) when the levels of salt concentration in the soil rises up for the plant of *Catharanthus roseus*, then the amount of an alkaloid in the roots of the plant called as ajmalicine having anti hypertension property gets raised up alogwith the antioxidant power (Verma and Shukla 2015). Due to this change in the sodium ions in the plant, it may cause alteration in other group of ions. Thus, it can be concluded that the situation of salinity brings a complimentary environment for more gaining of secondary metabolites by the plants (Verma and Shukla 2015).

GENETIC FACTORS

Few earlier works with respect to the genetic features have suggested that the synthesis of the secondary metabolites in plants is influenced by the genetic command. The plant genomic field comprises of many thousands of genes. But from this vast number, it is predicted that only few genes (15-25%) are responsible for the synthesis of plant secondary metabolites (Verma and Shukla 2015). Furthermore, they are regulated by multiple genetic factors. According to Broun et al. (2006), the genes in the plants are governed by variable factors of transcription which regulates the metabolic flux and this ultimately leads in effecting the expression for the pathway genes. It has been widely accepted that selective plant species are responsible for encoding a certain enzyme which are essential for the plant towards biosynthesis of secondary metabolites (Pichersky and Gang 2000; Verma and Shukla 2015). Regarding the constitution of the essential oil in the plants, experiments regarding the hybridization programmes and genetic works provided us with results that this is also very much dominated by the genetic factors (Figueiredo et al. 2008). Each and every gene in the plant profile goes along with variable expression profiles in multiple types of plant tissues. As a result of the higher proportion of the genes, it causes amplification in *Cistus creticus* with respect to the gathering of isoprenoids (Pateraki and Kanellis 2010). The works confirmed that the enzymes as well as the genes are essential components which play a prominent role in the biosynthesis pathways of the plant secondary metabolites (Verma and Shukla 2015).

In *Mentha spp*, genotypes CC or the Cc helps in the transformation of limonene from terpineol and also promotes the development of carvone which takes place due to the oxidation reaction of limonene. In the works of Woldemariam et al. (2013), it was established that NaMYC2 which is an aspect for transcription take part in a vital character regarding the management of biosynthetic pathways for the retaliation associated with the defence mechanism of *Nicotiana attenuata* (Verma and Shukla, 2015). Furthermore, in different species of *Salvia, Achillea, Cupressus, Perilla, Thymus, Pinus, Clarkia, Juniperus* and *Abies*, it has been found that constitution of the essential oil is very much committed to genetic elements (Figueiredo et al. 1997; Stahl-Biskup and Sáez 2002; Theis and Lerdau 2003; Nemeth 2005; Figueiredo et al. 2008). Also, the selection through the natural process is accountable in the alteration for synthesis of the volatile components and the makeup of the essential oils as well (Figueiredo et al. 2008).

Therefore, the development and production of the secondary metabolites of the plants are unquestionably regulated by different types of enzymes, factors of transcription, regulatory genes and unwanted situation caused by the pathogen which makes the plant to move into stress.These all result in fluctuations in the assemblage or alteration in the biosynthesis of the secondary metabolites. The concentration and amount of these secondary metabolites varies with respect to their requirement from the plant as an important component of defence which helps in making the plant to cope up or to remain alive in variable environmental anomalies which are not suitable for the growth and development of the plant (Verma and Shukla 2015).

PLANT ORGANS

The volatile aromatic components and the essential oil received from different structures of the plants are very much distinct with respect to their chemical composition. This is mainly because of the presence of variable and multiple type of plant anatomy which is responsible for the altered secretions randomly allocated all throughout the framework of the plant (Figueiredo et al. 2008). There are different types of structures present in the plant which helps in secreting out variable biosynthetic components. These aromatic volatiles are synthesized in the specific parts of the plant exclusively. This helps in bringing down the levels of auto toxicity in the plants and causing increased accumulation of constituents in particular places or targeted regions where their function for defence and alluring utility becomes very important.

In case of *Pittosporum undulatum and Achillea millefolium* structures like canals and trichomes have been seen (Figueiredo et al. 2008). But if more than one structure is present, it would differ in its make-up and its secretion will also vary. The formation of these structures for secretions may not every time be a concurrent process. They won't be liberating the common type of chemical component always. But in contrary to this, they can have multiple mechanisms of secretions of the chemicals and volatiles (Figueiredo et al. 2008). The constituents of the chemicals for the essential oil which was gathered from multiple parts of the crop was very much at par to the report of current times concerning the factors of transcriptome as well as the associated genes which are accountable for emergence of a particular type of secondary metabolite like terpenoids, as an example (Galata et al. 2014; Moghaddam and Mehdizadeh 2017). In few of the situations, it was found that within the taxonomy for a given genus having structures for volatiles liberation internally, the secretion made by it may be having homogenous or common type of component of the chemicals but the place where the structure for secretion is situated will prove us the insight regarding the ultimate task with respect to particular plant (Figueiredo et al. 2008). According to Niu et al. (2015), these types of findings have shown us that the impressions of the unigenes are very much related and exclusive to particular tissues in variable types of structures of the plant and helped in discovering recognizable pathways for the terpenoids (Moghaddam, and Mehdizadeh 2017). The chemical components in the essential oil of basil had a broad and inconsistent range which was according to changes in the colour of the leaves and flowers of the plant, type of origin of that plant and changes in the chemotypes (Carovic´-Stanko et al. 2010; Pirbalouti et al. 2013; Moghaddam, and Mehdizadeh 2017).

FERTILIZER APPLICATION

Different nutrients in the forms of fertilizers are applied to the soil for the benefit of the plants and for the growers to get a good output. It is a very common but major agricultural practice which plays a crucial role in the synthesis of essential oil, determination of the component elements in the oil and the final volume of the oil (Dudai 2005; Alizadeh et al. 2010; Karamanos and Sotiropoulou 2013; Moghaddam, and Mehdizadeh 2017). If any kind of variation occurs in the amount of these nutrients, then it will strongly influence the configuration of the volatiles and the oil contents (Amzallag et al. 2005; Bernstein et al. 2009; Moghaddam and Mehdizadeh 2017).When different types of micronutrients are applied in the soil and to the plants viz., *Cassia angustifolia*, gradually there is a buildup of the primary metabolites and subsequent elevation in the reserves of the secondary metabolites (Verma and Shukla 2015). Furthermore, the nutrients inputs like zinc sulphate, copper sulphate and ferrous sulphate has a significant effect in the amounts of the protein, phenols and the chlorophylls (Shitole and Dhumal 2012; Verma and Shukla 2015). When the nutrients are applied to the leaves, the oil content in the plant increases probably due to better uptake of the chemicals from the leaf cells directly into the plant system (Mondal and Al Mamun 2011; Moghaddam and Mehdizadeh 2017). In some of the earlier works, it has been documented how the application of the fertilizers and the chemical inputs helps the plant in changing the amount of essential oil in them and alterations in the constitution in crops of having therapeutic properties and volatile aromatic components (Hendawy and Khalid 2011; Nurzynska-Wierdak 2012; Sharma and Kumar 2012; Zheljazkov et al. 2012; Moghaddam, and Mehdizadeh 2017). But it is not that every previous report suggested a positive or a huge influence of the fertilizers over the concentration of the secondary metabolites. As in several other experiments, there was no promising result regarding the nutrient applications in the aromatic and volatile constituents of these plants which includes*Thymus maroccanus*(El Bouzidi et al. 2013),*Ocimum*gratissimum (Biasi et al. 2009), *Thymus leptobotrys* (Jamali et al. 2014) and *Thymus transcaspicus* (Tabrizi et al. 2011; Moghaddam and Mehdizadeh 2017). So, in order to get a better idea about the relation between the secondary metabolites and the synthetic inputs, it's essential to have sufficient knowledge and wisdom on how these individual elements of the fertilizers affect these important constituents of the plants.

Among the different type of chemicals applied as nutrient, nitrogen is one of the essential key elements for the growth and development of the crop. However, the consequence of the amounts of the administration of this element on the volume of the volatiles and that of the essential oil actually changes among different types of plant and sections (Moghaddam and Mehdizadeh 2017). Various plants in the mother nature have devised different way outs to acknowledge against the presence of the amounts of nitrogen in the atmosphere and the surroundings (Verma and Shukla 2015). Some reports have suggested a no-good effect regarding the implementation of nitrogen on different types of herbaceous plants and also in plants having aromatic and curative properties (Arabaci and Bayram 2004; Barreyro et al. 2005). In another example, the application of the nitrogen as an input to the plant elevates the amount of essential oil in cumin (Azizi and Kahrizi 2008) and that in the mint species (Abbaszadeh et al. 2009; Castro et al. 2010). But in another instance the same nitrogen declines the bio synthesis of essential oil in few cultivars of *Origanum vulgare* (Azizi et al. 2009; Moghaddam and Mehdizadeh, 2017). When nitrogen is applied as the nutrient input to the crops like Arabidopsis, it helps in signaling the plant regarding the expression of some particular genes and this mechanism has also been seen in some other plant types and species (Vidal and Gutierrez 2008; Verma and Shukla 2015).

Phosphorous is the other most important nutrient element (after nitrogen) which is hugely required by the plant and is very crucial for their ontogeny. It is the integral part of phospholipids, nucleic acid and for the coenzymes which helps in the development of amino acids and subsequently for the production of the RNA, DNA and ATP (Rouached et al. 2010; Moghaddam and Mehdizadeh 2017). Phosphorous also have great influence in the development of the plant as well as its content of the secondary metabolites (Verma and Shukla 2015). A decline in the carbon fixation in chloroplast of the cell results in phosphorus insufficiency which, in turn, has a pronounced effect in the photosynthetic capability of the plant (Nell et al. 2009; Ramezani et al. 2009). In garden sage, it was seen that phosphorous helps in increasing the concentration of total phenolic content, rosmaric acid content and total bulk of leaves, but with no pronounced role on the amount and the qualitative parameter of the essential oil content of the plant (Verma and Shukla 2015). With the application of phosphorous, the essential oil of chamomile (*Matricaria chamomilla*) is reduced (Emongor et al. 1990), but in contrast, there has been increased amount of essential oil content in basil (Ramezani et al. 2009), cumin (Tuncturk and Tuncturk 2006), and feverfew (*Tanacetum parthenium*) (Saharkhiz and Omidbaigi 2008), fennel (*Foeniculum vulgare*) and sage (*Salvia officinalis*) (Nell et al. 2009; Moghaddam and Mehdizadeh 2017). Therefore, it may be concluded that phosphorous influences in gaining of the plant biomass and boos up the secondary metabolite content (Nell et al. 2009; Verma and Shukla 2015).

Potassium also holds a prominent place as a crucial nutrient component which is very much required by the plant and deficiency of which makes the plant suffer with adverse consequences. Like other nutrient inputs, potassium has also variable result on the amount of the volatiles and the contents of the essential oil and in the constitution of multiple sorts of aromatic and health benefitting compounds. Some earlier studies have shown us that application of potassium to the plant have resulted in elevated essential oil content in various types of aromatic plants (Davies et al. 2009; Said-Al Ahl et al. 2009; Zaghloul et al. 2009; Moghaddam and Mehdizadeh 2017).

TIME OF HARVEST

The particular period of harvest of any herbaceous aromatic plant also plays a very important role to influence its qualitative attributes of the aroma volatiles, secondary metabolites and the constituent of the essential oils. From several experiments by different scientists, it has been very much clear that during different phases of growth and development of a plant the constitution of the secondary metabolites in them also varies and get modified accordingly (Schmidt 2010). It is, therefore, important to keep an eye over these variations of the secondary metabolite by understanding the plant growth phases more accurately. In few instances it is observed that it can be a very small window of few to some days when these secondary metabolites and aroma volatiles as well as the essential oil content gets to enter on its desirable qualitative standards. So, it is crucial to know when the particular window would be there so that the personnel involved can get the maximum utility from the plants. Studies have indicated how change in the developmental phase of the plant can bring alterations in the content of the volatiles. In an experiment with *Artemisia vulgaris* of Vietnam, it was documented that with respect to the variation of the synthetics during the full period of the growth of the plant it had b-pinene and 1, 8-cineole at a concentration lower than the amount of 1.2% and 10% before the time of flowering. But a considerable change was seen in the amount of these chemicals by the time the flowering has been completed. During this period, the concentration of b-pinene and 1, 8-cineole got changed to 10.4% and 24% respectively (Nguyen Thi Phuong Thao et al. 2004; Schmidt 2010). Hence, the scientist got positive result in this regard justifying the impact of plant growth phase over volatiles.

Ester is a principle element in determining the essential oil content of lavender, ascertaining the value of the oil of the plant in the market. But this content of the ester in the oil fluctuates very much and as a result of which the final standard and value of the oil in the sector of trade changes accordingly. Some layman practices are there to judge the state of maturity of the flowers, when the oil yield would be in good amount. As a basic unwritten criterion, it is stated and believed that the oil in the flowers of lavender will obtain its maximum streak and characters when the lavender plant will show near about two-third of the opening of the flowers in the field and at this particular stage of the plant it is best required that the harvesting should be carried upon. Today with the development of technological interventions, many modern mechanisms are devised to know about the ideal time of harvest. In the present time many advanced techniques like chromatography through gas and micro distillation procedures are being used in which the sample of flowers are plucked from the fields and they are examined for their amount and standard of essential oil in them. If suitable results are obtained from the sample of flowers then the procedure of harvesting is being initiated or at least an idea is obtained regarding when to carry out the harvest. In rose, it is advisable that the petals from the plant should be plucked in the earlier hours of the day i.e., between 6 a.m. to 9 a.m. Time outside these mentioned hours of the day is not suitable for the harvesting and plucking of the crops in average, because any delay results in many negative consequences to the oil yield. As the day progresses the heat also increases and it causes considerable reduction in the final output in the amount of the oil. But in case of another group of plants viz., pines and eucalyptus, where the glands of the oil are inserted inside the leaf, harvesting time around a day has whatsoever no significant influence on the amount and the quality of their oil output (Schmidt 2010).

MECHANICAL AND CHEMICAL INJURIES

The injuries caused to the plant or plant parts at any time may cause long lasting effect and also influences the volatiles. But it is unfortunate that the role of various injuries which may have taken place from physical or synthetic wounding (example of physical injury may be mechanical damage due to improper post harvest handling causing abrasions and brushes and for chemical injury is problem happening due to irregular applications of chemicals like herbicides) and it effect on the quality, constitution of the oil and its final output has not been very hugely studied (Figueiredo et al. 2008). So, it is very much required today to give more attention towards this sector and to monitor how the injuries cause changes in the content of secondary metabolites. When the plant is received with a healthy environment with the optimum contents of the essential prerequisites for its growth and development, then the plant can be said in good physical condition and at that time volume of the secondary metabolite produced by it can be said as a *constitutive synthesis*. But when the plant receives an undesirable situation which may result in occurrence of injury to the plant of any sorts, then the plant may result in the synthesis of chemical elements which in earlier has not been produced by the plant. This type of the production is called as the *induced synthesis*. These two types of synthesis i.e., the induced and the constitutive type of production from the plant the dissimilarities between them cannot be easily established, because in a large group of plants which are good in their physical condition the volatile components liberated from them gets transformed into induced type of synthesis, when the given plant is subjected to any form of physical or chemical wounding. So, it is very clear that with the change in situation or environmental condition, the one type of synthesis gets switched into another.

The outcome of injuries which are created from the activities of different predators is very much crucial to those groups of plants which synthesize oleoresin and the resin is gathered in the plant's multiple secretory structures. Canals and ducts in the plants are the example of these types of structures. Studies on *Pinus pinaster* have demonstrated that as a result of punctures in the crop, the oil content in the species got elevated up to 2.5 times. When the plant sustained infection from the mycelium of the *Verticicladiella*sp., the amount of oil in the plant got raised up to about 60 times. It was also found that the inoculation through the mycelium of the mentioned strain showed a significant outcome in the synthesis of the terpenes (Figueiredo et al. 2008). Thus, it is very clear that alteration comes in the plant internal environment when it is subjected to any kind of external injury and therefore it acts accordingly. When the plant receives any kind of injury that might be from external non-living sources or through the effect from infestation through disease causing agents, then the plant automatically moves to a condition of stress and due to this situation, it may lead to induced synthesis of huge quantities of volatiles from the plant. This not only cause variable consequences to the plant internal metabolism but apart from this a difficult situation is created for the personnel like florists, flower pickers or farmers who are associated to the trade in picking and operating of this plant elements. The persons may develop allergies and may other health related problems (Figueiredo et al. 2008).

STORAGE

Storage is one of the most vital steps of the post-harvest management. The secondary metabolites as well as the components of the aroma volatiles may get very much influenced by the way in which storage is being carried out for the associated plant or plant parts. But apart for storage, some technologies in the post-harvest chain of operations also influences the volatile contents. After harvesting crops, drying and dehydration is carried out as an important step in the post-harvest chain of operations. This may result in causing many changes in the plant, which are in an undesirable way with respect to the physical and biochemical attributes within. Due to this developed alterations, the value and standard of the commodity or the desired material in the market may get reduced as the process of dehydration results in leaching down and loss of the various elements and principle constituents which are responsible for development and building up of the aroma volatiles and framework in the plant (Figueiredo et al. 2008). But dehydration also has some beneficial attributes which helps the plants and its valuable volatiles in long run. Apart from this, removal or exclusion of moisture from the plant parts to a safe storable limit helps in bringing down the levels of contamination caused by the microorganisms. This also helps in stopping of few inner biochemical process within in the plant which otherwise would have caused an impact on the plant in a very obstructive way.

Storage is a single thing but there are many living and non-living attributes which comes along with the storage and relates themselves to the volatiles. Many parameters during the time of storage like the temperature, illumination range of the room, percentage of relative humidity, age of the plant part which is stored, presence of any chemical reactions like oxidation or infestation by biotic elements etc., helps in influencing the final output as well as the constituent of the volatile aromatic components. All these things or attributes are of external origin. In addition, plants have their own internal frameworks which also play a vital role upon the secondary metabolites. As it has been said earlier that the specific anatomies of the plant helps in determination in the secretion of the aromatic components and furthermore, their role in the post-harvest life of the plant is important which helps in influencing the constitutional make up of these components. It has been found that those secondary structures of the plant responsible for secretion, which are embedded deep within are less susceptible to losing and alterations in the constituents of the volatile components but on contrary to this, the anatomies of the plant which are present supervenient like trichomes as an example can cause exudation of the volatiles if any kind of damage is occurred in the layer of cuticle.

In some plant species like *Jasminum grandiflorum*, *Ocimum basilicum*, *Anethum graveolens*, *Carum carvi*, *Cananga odorata*, *Narcisus poeticus*, *Chamomila recutita*, *Zingiber offcinale and Sassafras albidum*, it has been reported that their final output has got lowered and occurrence of modification in the make-up of the aromatic constituents have taken place due to the impact of storage situation over them as well as due to the process of dehydration (Figueiredo et al. 2008). Curing, after plucking operation, is a kind of dehydration process done under shade for selective group of horticultural crops. It becomes a very important technique of post-harvest management which helps strongly in proper development of the aroma. The curing is required for the harvested beans of *Vanilla planifolia* for the optimum synthesis of volatile constituents in them. Due to the process of curing in vanilla the enzymes which are hydrolytic in nature like the β-glucosidase and glycosyl hydrolases gets detached in a superficial way from the substrate called glycovanillin and other types of precursors of the flavour components. The former group of enzymes (β-glucosidase and glycosyl hydrolases) is present in high quantities in the area of the external wall of the fruit and the latter group (glycovanillin and favour precursors) are present in good amounts in the areas of the placenta which is located near the seeds. Thereafter, the technique of curing helps in permitting the exposure for the substrates as well as the enzymes which causes fastening the process of hydrolysis, and due to this the flavour output like the vanillin as well as other important elements for the flavour are liberated (Havkin-Frenkel 2005; Figueiredo et al. 2008).

FUTURE STRATEGIES

Some of the points which can be taken into consideration and contemplated as future strategies in various aspects of maintenance and management of secondary metabolites of the plant, aroma volatiles and essential oils are discussed here under.

- Environment plays a significant role in influencing secondary volatile components liberated out of the plant. If the environment is good and optimum to the plant, it benefits in many ways. But on the contrary, the same environment at adverse situations or catastrophies, hampers the plant a lot. Environmental factors being beyond human reach or with limited control, at least some infrastructures or frameworks may be facilitated to help in protecting the plant from these severe ups and downs.
- Many examples of plants are there regarding how abnormal condition or situation of stress created due to undesirable ranges of temperature, drought and salinity triggering adaptive mechanism of the plant and as a result of which more

secondary metabolites are biosynthesized. So, taking the idea from this type of plants, response in future programmes with controlled environment of stress may be provided to the plants regarding temperature, moisture and sodium ions so that more production of secondary metabolites and volatiles can be obtained from them without hampering the plant growth and development.

- Many secondary structures are associated with the plant system which causes the secretion of the secondary metabolites. So, it is required to focus more on those type of the aromatic plants which have a greater number of specialized anatomies, so that more output can be expected.
- A major problem in the field as well as after harvest, during handling of the produces, is physical and mechanical injuries. Faulty plucking and inappropriate management steps render aromatic plants to abrasion, bruising and mechanical damage. This causes a major setback to the quantity of the aromatic volatiles produced. Furthermore, the quality is also extremely compromised as many new unknown and unwanted chemical components get added to the oils and affects the aroma due to wounding. Therefore, it is necessary to take care of the plant and plant parts properly and make sure about minimization of wounding. Harvesting techniques and management procedures are also required to be developed and modified accordingly.
- Application of nutrients either of micro or macro type has a mixed response over the quantity and quality of secondary metabolite of the plants and aromatic volatiles. Experiments are needed to be carried out further in these aspects to have more clear understanding and broader research outputs.
- Maturity index plays a vital role to determine the content of these aromatic profiles. As the optimum stage of maturity of a produce is good for its sound nutrient parameter, the proper stage of maturity is required for is desirable volatile parameters. Knowledge in this aspect is very important as to when harvesting of the crops should be made to achieve the best out of them. Today many developed techniques are there which helps in determining or predicting the time of maturity. It is very much required that personnel’s involved in the sector should develop sharp understanding and insight for accurate predictions.
- Lastly storage is needed to be very properly taken care of, as abnormalities of situations or environment during storage of any improper storage type or infrastructure will cause in declination in the quality of the aroma volatiles. Many modern ways and storage techniques have been developed which can be suitably employed for long keeping of the aroma compounds.

CONCLUSION

The entire chapter deals with how the various factors help in influencing and alteration of the secondary metabolites of the plants and the aroma volatiles. It can be realized after reading the chapter that how change in these attributes brings changes in the concentrations and constitutional make up of these aromatic compounds. Today many rival firms are there in the markets which are producing synthetic perfumes and aromatic substances. As we know that the outcome from natural volatile sources are not in abundance and sometimes there unavailability shoots up their price very high in the trade. On the contrary, the challenger synthetic substances are easily available and the price is also within the grip of the common man. Continuous persistence of the situation will lead to development of a trend where synthetic alternative would be preferred over the precious age-old traditional and natural volatile aromatic reserves of the plants. It is, therefore, very much required that the person or the grower who is related to the business should have a proper understanding and a crystal-clear idea regarding the impact of the governing living and non-living parameters over the plant secondary biosynthesis. Attributes which are beyond the grip of human control like environmental abnormalities, has little to do with. But in some other cases, knowledge and technology will help in providing better constituent and quality of the volatiles. For instance, if the grower knows the optimum stage of maturity of the plant, then the volatile constituent in the obtained yield would have a better qualitative standard and likewise selection of proper storage technique afterwards also facilitates the grade of the aroma standards.

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Chapter 11

PHARMACOLOGICAL ACTIVITIES OF COUMARINS AND THEIR DERIVATIVES

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ABSTRACT

Coumarins and its derivatives are natural compounds originally derived from many plants, such as tonka bean (*Dipteryx odorata*), vanilla grass (*Anthoxanthum odoratum*), sweet woodruff (*Galium odoratum*), sweetgrass (*Hierochloe odorata*) and sweet-clover (genus Melilotus), etc. They consist of a benzene ring joined to a pyrone ring. They can be considered as the lactone derivatives of ortho hydroxycinnamic acid, placed in the benzopyrone chemical class. Coumarins and their derivatives are used in several industries including perfumes and aromatizers, laser dyes. Nowadays, they play important role in the pharmaceutical industry. Coumarins and its derivatives have anticoagulants, antioxidants, anti-cancer, anti-inflammatory, antimicrobial, immunomodulatory activities, etc. In this chapter, we summarize the pharmacological actions of coumarins and their derivatives.

Keywords: coumarins, immunomodulatory activity, anticoagulants, antioxidants, anti-cancer

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COUMARINS

About Coumarin

Coumarins are of abundant structures. In 1820, coumarin was first isolated by Alfred Vogel of Munich, Germany and by Nicolas Guibourt of France (Sarker and Nahar 2017). 48 years later, it was synthesized successfully by the English chemist William Henry Perkin (Perkin 1868). Since then, the document related to coumarin and its derivatives was released and applied for a range of applications such as perfumes, cosmetics, and medicinal chemistry. Coumarin compounds are benzopyrones that have a benzene ring link with a pyrone ring (Figure 1). Coumarin derivatives often are secondary metabolites produced in seeds, roots, leaves of plants (Penta 2016).

Classification of Coumarin

Mishra et al. (2020) assumed that the combination of the different substituents and conjugates could change coumarin's biological activities. The coumarin structure is model framework to design and synthesize pharmacological compounds associating with various biological sites (Lacy and O'Kennedy 2004). Coumarins are known as 1, 2-benzopyrone, they can be divided into 5 types: simple coumarins, furanocoumarins (can be further grouped into linear and angular types), pyranocoumarins and pyrone-substituted coumarins (Figure 2).

Representative coumarins derivatives as simple coumarins are hydroxyl coumarins and 6, 7-dihydroxy coumarins. They are alkoxylated, hydroxylated and alkylated coumarin derivatives and their glycosides. (e.g., Skimmin, umbelliferone, herniarin, limettin (Figure 3)).

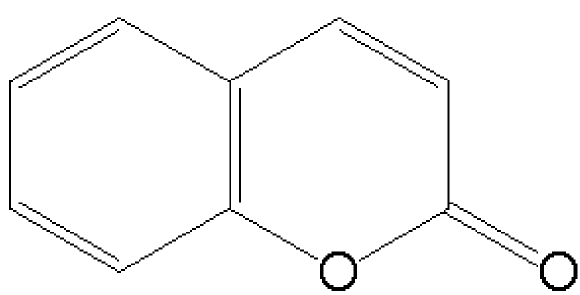


Figure 1. Coumarin structure.

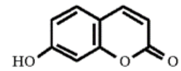
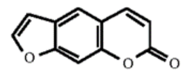
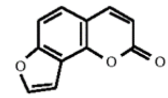
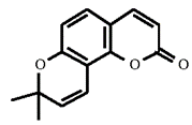
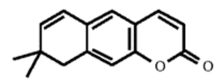
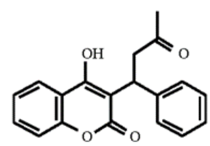
Classification	Features	Examples
SIMPLE COUMARINS	Hydroxylated, alkoxylated or alkylated on benzene ring	 7-hydroxycoumarin
FURANOCOUMARINS	5-membered furan ring attached to benzene ring. Linear or Angular	 Psoralen  Angelicin
PYRANOCOUMARINS	6-membered pyran ring attached to benzene ring. Linear or Angular	 Seselin  Xanthyletin
PYRONE-SUBSTITUTED COUMARINS	Substitution on pyrone ring, often at 3-C or 4-C positions	 Warfarin

Figure 2. The main coumarins structures (Lacy and O'Kennedy 2004).

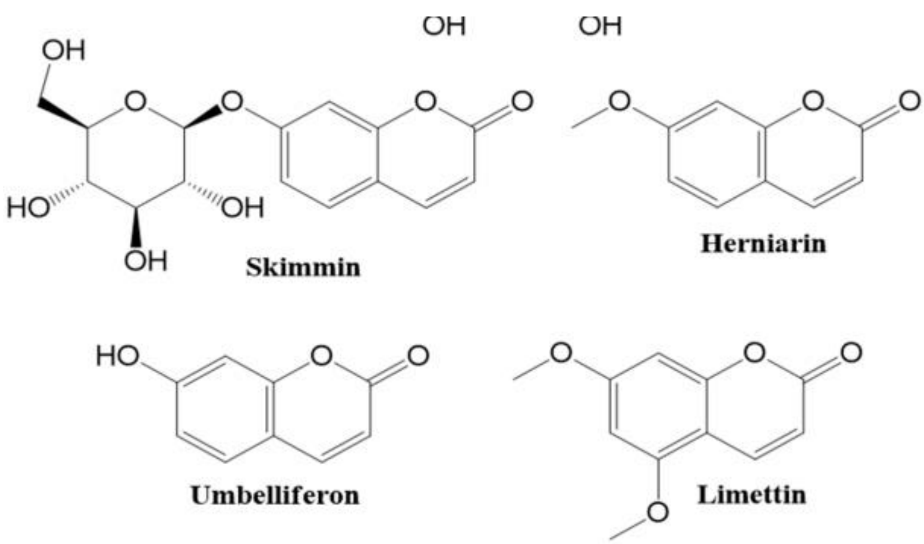


Figure 3. Simple coumarins structures (Küpeli Akkol et al. 2020).

The feature of furanocoumarins is a combination of a furan ring and coumarins. There are two types C6/C7 (linear) type and C7/C8 (angular) type according to the attachment position of the furan ring. (e.g., Isopimpinellin, pimpinellin, isobergapten, xanthotoxin (Figure 4).

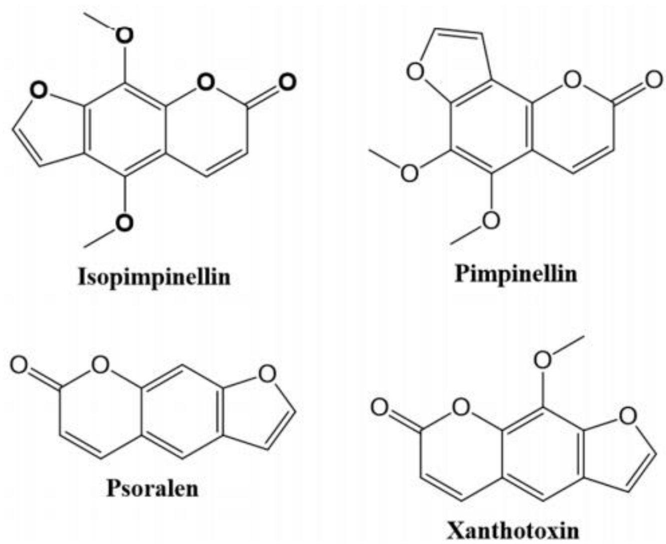


Figure 4. Structures of furanocoumarin (Küpeli Akkol et al. 2020).

Pyranocoumarins are compounds that consist of a benzene ring and six-membered pyran ring via C6-7 (linear) or C7–8 (angular). (e.g., xanthyletin, visnadin, seselin (Figure 5)).

There are three sorts of pyrone-substituted coumarins. They are 4-hydroxycoumarin (Novobiocin and Dicumarol), 3,4-benzocoumarin (Aeternaryiol) and 3-phenylcoumarin (Coumestroln and Gravelliferone) (Figure 6) (Küpeli Akkol et al. 2020).

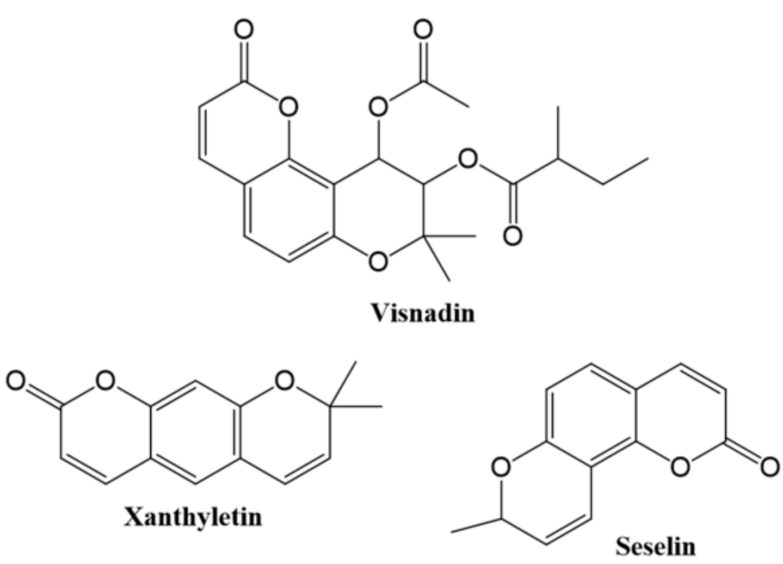


Figure 5. Some pyranocoumarins strutures (Küpeli Akkol et al. 2020).

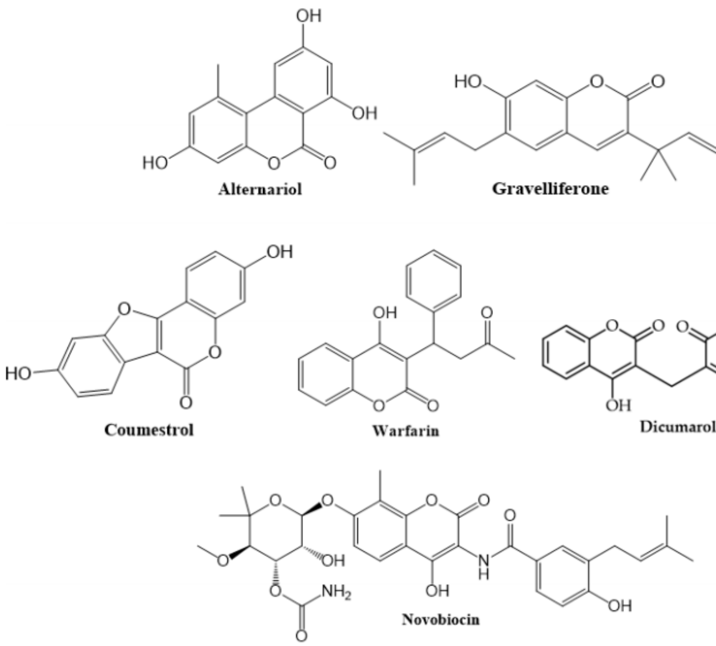


Figure 6. Pyrone-substituted coumarins (Küpeli Akkol et al. 2020).

Properties

Chemical properties of the lactone of an α, β-unsaturated aromatic acid are those of coumarin

Hydrolysis

When the lactone and an alkali react together the result is the corresponding salts of coumarins acid or o-hydroxy-cis-cinnamic acid. The products of this reaction can be reverted to coumarins upon acidification with an inorganic acid.

Hydrogenation

Depending on experimental conditions, hydrogenation of coumarins can make a lot of compounds such as 3, 4-dihydrocoumarins with a Ranyel nickel catalyst but continued hydrogenation at higher temperatures may create octa-hydrocoumarins.

Oxidation

It is not ready to oxidize coumarins but the Fenton's reagent can be a cause of oxidation coumarin, it is converted into 7-hydroxycoumarin.

Reduction

Lithium aluminium hydride reduces coumarins to o-hydroxycinnamyl.

Bisulfite Reaction

Coumarins react with sodium bisulphite solution to create soluble sodium 3- or 4-hydrosulfonates. It is possible to regenerate and purify coumarins by acidification.

Sulfonation

Coumarins combine with sulphuric acid to form coumarin-6-sulfonic acid at a suitable temperature. At higher temperature, this reaction can give coumarin-3, 6-disulfonic acid

Nitration

Fuming nitric acid reacts with coumarin to give 6-nitrocoumarin.

Halogenation

Coumarins combine with bromine to make 3, 4-dibromocoumarin under pertinent conditions. Under harder conditions, a formation of 3-bromocoumarin and 3, 6-dibromocoumarin can happen.

Coumarins react with chlorine in dichloroethane or without solvent to form 3-Chlorocoumarin.

Methylation

In the presence of sodium hydride, methyl 2-methoxycinnamate will be formed if a methylating agent and a coumarin react together.

Dimerization

If coumarins exposure to sunlight or UV radiation for a long time, a coumarin dimer will be formed (Boisde and Meuly 2000).

Structure and Activity Relationship

A lot of studies indicated a noticeable array of pharmaceutical fields and biochemical of coumarins, acting as anticoagulant, antioxidants, antivirals, antimicrobials, antitumor agents, anti-inflammatory, anti-HIV, hepato-protective, antithrombotic, anti-carcinigenic, anti-tuberculosis activities (Penta 2016). Therefore, it is important to determine the chemical structure with pharmacological activity. The combination of several heterocycles can change the feature of parent material and create compounds which often display promising properties (Medina et al. 2015). For example, if the coumarins add a methoxy group at the C-7 and a 3-methyl 2- butenyl group at C-8 of osthole, it will be led to the compounds which can affect plasma alkanine transferase (ALT) and prevent from caspase 3-activation. Besides, compensation of a coumarin structure with a catechol can increase the danger of tumour cell lines (Musa et al. 2008).

Coumarin and 4-hydroxycoumarin do not show anticoagulant activity. Jain and Joshi indicated that a substituent at the C-3, a hydroxy group at C-4 and a bis molecule are minimal conditions for anticoagulant activity (Figure 7) (Jain and Joshi 2012).

The o-hydrolation, the lactonization and the trans-cis isomerization of the side chain double bond can give the coumarin structures from cinnamic acid (Figure 8) (Jain and Joshi 2012). The transform is stable and could not cycle, so anisomerization of some types and the enzyme isomerase, which is implicated, is necessary. On the other hand, the cis form is not stable; it often tends to go to the transform. The combination of coumarin and a glucose molecule makes the cis-trans transformation easy.

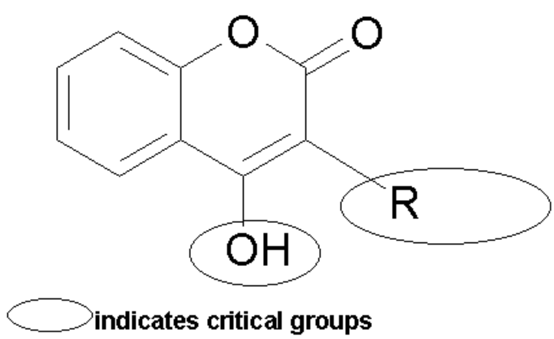


Figure 7. The 3-substituent and 4-hydroxy group make the anticoagulant activity (Jain and Joshi 2012).

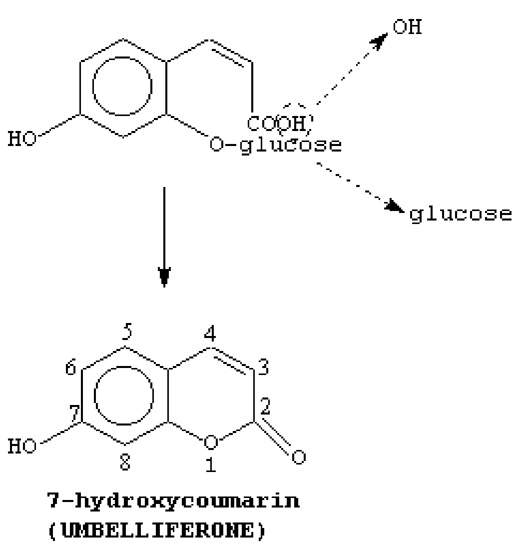


Figure 8. The unstable cis form of coumarin (Jain and Joshi 2012).

PHARMACOLOGY ACTION OF COUMARINS AND ITS DERIVATIVES

Anticoagulant Activity

According to Bairagi et al. (2012), blood-coagulant factors II, VII, IX, X are called vitamin K-dependent factors. The precursors of these factors, in the presence of calcium ions, allow them to bind to phospholipids' surfaces inside blood vessels, only if the glutamic acid residues of the precursors are carboxylated. Gamma-glutamyl carboxylase is the enzyme that carries out the glutamic acid's carboxylation. The carboxylation reaction will proceed only if the carboxylase enzyme can convert a reduced form of vitamin K (vitamin K hydroquinone) to vitamin K epoxide at the same time. The vitamin K epoxide is recycled back to vitamin K and vitamin K hydroquinone by another enzyme, the vitamin K epoxide reductase (VKOR). Warfarin inhibits this VKOR enzyme, especially VKOR1 subunit, reduce vitamin K epoxide to vitamin K1; relatively warfarin substances, those which sensitive to vitamin K antagonists, reduce vitamin K1 to vitamin KH2. As a result, available vitamin K and vitamin K hydroquinone in the tissues is decreased that inhibits the carboxylation activity of the glutamyl carboxylase. When this occurs, the coagulation factors are incapable of binding to the endothelial surface of blood vessels (biologically inactive) due to their unable to carboxylated at certain glutamic acid residues. In several days, the body's stores of previously-produced active factors are reduced, and replaced by inactive factors. This alteration leads to the apparently anticoagulation effect. In the end, warfarin diminishes blood clotting in the patient. Warfarin is the coagulation that is best suited in areas of slowly-running blood, namely in veins and the pooled blood behind artificial and natural valves, pooled in dysfunctional cardiac atria. Therefore, warfarin is clinically indicated for patients with atrial fibrillation, artificial heart valves, deep venous thrombosis, and pulmonary embolism (Bairagi et al. 2012; Venugopala et al. 2013b).

Antioxidant Activity

Many plant-derived and synthetic coumarin derivatives were assessed for their antioxidant activity. This activity is related to the competence in inhibiting lipid peroxidation to scavenge the reactive species, such as hydroxyl and superoxide radicals, and hypochlorous acid. The attention of free hydroxyl groups is essentially related to antioxidant activity, and compounds, where free hydroxyl groups are acetylated, showed the optimum antioxidant activity (Barot et al. 2015).

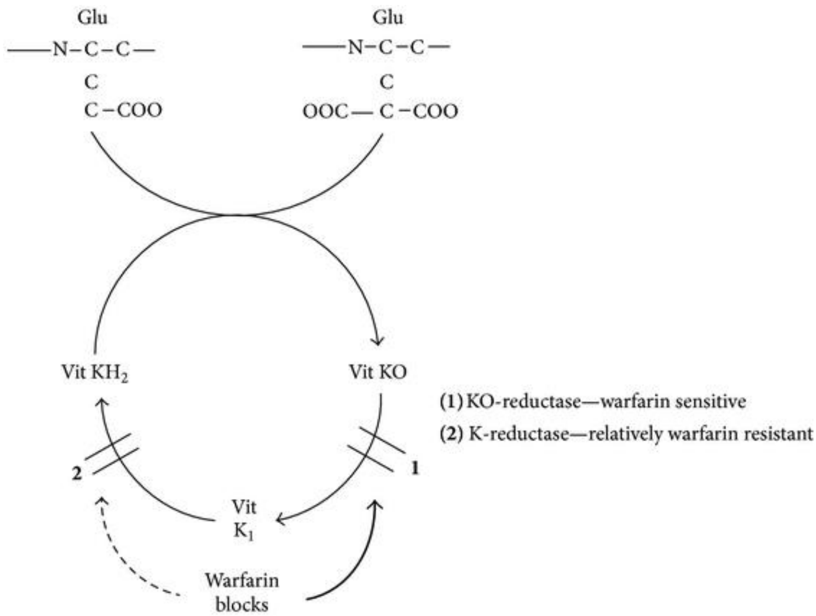


Figure 9. Mechanism of action of coumarins and its derivative on anticoagulant activity (Venugopala et al. 2013b).

In vitro antioxidant activity of coumarin compounds were demonstrated by DPPH, Superoxide and nitric oxide free radical scavenging methods. From the results of these methods, researchers showed that in comparison with ascorbic acid, 4-hydroxycoumarin and 5-chlor-4-hydroxy coumarin expressed great antioxidant activity, and the 7-hydroxy-4-methylcoumarin showed good antioxidant activity (Patel and Patel, 2011).

Barot et al. (2015) have summed up that Fraxin, extracted from *Weigela florida* Var. glabra leaves (Caprifoliaceae), represented free radical scavenging effect (at high concentration 0.5 mM) and cell-protective effect against H_2O_2-mediated oxidative stress, while esculetin showed good antioxidant activity. Grandivittin, agasyllin, aegelinol benzoate and osthol – the coumarin derivatives expressed their antioxidant activity by effect on human whole blood leukocytes and isolated polymorphonucleated chemiluminescence. Esculin and fraxin were studied in stems, fruits of *Actinidia deliciosa* (kiwifruit) and *Actinidia chinensis* (Figure 10).

As mentioned earlier, the antioxidant activity is mainly related to the acetylated ability of free hydroxyl group. Protein transacetylase (TAase) is able to catalyze the transfer of the acetyl group from DAMC (7, 8-diacetoxy-4-methylcoumarin) to GST (glutathione S-transferase). This reaction leads to the acetylation of some lysin residues in active sites and then, inhibits GST from catalyzing activity. In comparison with other coumarins, DAMC showed the highest catalytic activity, while 4-phenylcoumarins expressed far less activity (Barot et al. 2015).

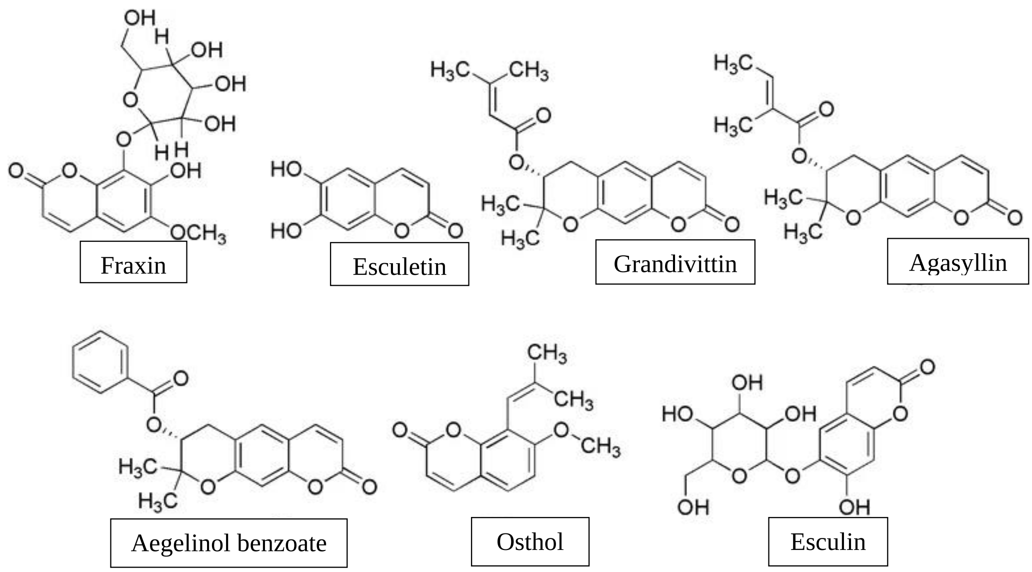


Figure 10. Structure of coumarins derivatives express antioxidant activity (Barot et al. 2015).

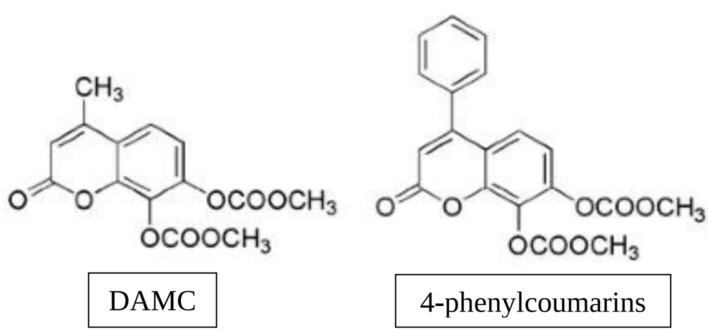


Figure 11. Structure of DAMC and 4-phenylcoumarins (Barot et al. 2015).

The relationship between oxidative stress and various biological processes has been described. The high levels of free radical and reactive oxygen species (ROS), such as hydrogen peroxide (H_2O_2), hydroxyl radical and other free radicals which cells manufactured, could cause damage to lipids, proteins and DNA. Hence, they contribute to the development of some harmful substances, namely carcinogenesis, inflammation, and aging in aerobic organisms. By inhibiting oxidase process, coumarins and their derivatives play an important role in pathogenesis of multifactorial diseases. In the coumarins family, the compounds with a 7-benzyloxycoumarin structure core are recognized as good and selective inhibitors of MAO B enzyme. Many research indicated that MAO B inhibition is related to the prevention of ROS formation. In addition, MAO B is an important drug target in neurological and neurodegenerative diseases. Coumarins are also proved to be the acetylcholinesterase (AChE) inhibitors. Moreover, some like-coumarins substances have been developed to be capable of inhibiting amyloid-beta (A) aggregation, a key protein in Alzheimer's disease pathogenesis (Mishra et al. 2020). The antioxidant activity of coumarins and their derivatives are also the basis of other effects of them, such as anti-cancer, anti-inflammatory. Therefore, many researchers focus on the antioxidant activity of coumarins and its derivatives have been performed in the last few years.

Anti-Cancer Activity

Coumarins and its derivatives are proved to be anti-cancer compounds by its cytostatic properties and cytotoxic activity. Thakur et al. (2015) indicated that coumarins target a number of pathways in cancer, namely kinase, carbonic anhydrase (CA), HSP 90, telomerase inhibition. They also serve as cell cycle arrest causing agents, antimitotic agents, etc.

First of all, kinase enzymes play an important role in modulating the signal of a multitudinous growth factor. Activated forms of these enzymes can result in the increase of cell proliferation, prevent apoptosis, in the end, and contribute to the angiogenesis and metastasis in several cancers. The activation of kinase enzymes caused by soma mutation, which is a basic mechanism of tumour-forming (Thakur et al. 2015). Thus, coumarins and its derivatives have a core structure as the figure. In 2014, Nars et al. synthesized and evaluated coumarin derivatives for anticancer activity on resistant pancreatic cells and drug-sensitive cell lines: Hep-G2 and CCRF. They showed that R_4 should be bromine because bromine takes an electronegative effect on coumarin moiety; R_5 could be any substitution due to the small effection of this position. When R_4 = H, R_5 = OH, they observed the weakest anti-cancer activity. Coumarinhydrazide-hydrazone pharmacophore indicated better activity than compounds having either coumarin or hydrazide-hydrazone pharmacophore (Nasr, Bondock, and Youns 2014).

Secondly, coumarins capture G0, G1, S and M phase of cell cycle, this results in apoptosis (Singh et al. 2014). They affect apoptosis by caspase-dependent intrinsic pathway and alteration in the cellular level of Bcl-2 family proteins (Saidu et al. 2012). Proapoptotic Bax/Bak and intracellular reactive oxygen species (ROS) intensify their manifestation; corollary of this increase, mitochondrial potential gets highly depleted. PUMA, the transcriptional target of tumour suppressor proteins p53, interacts with Bcl-2 family proteins and impulses the activation of Bax/Bak. Thus, they are important in multiple apoptotic models (Vázquez et al. 2012).

Moreover, Pan et al. (2011) indicated that coumarins served as angiogenesis prevention by repressing fibroblast growth factor-2 (FGF-2) mediated proliferation, migration, and tubule formation. By observing nuclear factor-κB (NF-κB) and phosphorylation of IKKα, coumarins were examined in decreasing the expression of vascular endothelial growth factor (VEGF) at mRNA level while phosphatidylinositide 3-kinases (PI-3K)/Akt signaling pathway is not affected.

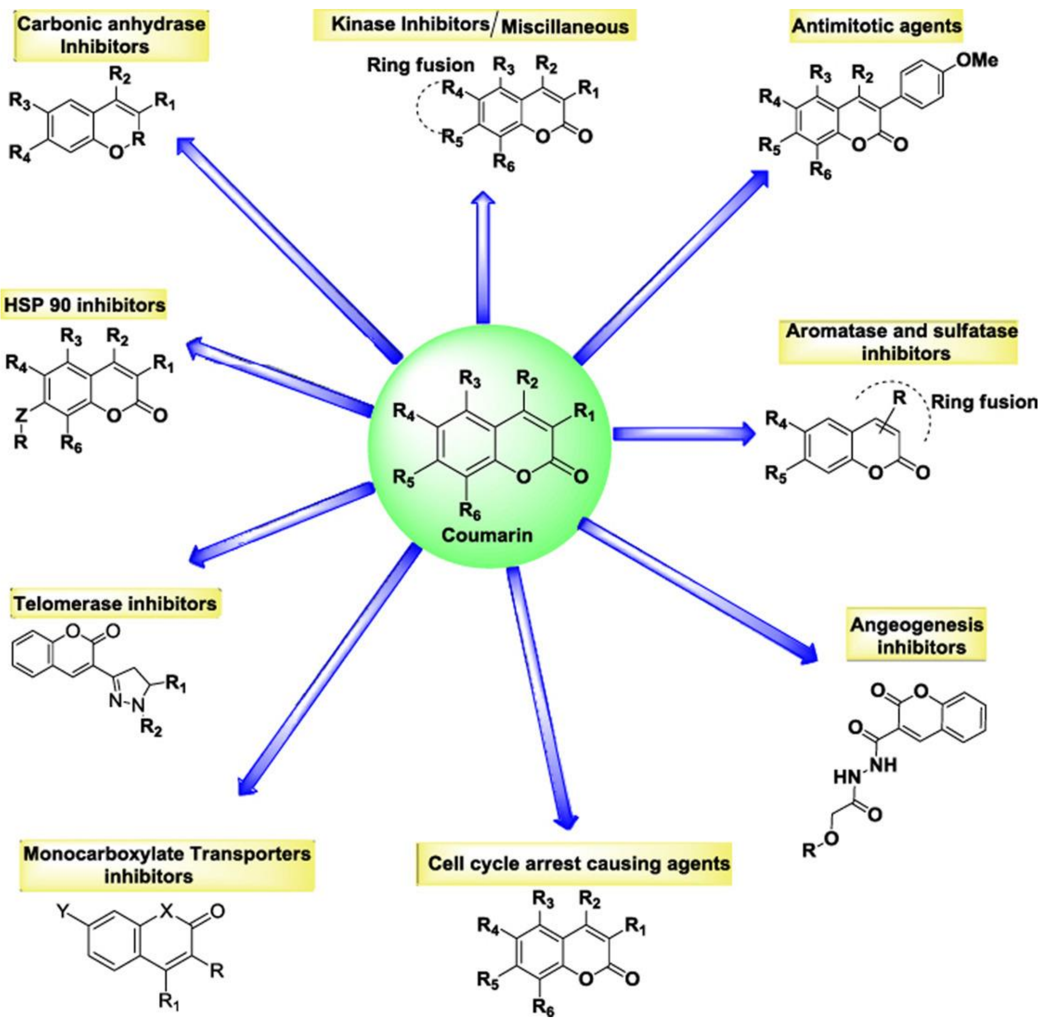


Figure 12. Structure-activity relationship of coumarins together with its anticancer activity (Thakur et al. 2015).

Thakur et al. (2015) have summarized the structure-activity relationship between the structure of coumarin derivatives and targets in the treatment of cancer (Figure 12).

Due to the coumarins' ability to affect many tumour cell lines by many pathways, they are examined in action against breast cancer, leukaemia, lung cancer, gastric cancer, etc.

Antimicrobial Activity

Coumarin itself has a very low antibacterial activity (Venugopala et al. 2013a).

Umbelliferone (UMB) is a natural coumarin from edible plants and fruits (Cruz et al. 2020). The potent antimicrobial activity of umbelliferone (UMB) was evaluated against methicillin-resistant *S. epidermidis* (MRSE) in a study via impairing MRSE biofilm by turning down the initial attachment and intercellular adhesion (Swetha et al. 2019). UMB exhibited a maximum of 83% biofilm inhibition of MRSE at 500 μg/ml concentration, which was fixed as MBIC (Swetha et al. 2019). The surface independent antibiofilm efficacy of UMB was exhibited through the dose-dependent antibiofilm activity of UMB with a maximum inhibition at 500 μg/ml concentration (Swetha et al. 2019). The minimum inhibitory concentration (MIC) of UMB using microdilution methods against Staphylococcus aureus and *Pseudomonas aeruginosa* were 500lg/mL, while activity against methicillin-resistant *S. aureus* (MRSA) and E. coli was exhibited by MIC value of 1000lg/mL (Mazimba 2017).

Psoralen, a natural furocoumarin, was extracted from various plants, showed anti-microbial activity in many studies. It inhibited the growth of planktonic *P. gingivalis* and biofilms of *P. gingivalis* (Li et al. 2018a). The MIC of psoralen against *P. gingivalis* was 6.25 μg/ml and the MBC of drug was 50 μg/ml(Li et al. 2018a). In another study, psoralen exhibited anti-microbial activity against different gram-positive and gram-negative bacteria such as *P. bituminosa, P. corylifolia,* so on (Koul et al. 2019). Besides, Psoralen also showed effects with Methicillin-Resistant Staphylococcus aureus (MRSA) strains but not significantly (Cui et al. 2015).

Agasyllin and Aegelinol are pyranocoumarins with significant antibacterial activity (Basile et al. 2009). At a concentration between 16 and 125 μg/mL, these coumarins exhibited a significant antibacterial effect against both Gram-negative and Gram-positive bacteria (Basile et al. 2009). Especially the ATCC strains *Salmonella typhi, Staphylococcus aureus, Enterobacter earogenes* and *Enterobacter cloacae* were the most inhibited (Basile et al. 2009). Minimum Inhibitory Concentrations (MIC) of aegelinol and agasyllin are 16 and 32 μg/mL, respectively (Basile et al. 2009). Moreover, their anti-microbial activity was also shown against Helicobacter pylori: a dose-dependent inhibition was shown between 5 and 25 μg/mL (Basile et al. 2009).

Recently, Qu et al. (2020) reported on DCH, a new coumarin compound, which effectively combats methicillin-resistant *Staphylococcus aureus* (MRSA) *in vitro* and *in vivo* and shows potent antibiofilm activity without detectable resistance.

Anti-Inflammatory Activity

Coumarins can effectively reduce tissue oedema-associated inflammation by suppressing both lipoxygenase and cyclooxygenase enzymatic activities and prostaglandin synthesis and release (Hassanein et al. 2020). Many studies showed that coumarins and their derivatives have anti-inflammatory activity (Fylaktakidou et al. 2004; Bansal et al. 2013). Coumarin itself demonstrated anti-inflammatory activity via the treatment of oedema (Kirsch et al. 2016).

Osthole, a natural coumarin from *Cnidium monnien* (L.) Cusson (Jarząb et al. 2017), proved anti-inflammatory activity through many different tests (Jarząb et al. 2017; Zafar et al. 2020). The test was performed according to Fan et al. that the anti-inflammatory effect of osthole showed by blocking the activation of the NF-κB and MAPK/p38 pathways (Fan et al. 2019). Moreover, osthole takes therapeutic potential in the treatment of ulcerative colitis (UC) (Fan et al. 2019). In *in vitro* study, osthole inhibited the production of proinflammatory cytokines interleukin (IL-6), NO, PGE2, and tumor necrosis factor-α (TNF-α) in LPS-induced macrophages (Fan et al. 2019; Kong et al. 2019; Li et al. 2012). Osthole inhibited cyclooxygenase-2 (COX-2) in the acFSGS model (Yang et al. 2014; Li et al. 2012), cyclooxygenase (COX-1) and 5-lipoxygenase (5-LO) (Revankar et al. 2017). Additionally, Osthole regulates inflammatory mediator manifestation via correcting nuclear factor kappa B (NF-κB), mitogen-activated protein kinases, protein kinase C, and reactive oxygen species (Liao et al. 2010; Kong et al. 2019) . Osthole also inhibited the expression of COX-2 and NOS in L5 dorsal root ganglion (DRG) on the rat model of sciatica induced by lumbar disc herniation (Wei et al. 2011). In a rat model of chronic kidney failure (CRF), osthole protects against inflammation through inhibition of NF-κB and TGF-β1, and activation of PI3K/Akt/nuclear factor (erythroid-derived 2)-like 2 signalling (Huang and Dong 2017).

Angelicin, also known as a furocoumarin from *Psoralea corylifolia* L. fruit, reported anti-inflammatory activity via many different tests (Wei et al. 2016). In acute lung injuries and asthma, Angelicin decreased inflammation-induced-damage by lowering cytokine production and reducing the infiltration of neutrophils and macrophages (Mahendra et al. 2020). Both NF-κB and MAPK pathway was also affected by angelicin in which angelicin inhibits the phosphorylation of IκB, p65, p38, and JNK (Mahendra et al. 2020). Angelicin also protected neuroprotective by inhibiting the production of nitric oxide and reducing the damage caused by hydrogen peroxide in LPS-induced inflamed mouse BV2 microglia cells and HT22 mouse hippocampal cells respectively (Mahendra et al. 2020). Angelicin showed anti-inflammatory property in inflammatory- related respiratory and neurodegenerative ailments through the activation of NF-κB pathway (Mahendra et al. 2020). A other study highlighted the ability of angelicin to markedly reduce the inflammation response in rats with periodontitis (Li et al. 2018b). Angelicin significantly regulated IL-6 and TNF-α levels, and decreased inflammatory cells in LPS-induced ALI mice (Liu et al. 2013). Moreover, angelicin prevented the phosphorylation of IκBα, NF-κBp65, p38 MAPK, and JNK in LPS-induced ALI (Liu et al. 2013). Angelicin also protects the body from Ovalbumin (OVA)-Induced Airway Inflammation in a Mouse Model of Allergic Asthma (Wei et al. 2016).

Seseline, a member of pyranocoumarin group, showed anti-inflammatory activity via the inhibition of croton oil-induced ear dermatitis in mice (Menghini et al. 2010).

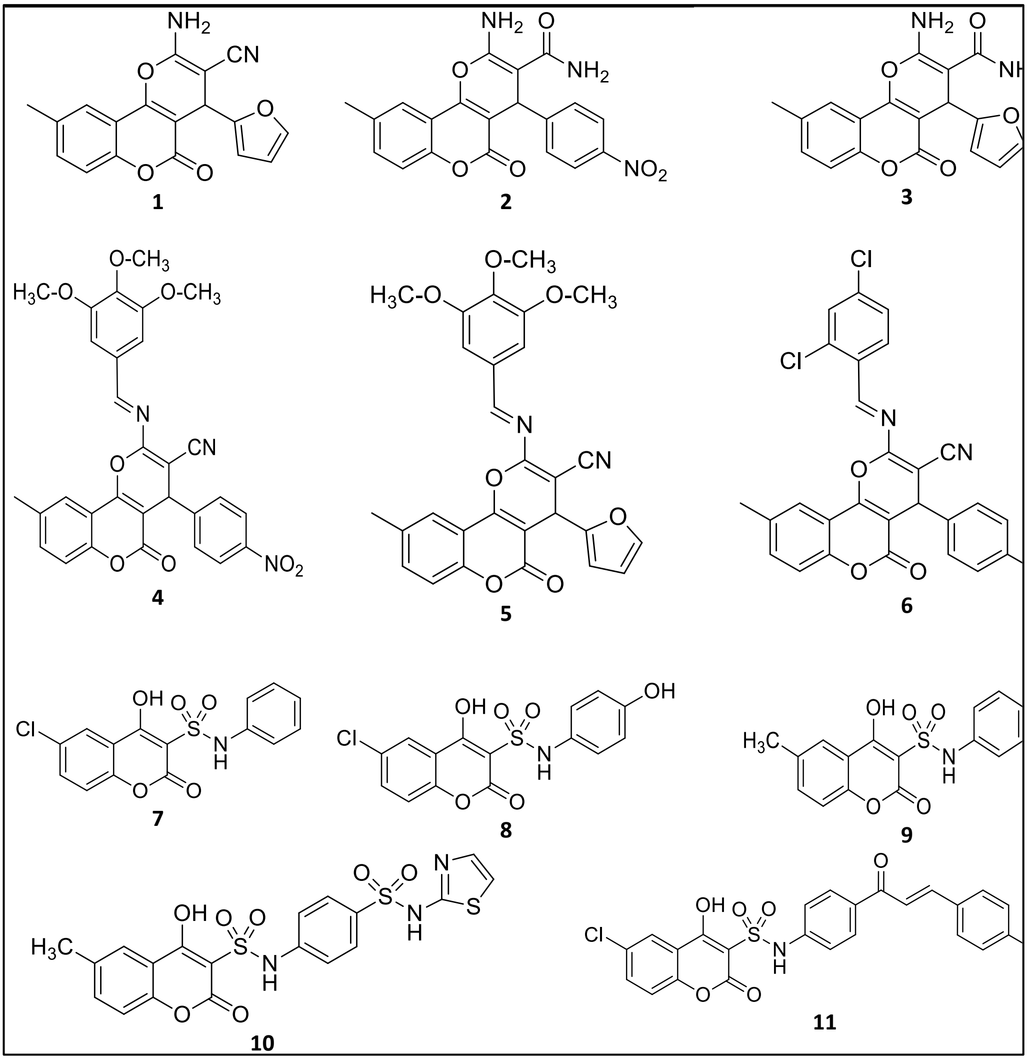


Figure 13. Newly Synthesized Coumarin Derivatives1-11(Alshibl et al. 2020).

By chemistry methods, the recent study showed Newly Synthesized Coumarin Derivatives through hydroxycoumarin and its dihydropyran derivatives, including pyranocoumarins (1-6) and coumarin-sulfonamides (7-11), as Anti-inflammatory agents (Figure 13) (Alshibl et al. 2020).

The newly synthesized compounds were separately tested for their *in vitro* anti-inflammatory activity anti proteinase enzyme (El-Serwy et al. 2017). Proteinases mostly exist in the lysosomes of neutrophils. Leukocytes proteinases play an important role in the development of tissue damage whereas proteinase inhibitors demonstrate significant levels of protection which proteolytic activity of neutrophils and against tissue damage during inflammatory reactions (Leelaprakash and Dass 2011). As shown in the study, antiproteinase activity at 250 µg/mL showed that the pyranocoumarins 1-4 and coumarin-3- sulfonamide 11weremore potent *in vitro* antiproteinase activity than reference standard aspirin. While compounds 5-7 and 10 were as potent as aspirin, the remaining compounds showed lower potent activity than aspirin. Some effective compounds 1, 2, 8 and 10 (Alshibl et al. 2020) were also tested *in vivo* for their acute anti-inflammatory activity on formaldehyde-induced rat paw oedema (Ibrahim et al.). They showed significant inhibition of oedema (Alshibl et al. 2020). In this study, compound 2 exhibited the most significant anti-inflammatory activity *in vivo* (Alshibl et al. 2020). This test provided evidence that compound 9 was the most active toward COX-2 isozyme (Alshibl et al. 2020).

Immunomoduator Activity

Macrophages, lymphocytes, especially as cytotoxic cells such as cytotoxic T lymphocytes, natural killer cells and LAK cells play an important role in our immune defence against tumors (Li et al. 2004).

Coumarin showed the immunomodulatory activity via enhancing the macrophage migration activity in the presence and absence of LPS and increasing nitric oxide release (Stefanova et al. 2007).

Esculetin, a natural coumarin from *Cichorium intybus* and *Bougainvillea spectabilis* Wild (Nyctaginaceae) (Venugopala et al. 2013a), showed immunomodulatory effects on murine macrophages and lymphocytes, both *in vitro* and *in vivo* (Leung et al. 2005). In an *in vivo* study, esculetin increased the number of immune cells when the host faced foreign invaders via increasing the mitogenesis of mice splenic lymphocytes towards LPS and Con A stimulations (Leung et al. 2005). In a dose-dependent manner, it also enhanced the migration of the thioglycollate-elicited macrophages *in vivo* that would be an immunomodulator with the potential to defend against tumors (Leung et al. 2005). Moreover, esculetin increased the endocytic activity, and enhanced the nitric oxide production and iNOS gene expression in LPS-treated macrophages (Leung et al. 2005).

Umbelliferone, also known as 7- hydroxycoumarin, exhibited the immunomodulatory potential via protection against Salmonella infection by activation of macrophages (Stefanova et al. 2012). NO release by macrophages from mice treated with 7-OHC for different periods at a daily dose of 50 $mgkg^{-1}$ (Stefanova et al. 2012).

Braylin, a natural coumarin, showed immunomodulatory activity on the complete Freund's adjuvant (CFA) model (Espírito-Santo et al. 2017). Braylin inhibited peritoneal exudate macrophages statistically until 10 µM (Espírito-Santo et al. 2017). It was shown that, in a concentration-dependent manner, braylin treatment could reduce the production of IL-1β, IL-6 and TNF-α by macrophages stimulated with IFN-γ and LPS (Espírito-Santo et al. 2017).

Imperatorin, a furanocoumarin isolated from *Angelica dahurica* (Zhang et al. 2019), *Angelica archangelica* (Umbelliferae) (Venugopala et al. 2013a), *Notopterygium incisum*

(Teye Azietaku et al. 2016), *Angelica sinensis* (Xin et al. 2019), *Rhodiola bupleuroides* (Kwon et al. 2017) and *Foeniculum vulgare* Mill. (Kerekes et al. 2019), was used as an immunomodulatory agent to treat allergic airway inflammatory (Lin et al. 2016).

Osthole exhibited immunomodulatory activity on M2 macrophages by down-regulating p-STAT6 and the p-ERK1/2-C/EBP β axis (Wang et al. 2018). Another study showed the immunomodulatory effects of osthole on dendritic cell maturation and function (Chiang et al. 2017). With experimental evidence, osthole showed immunomodulatory property by decreasing NF-κB activation, reducing tumour necrosis factor nitric oxide (NO), (TNF)-α, and cyclooxygenase expression, and inhibiting the phosphorylation of p38 mitogen-activated protein kinase and c-Jun N-terminal kinase 1/2 (JNK1/2) (Chiang et al. 2017). From that exhibited osthole as an immunomodulatory agent to treat Th2-mediated allergic inflammation (Chiang et al. 2017).

Seselin, a coumarin from Plumbago zeylanica, inhibited IL-2 and IFN-gamma production in a concentration-dependent manner (Tsai et al. 2008). Moreover, seselin also inhibited the IL-2 and IFN-gamma gene expression in phytohemagglutinin (PHA)-activated cell proliferation in human peripheral blood mononuclear cells (PBMC) (Tsai et al. 2008). From that predicted seselin is likely an immunomodulatory agent present in Plumbago zeylanica (Tsai et al. 2008).

CONCLUSION

Overall, coumarins are derived from many plants (e.g., vanilla grass, tonka bean, sweetgrass, vanilla grass, sweet woodruff, etc.), and they have various activities such as antibacterial, antioxidant, anti-inflammatory, anticoagulant, anticancer, antitubercular, etc. Because of their multiple biological activities and pharmacological properties, they have been drawn much consideration by many medicinal chemists. Although the design and synthesis of selective and potent coumarins is a challenging goal for chemists, we still hope that it will be used for clinical therapies and treatment in complex multifactorial diseases.

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Chapter 12

PHYTOCHEMICAL AND PHARMACOLOGICAL ASPECTS OF SOME VIETNAMESE AROMATIC PLANTS

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ABSTRACT

Aromatic plants play an important role in the health-care needs and medical treatments of many countries, especially in Asian. Vietnam has a climate and soil suitable for many types of aromatic plants to grow, typically cinnamon, grapefruit, lemongrass, aloe wood, etc. In the past, people frequently used traditional methods such as pounding, boiling, or using the plants directly to treat illness or improve health. But nowadays, with the development of medical and technology, scientists found out and extracted the main bioactive compounds including alkaloids, phenols, terpene, in the form of essential oil. The essential oil is widely used in medicinal practices like treating colds, headaches, anti-inflammatory, antioxidant, anticancer, etc. This chapter will focus on the phytochemicals and pharmacological of aromatic plants in Vietnam.

Keywords: aromatic plants, essential oil, bioactive compounds, anti-inflammatory, antioxidant, anticancer

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INTRODUCTION

Vietnam is located in Southeast Asia with a tropical monsoon climate. The climate in Vietnam has great differences among regions, while the North has a winter; the South is warm all year round. With such location and climate, Vietnam is one of the twenty-five countries that have a uniquely high level of biodiversity. Therefore, aromatic plants in Vietnam also grow a lot. Before Vietnamese people frequently used aromatic plants to treat some common diseases according to oral folk remedies, they are also widely used in Vietnamese traditional medicine. In recent years, aromatic Vietnamese plants are more interested and researched. But there are a limited number of reviews on these plants in Vietnam. This chapter will focus on some common aromatic plants in Vietnam and describe their phytochemical and pharmacological aspects.

AROMATIC PLANTS IN VIETNAM

Cinnamomum cassia

Cinnamon (*Cinnamomum cassia*) is a tropical aromatic plant of the Lauraceae family. It not only use in traditional Asian medicine but also a traditional spice, widely used around the world. *Cinnamomum cassia* is distributed in China, Vietnam, Indonesia, and other tropical countries.

Phytochemicals

Scientists identified more than 160 components in cinnamon. Among them, the most plentiful phytochemicals are terpenoids and the bioactive compounds are phenylpropanoids. In addition, the components are not only found in the bark but also occurred in the leaves and twigs of *Cinnamomum cassia.*

Terpenoids

The main compounds in essential oils of *Cinnamomum cassia* are terpenoids including monoterpenes, diterpenes and sesquiterpenes.

12 monoterpenes: endo-borneol (–)–α–terpineol, 1–terpineol cis–β–terpineol, α–terpineol, β–bisabolene, α–bisabolol, linalool, camphene, β–pinene, camphor, genanyl acetate.

25 diterpenes: cinnzeylanol, anhydrocinnzeylanol, cinnzaynalone, 2,3-dehydroanhydrocinnzeylanine,1-acetylcinncassiol A, anhydrocinnzeylanine, 18*S*-cinncassiol A 19-*O*-β-D-glucopyranoside, 18*R*-cinncassiol A 19-*O*-β-D-glucopyranoside, 18-hydroxycinnzeylanine, cinncassiol A, cinncassiol B, cinncassiol C, cinncassiol D,

cinncassiol E, cinncassiol F, cinncassiol G, 16-*O*-β-D-glucopyranosyl-19-deoxycinncassiol G, cinnacasol, perseanol, cinncassiol D_1, D_1 glucoside, D_2 glucoside, D_3 glucoside, D_4 glucoside, 18-hydroxyperseanol.

27 sesquiterpenoids: curcumene, δ-cadinene, espatulenol, caryophyllene oxide, *trans*-caryophyllene, germacrene D, caryophyllene, α-cubebene, (−)-isoledene, α-bulnesene, patchouli alcohol, α-copaene, α-muurolene, α-cadinol, copaene, isoledene, 1-(1,5-dimethyl-4-hexenyl)-4-methylbenzene, cedrene, α-calacorene, cinnamoid A, cinnamoid B, cinnamoid C, cinnamoid D, cinnamoid E, (−)-15-hydroxy-tmuurolol, 15-hydroxy-α-cadinol and *ent*-4β,10α-dihydroxyaromadendrane (Sun et al. 2016).

Phenylpropanoids

The bioactive compounds in *Cinnamomumcassia*belong to phenylpropanoids are cinnamaldehyde, methoxycinnamic acid in the essential oil of bark, they accounted for 42.37% and 43,6% respectively; coniferaldehyde, *o*-methoxycinnamaldehyde, 2-methoxycinnamaldehyde, 2′-methoxycinnamaldehyde, cinnamylalcohol, *cis*-cinnamaldehyde, *trans*-cinnamaldehyde, ethyl cinnamate, eugenol, cinnamyl acetate, 2-hydroxycinnamic acid, 2-hydroxycinnamaldehyde, 4-methoxycinnamaldehyd, and cinnamic acid are found in a different part of *Cinnamomum cassia* (Zhang et al. 2019).

Glycosids

To date, there are three glycosides have been identified from the twigs of *Cinnamomum cassia*like cinnacasolide A, cinnacasolide B and cinnacasolide C; cinnacasside A and cinnacasside C are isolated from the twigs and leaves of *C.cassia*. There are 19 glycosides were identified including cinnacasside B, cinnacasside F, cinnacasside G, cinnacassoside D, cinnacassoside A, cinnacassoside B, cinnacassoside C, 3,4,5-trimethoxyphenol-β-D–apiofuranosyl (1→6)-β-D-glucopyranoside, 3-trimethoxy-4-hydroxyphenol-β-D–apiofuranosyl(1→6)-β-D-glucopyranoside, 3,4-dimethoxy-phenol-β-D–apiofuranosyl (1→6)-β-D-glucopyranoside, (−)-lyoniresinol 3α-*O*-β-D-gluco-pyranoside, methyl 2-phenylpropanoate-2-*O*-β-D-apiofuranosyl-(1→6)-*O*-β-D–gluco-pyranoside, cinnacasolide E, 3,4,5-trimethoxyphenol-β-D-apiofuranosyl-(1→6)-*O*-β-D-glucopyranoside, samwiside, phenol-β-D-apiofuranosyl-(1→6)-*O*-β-D-glucopyranoside, (6*R*,7*R*,8*R*)-7a-[(β-D-glucopyranosyl)oxy]lyoniresinol, (6*S*,7*R*,8*R*)-7a-[(β-D-gluco-pyranosyl)oxy]lyoniresinol,(6*R*,7*S*,8*S)*-7a-[(β-D-glucopyranosyl)- oxy]lyoniresinol (Zhang et al. 2019).

Lignans

In recent years, they have found 26 lignanoids in *Cinnamomum cassia* including Cinncassin E, cinncassin D, picrasmalignan A, (+)–leptolepisol C, (−)-(7*R*,8*S*,7′*R*,8′*S*)-syringaresinol, (+)-isolariciresinol, (−)-secroisolariciresinol, (+)–*erythro*–(7*R*,8*S*)-

guaiacylglycerol-8-vanillin ether, (+)-*threo*-(7*S*,8*S*)-guaiacylglycerol-β-coniferyl aldehyde ether, (+)-*erythro*-(7*S*,8*R*)-guaiacylglycerol-β-coniferyl aldehyde ether, (−)–*erythro*–(7*R*,8*S*)-guaiacylglycerol-β-*O*-4′-sinapoyl ether, (−)–*erythro*-(7*S*,8*R*)-syringylglycerol-8-*O*-4′-(sinapoyl alcohol) ether, (7*S*,8*R*)-lawsonicin, 5′–methoxylariciresinol, (+)–(7′*R*,8*R*,8′*R*)-5,5′-dimethoxylariciresinol, (+)-(7′*S*,8*R*,8′*R*)-5,5′-dimethoxylariciresinol. Besides, the leaves of *Cinnamomum cassia* occur cinnacassin F (121), cinnacassin G, cinnacassin H, cinnacassin I, cinnacassin J, cinnacassin K, cinnacassin L, cinnacassin M, cinnacassin N and cinnacassin O (Zhang et al. 2019).

Lactones

Cinnamomulactone, 5*R* – methyl–3–heptatriacontyl–2(5*H*) –furanone, cinncassin A_2, cinncassin A_3, cinncassin A_4, cinncassin A_5, cinncassin A_6, cinncassin A_7 and cinncassin Awas extracted from the twigs of *Cinnamomum cassia* (Zhang et al. 2019).

Pharmacological Aspects

Antibacterial Effects

Cinnamaldehyde, which were extracted from bark of *C.cassia*, can inhibit *Clostridium perfringens* and *Bacteroides fragilis* (Alzoreky and Nakahara 2003).Then, in 2019, it was proved that the ethanol isolated from *Cinnamomum cassia* can treat urinary tract interactions caused by *P. aeruginosa* (El Atki et al. 2019). Besides, some microbacterials were inhibited by *Cinnamomum cassia* extract such as *E. coli, E. faecalis, K. pneumoniae* (Paul et al. 2013). In addition, essential oil of bark of *Cinnamomum cassia* inhibited *S.hyicus, S.aureus* (Vaillancourt et al. 2018).

Anticancer Effects

Cinnamaldehyde, an active compound was extracted from the bark of *C. cassia*, induces apoptosis due to reactive oxygen species (ROS) generation. HL-60 cells died by the mechanism of mitochondrial trans-membrane potential and the activity of caspase-3 (Nishida et al. 2003).

Anti-Inflammatory Effects

The anti-inflammatory effect of *Cinnamomum cassia* by using lipopolysaccharide-stimulated mouse macrophage and carrageenan-induced mouse paw oedema model has been studied and demonstrated (Liao et al. 2012). In addition, a few researchers reported that the essential oil of leaves *Cinnamomum cassia* and cinnamaldehyde may reduce the production of NO (Pannee et al. 2014). Moreover, in 2018 it was confirmed that water extract of bark *Cinnamomum cassia* can moderately decrease IL-1, MDA, TNF-α levels and joint swelling in a concentration-dependent manner in rats with CFA-induced and formaldehyde-induced arthritis (Sharma et al. 2018).

Antidiabetic and Anti-Obesity Effects

The water extract of bark *Cinnamomum cassia* (100, 250 and 500 mg/kg) may completely prevent streptozotocin (STZ)-induced diabetes in mice by inhibiting the expression of iNOS and the activation of NF-κb (Zhang et al. 2019). Later, the acetone extract of barks of *Cinnamomum cassia* showed good potential of declining the plasma glucose level through inhibiting rat α-glucosidase (Kang et al. 2014). It was also demonstrated that coumarin extract of *Cinnamomum cassia*(200mg/kg) may significantly control the level of blood glucose, serum insulin, lipid distribution and liver antioxidant enzymes in STZ induced diabetics rats(Kumar et al. 2014).

Besides the hypoglycemic activity, *Cinnamomum cassia* also can improve some complications of diabetes. In 2013, it has been reported that ethanol extract of *Cinnamomum cassia* barks (10µM) can resist the growth of high–glucose-induced mesangial cells by depressing the expression of IL-6, collagen IV and fibronectin(Luo et al. 2013). Furthermore, *in vivo*, water extract of *Cinnamomum cassia* barks (100 and 300 mg/kg) reduced the levels of glucose, insulin, total cholesterol and ALT, suppressed lipid accumulation in liver, and prevented oral glucose tolerance and insulin resistance in obese mice. It also increased ATP level *in vitro* via increasing the mRNA expressions of mitochondrial biogenesis-related factors in C2C12 myoblast (Song et al. 2017).

Neuroprotective Effects

Recently, scientists are interested in the neuroprotective effects of *Cinnamomum cassia* such as anti-anxiety, cognitive improvement and anti-depressant. Ethanol extract of *Cinnamomum cassia* barks has an anti-anxiety effect, the extract substantially increased the proportion of entries and the time spent in the open arms in the elevated plus-maze test through regulating the 5-hydroxytryptamine1A (5-HT_{1A}) and γ-amino butyric acid (GABA)-ergic system(Yu et al. 2007). Then, it has been demonstrated that the specific changes of 5-HT_{1A} receptors in the dorsal raphe nucleus were caused by the anxiolytic effects of the ethanol extract of *Cinnamomum cassia* barks (100 and 750 mg/ml) (Jung et al. 2012).

Other Effects

Water extract of *Cinnamomum cassia* barks (10, 30, 50 µg/ml) may inhibit the proliferation of VSMCs via arresting G_0/G_1 and down-regulating the expression of cell cycle positive regulatory proteins (p21 and p27), which can improve cardiovascular disease caused by a proliferation of vascular smooth muscle cells(Kwon et al. 2015).Water extract of *Cinnamomum cassia* barks (10-50µg/ml) resisted the cytotoxic effect of *cis*-diammine dichloroplatinum (CDDP) *in vitro* via preventing CDDP-induced increased expression of mitochondrial Bax protein, releasing of mitochondrial cytochrome c, caspase-3 activation, DNA fragmentation and generation of ROS, up-regulating the expression of the cytoprotective gene (heme oxygenase (HO)-1)(ElKady and Ramadan 2016).Besides, the anti-tyrosinase activity of the essential oil of *Cinnamomum cassia* barks has been proved (Chang et al. 2013). Moreover, phenolic glycosides of *Cinnamomum cassia* inhibited T cell proliferation induced by ConA, which is responsible for the immunoregulation effects of *Cinnamomum cassia* (Zeng et al. 2014).

Citrus grandis

Pomelo (*Citrus grandis*) is a popular tree of the Rutaceae in some countries in Asia such as Vietnam, Thailand, China, etc. In Vietnam, pomelo is a typical autumn tree and brings high economic value.

Phytochemicals

Citrus grandis is not only known as a type of fruit with high nutritional value but also the peel of it has a lot of bioactive compounds using in medical.

Meat of Citrus grandis

Citrus grandis fruit contains a range of nutrients such as vitamin A, carotenes, vitamin C and many other phytochemicals including classes of flavonoids, glucarates, coumarins, monoterpenes, triterpenes, glucarates and phenolic acids. In addition to the common compounds found in the fruits, *Citrus grandis* also has such characteristic properties such as hesperidin, narigidin, tangerritin limonene, quercetin, tangegeredin and nobiliten (Gyawali and Kim 2014).

Peel of Citrus grandis

In fact, *Citrus grandis* peel is used for processing into essential oils. There are about 36 or 33 total ingredients in *C. grandis* essential oil with a limonene content of 71.48%, and other compounds such as tannins, flavonoids, polyterpenes, alkaloids, saponins, terpenoids, amino acids, etc. (Kademi and Garba 2017).

Pharmacological Aspects

Antimicrobial

Diffusion methods were followed to define the antimicrobial effect of peel essential oil in a study. The results showed moderate effects against different strains of bacteria and fungi such as *Psedomonas aeruginosa, Bacsillus subtilis, Bacilus cereus, Salmonella enterica, Samonella enteritidis, Streptococcus faecalis, Streptococcus iniae, Penicillium chrysogenum and Micrococcus luteus*. Specifically, compounds with antibacterial activity in *C. grandis* peel essential oil include linalool, γ-terpinene, α- and β-phellandrene, α-pinene, coumaric acid, meranzen hydrate, isomeranzin (Kademi and Garba 2017). Besides, It was also demonstrated that the carotenoid extraction of the *C.grandis* peel against *Bacillus subtilis, Staphylococcus aureus, Escherichia coli, Aspergillus niger, Aspergillus flavus, Penicillium chrysogenum, Rhizopus oryzae [Rhizopus arrhizus]* and *Saccharomyces cerevisiae* (Tao et al. 2010).

Anticancer

Research used pomelo peels extract to reduce tumor size in a mouse model with tumour S180. The results showed that pomelo peels with the content of 100 and 300mg/kg inhibited 27.86% and 50.28% of tumors compared with 5-FU which was 52.77% (Yu et al. 2018).

Antioxidant

C. grandis contains a lot of antioxidant nutrients not only in meat but also in the skin and leaves such as phenolic compounds, antioxidant vitamins such as tocopherol, vitamin C, etc. (Tsai et al. 2007). The antioxidant activity of those compounds was proved due to many studies. So most of the studies reporting the antioxidant effect of pomelo peels extract used phytochemical to prove the antioxidant activities. The Long-Evans female rats were induced liver injury by carbon tetrachloride (CCl4), and then they were treated with the extract. The extract reduced levels of antioxidative stress markers including MDA, NO, advanced protein oxidation products and restored catalase and GSH activities (Tocmo et al. 2020).

Aloe vera

Aloe vera is a plant belonging to the Asphodelaceae family, is native to North Africa so *Aloe vera* has a good drought tolerant and mainly distributed in hot and dry areas. Nowadays, we can see them in Africa, some countries in Asia like China, the Southeast Asia countries, etc. The bioactive compounds from *Aloe vera* are very effective in various treatments such as burns, allergic reactions, ulcers, diabetes, skin diseases, etc.

Phytochemicals

Phytochemical compounds in *Aloe vera* were screened by qualitative and GC-MS method. They have found tannin, saponin, flavonoids, terpenoids, organic acids, enzymes, vitamins, minerals, mono and polysaccharides. Among them, there are 26 bioactive compounds in the ethanolic extract of *Aloe vera* including methyl ester, 9,12,15-octodecatrienoic acid, oleic acid, phytol, etc. (Sathasivam and Muthuselvam 2008).

Aloe vera contains a lot of vitamins such as vitamins A, C, F, which have good antioxidant effects, vitamin B (thiamin), niacin, vitamin B2 (riboflavin, vitamin B12, choline, acid folic (Coats 1979). They have found biochemical catalysts such as amylase, lipase in leaves of *Aloe vera*. In other hand, carboxypeptidase, inactivates bradykinins also appear in the plant. There are some minerals including sodium, potassium, calcium, magnesium, manganese, copper, zinc, chromium and iron in the aloe plantain the gel or inner parenchyma of aloe leaves contain both mono and polysaccharides. The most important are the long-chain polysaccharides, glucose, and mannose. The sterols in *Aloe vera* include campesterol, sitosterol and lupeol. Moreover, *Aloe vera* has salicylic acid and 20 of the 22 necessary amino acids required by our body and seven essential amino acids that the body cannot synthesize (Joseph and Raj 2010).

Pharmacological Aspects

Antitumor and Antioxidant Effects

One of the studies demonstrated that *Aloe vera* significantly inhibited the number of Ehrlich ascites carcinoma cells (El-Shemy et al. 2010). In trypan blue cell assay, *Aloe vera* is used against acute myeloid leukaemia and acute lymphocytes leukaemia cancerous cells. In MTT cell viability test, aloe-emodin can against two human colon cancer cell lines including DLD-1 and HT2. The results demonstrated the anticancer activity of *Aloe vera*. In addition, *Aloe vera* contains many vitamins and minerals which proved to have an antioxidant effect.

Antibacterial and Antifungal Effect

The maximum antibacterial effect of *Aloe vera* was seen in acetone extract, it can inhibit the growth of *Staphylococcus aureus, Streptococcus pyogenes, Pseudomonas aeruginosa* and *Escherichia coli*. Besides, *Aloe vera* also inhibits two gram-positive bacteria *Shigella flexneri* and Streptococcus sprogenes (Sathasivam and Muthuselvam 2008). In addition, *Aloe vera* may against *Aspergillus flavus* and *Aspergillus niger*. The activity of the acetone extract of *aloe vera* is better than all other extracts. However, the evidence for the control of fungi in human skin remains to be established.

Anti-Inflammatory Activity

Aloe vera inhibits the production of prostaglandin E_2, but it does not affect thromboxane B2 production. *Aloe vera* also declines by 20% interleukin – 8 produced by CaCo2 cells (Langmead et al. 2004). Furthermore, *Aloe vera* can hypoglycemic and hypolipidemic, wound healing, antimutagenic, immunomodulatory, or gastroprotective (Joseph and Raj 2010).

Cymbopogon citratus

Lemongrass (*Cymbopogon citratus*) is a plant belonging to Gramineae family, it is a tufted perennial grass growing to a height of 1 meter. Lemongrass is native to South India and Sri Lanka but now it is widely distributing in the tropical areas of America and Asia. The fresh plant is used extensively as a spice plant or used medicinally and is the source of the essential oil. Besides, studies illustrated that *C. citratus* also has various pharmacological activities including anti-amoebic, anti-bacterial, anti-diarrheal, anti-filarial, anti-fungal and anti-inflammatory properties.

Phytochemicals

Active compounds in *Cymbopogon* extract have been screened by using standard techniques for the plant secondary metabolites. The phytochemicals including tannin, alkaloids, glycosides, phenols, flavonoids, carbohydrates, steroids, and phytosteroids has been detected. Besides, glycosides and phenols do not appear in acetone and chloroform leaf extracts (Umar et al. 2016).

Essential oils: Citral, myrcene, geranial, geraniol, limonene, burneol, citronellol, nerol, neral, α-terpineol, elemicin, caffeic acid, apigenin, luteolin, kaempferol, quercetin, chlorogenic acid, and geranyl acetate, fumesol, furfurol, isopulegol, isovaleranic aldehyde, L-linanool, methylheptenone, ndecyclic aldehyde, terpineone, p-coumaric acid, valeric esters (Beshel 2015; Cheel et al. 2005).

Vitamins: folate, niacin, pyridoxine, riboflavin, A, C, E (Kandhro et al. 2011).

Minerals: Na^+, K^+, calcium, magnesium, Mn, Se, P, iron and zinc (Kandhro et al. 2011).

Macronutrients: carbohydrates, proteins and a little bit of fat (Kandhro et al. 2011).

Pharmacological Aspects

With those bioactive compounds, the *C. citratus* is an important aromatic plant and has been used to produce essential oil. The main pharmacological qualities of the plant are antibacterial, antifungal, antiprotozoal, anti-inflammatory, antioxidant, cardioprotective, etc.

Antimicrobial Activity

The leaf and root extract of *C. citratus* have antimicrobial activity against *Staphylococcus aureus* (MIC=20µg/ml), *Salmonella typhi* (MIC=24 µg/ml), *Eschenchia coli* (MIC=14 µg/ml) (Umar et al. 2016).

Antifungal Activity

Tannin and phenolic compounds in extract of *C. citratus* can inhibit fungal growth and also protect certain plants against infection. *C. citratus* can act against *Candida* *albicans*, but this effect is low with a mean zone of inhibition of 7.66 and 8.66, MIC = 28 µg/ml and 32 µg/ml for leaf and root extract respectively. So the treatment against *Candida albicans* may not be successful (Umar et al. 2016).

Antioxidant Activity

Phenolic acid and flavonoids play an important role in antioxidant and free radical scavenger due to their pharmacological effect. The appearance of vitamins in *C.citratus* also contributes to the antioxidant effect (Prachee et al. 2019).

Anti-Inflammatory Activity

The leaf of *C.citratus* has polysaccharide-stimulated dendritic cells, which is proved and used in treating inflammatory diseases, especially the gastrointestinal tract (Figueirinha et al. 2010).

Anti-Malarial Activity

The essential oil of *C.citratus* was testing in malaria mice, the study related to this effect just stable *in vivo* (Tchoumbougnang et al. 2005).

Antihepatoxic Activity

The leaf extract of *C.citratus* against cisplatin-induced hepatic toxicity in rats. This is a potential effect to develop new drugs in the future (Oladeji et al. 2020).

Angelica sinensis

Angelica sinensis (Duong quy – in Vietnamese) is a traditional medicinal using for tonifyingm replenishing and invigorating blood, it also relieves pain, lubricates the intestines, and treats female irregular menstruation and amenorrhea. The plant frequently distributes in China, North Korea, Vietnam, etc. In Vietnam, *A. sinensis* is growing in Hoa Binh, Lao Cai, Lai Chau, Da Lat, etc.

Phytochemicals

The main bioactive compounds in *Angelica sinensis* are organic acid, phthalides and polysaccharides.

Polysaccharides

Polysaccharides in *Angelica sinensis* are very important compounds, which are mainly used to treating amnesia, liver diseases and gynaecological disorders. There are a maximum 26.03% of polysaccharides in the root extract of *Angelica sinensis* and a minimum 2.25%. They have isolated 36 polysaccharides from *Angelica sinensis* root, including fucose, galactose, glucose, arabinose, rhamnose, and xylose(Beck and Chou 2007).

Organic Acids

Angelica sinensis contains a variable amount of organic acids and their ester such as ferulic acid, coniferyl ferulate, succinic acid, nicotinic acid, folic acid, valerophenone-O-carboxylic acid, vanillic acid, linoleic acid, palmitic acid, oleic acid, etc. (Ma et al. 2015). The minimum content of ferulic acid was 0.08%, with a range of 0.221-1.75 mg/g.

Phthalides

To date, they isolated 30 phthalides compounds from *Angelica sinensis*, including 22 non-alkaloids phthalides, and 8 phthalides derivatives. The main components are ligustulide (E and Z), butylidenephthalide (E and Z), butylphthalide, senkyunolide A-I, senkyunolide P, senkyunolide K, levistolide A, riligustilide, tokinolide B, and neocnidilide (Beck and Chou 2007).

Other Compounds

Besides those compounds, *Angelica sinensis* also contain flavonoids (related to antioxidant activity), 17 types of amino acids (account for 6.5% of the total chemical components of *Angelica sinensis*), 7 types of non-synthesized amino acids, adenine, phospholipid, choline, uracil, vitamin B_{12}, vitamin A, xanthotoxin, minerals such as calcium, zinc, potassium, copper, manganese, sodium, iron, etc.

Pharmacological Aspects

Antioxidant

Anti-lipid peroxidation activity in rat liver homogenate were studied. The activation of *Angelica sinensis* was compared to α-tocopherol. The result illustrated that extract at 0.5-5 mg/ml showed anti-lipid peroxidation activity ranging from 20.3% to 70.1%. The extract of *Angelica sinensis* also showed free radical scavenger activity with the IC_{50} values of 2.69 mg/ml. Moreover, the extract can anti-superoxide at concentrations of 01-10 mg/ml with activity ranging from 38% to 86% (Wu et al. 2004).

Neuroprotective Activity

Z-Ligustlide in *Angelica sinensis* can inhibit the spontaneous contraction of rat uterus; it also inhibits prostaglandin F-2α, oxytocin, and acetylcholine chloride. The rabbits used dextran T500 were treated by *A. sinensis,* Z-Ligustilide show the microcirculation improvement by recovering the conjunctival capillary and venue diameter, increasing the number of capillaries and blood flow. Ferulic acid is the main organic acid in *A. sinensis*; it causes vasodilation to reduce blood pressure. The extract of

Angelica sinensis has been proved that it has anti-atherosclerosis effects and anti-platelet aggregation effects (Wu and Hsieh 2011).

Anti-Inflammatory Activity

The ferulic acid in the extract of *Angelica sinensis* may against NO caused apoptosis, it also reduced TNF-α and TNF-β1 in rat. *Angelica sinensis* polysaccharides contributed to the anti-inflammatory by reducing TNF-α (Wu and Hsieh 2011).

Anti-Alzheimer Activity

Ho et al. have isolated and demonstrated the anti-alzheimer compounds in the extract of *A.sinensis*. They extracted four compounds: Z-ligustilide, 11 angeloylsenkyunolide F, coniferyl ferulate and ferulic acid. These compounds show the ability to inhibit Aβ 1-40 toxicity on dPC-12 cells, which proved for their anti-Alzheimer effect (Ho et al. 2009).

Cynara scolymus

Cynara scolymus (Actiso-in Vietnamese) also named artichoke, is a perennial plant native to the Mediterranean region. In Vietnam, actiso is growing in Da Lat, Ha Giang, Lao Cai, Vinh Phuc, etc. *Cynara scolymus* is commonly eaten as a vegetable; its leaves are frequently used in folk medicine in the treatment of hepatitis, hyperlipidemia, obesity and dyspeptic disorders.

Phytochemicals

Bioactive components from leaves, flowers and root of Cynara *scolymus* has extracted and isolated. There is protein (13.5%), carbohydrates (56.5%), lipid (0.1%) and vitamin C (12.2%) in the extract of *Cynara scolymus*. Besides, phenolic compounds, flavonoids (0.05-0.15%), saponins (1.5-3%)were also identified in the *Cynara scolymus* extract (Tsevegsuren et al. 2014).

Pharmacological Aspects

Antioxidant and Anti-Inflammatory Activity

The antioxidant effect of *Cynara scolymus* using $ABTS^+$ method and the anti-inflammatory was also proved by using Carrageenan-Induced Paw Odema Model (Ben Salem et al. 2017). The result shows that phenolic compounds are responsible for these anti-inflammatory effects of *Cynara scolymus* extract. The antioxidant effect of methanolic extract (ME), flavonoids extract, and water extract of *Cynara scolymus* were strong as compared to the antioxidant effect of acid ascorbic. According to the result, the most extract of *Cynara scolymus* exhibited reliable free radical scavenging activity. Polyphenols compounds are responsible for this effect (Alghazeer et al. 2012).

Antimicrobial Activity

The antimicrobial of *Cynara scolymus* using the hole-plate diffusion method has been studied. The result shows that the flavonoids and alkaloids extract are very effective in inhibiting the growth of Methicillin-resistant *Staphylococcus aureus (MRSA*), *Escherichia coli, Salmonella typhy, Bacillus subtitis, and Pseudomonas aeruginosa.* Among them, the maximum inhibition was seen on MRSA, *E. coli, S. typhi* (Alghazeer et al. 2012).

Anticancer Activity

Cynara scolymus contains taraxesterol, a compound that can inhibit skin tumors (Kaminaga et al. 1996).

Mentha arvensis

Mentha arvensis is the type species of Japanese menthol plant mint, a native of Japan. It appears and be grow in Europe and western and centre Asia, east to the Himalaya and eastern Siberia. The essential oil of *M. arvensis* was used in pharmaceutical, perfumery and food industries.

Phytochemicals

Mentha arvensis is demonstrated to contain terpenes including α-menthol, neomenthol, isomenthol, d-menthone, isomenthone, menthofuran, menthylacetate, cineol, p-cymene, aromadendrene, limonine, -phellandrene, pipertone, -pinene, carvacrol, α-pinene, α-phellandrene, -pinene, dipentene, cardinene, and –thujone, the concentration of these compounds relate to the season, type of climate and the plant processing (Alghazeer et al. 2012). The plant is also reported to possess the flavonoids such as quercetin, menthoside, isorhoifolin, vitamin K, thymol and eugenol. The most useful component in the *Mentha arvensis* is the essential oil. The essential oil is extracted from the stem, leaves of the plant. Menthol is the major compound of all the oils, with 78.16% in the shoot stem oil and 43.7% in the stolon stem oil (Thawkar et al. 2016).

Pharmacological Aspects

Antibacterial Activity

The essential oil of Mentha arvensis inhibited the growth of Helicobacter pylori, Salmonella enteritidis, Escherichia coli, methicillin-resistant Staphylococcus aureus, Campylobacter jejuni and Clostridium perfrigens. This effect is proved by using disc diffusion assay. The result showed promising against bacterial effect (Imai et al. 2001).

Antioxidant Activity

Recently, cineole, eugenol and thymol are reported to have good antioxidants and inhibit lipid peroxidation (Aeschbach et al. 1994). Moreover, the flavonoids like quercetin also can scavenge OH and superoxide free radicals and inhibit lipid peroxidation (Korkina and Afanas'ev 1997).

Radioprotective Activity

The radioprotective activity of the *Mentha arvensis* has been studied. The mice were treated with mint extract before, then exposed with radioactive. The result shows that the pre-treated mice may reduce the severity of a symptom of radiation sickness and the survival rate was significantly increased (Jagetia and Baliga 2002).

Cardiovascular Disease

Peppermint extract can inhibit platelet aggregation, which may be the main mechanism leading to the beneficial effects of the herb in patients with ischemic heart disease. It is very effective in enhancing the activity of glutathione peroxidase (Gul et al. 2014).

Anti-Inflammatory and Anti-Allergic Activity

The ethanolic and aqueous extracts of *Menthaarvensis* have histamine release inhibition in rats. Results for anti-allergic revealed that ethanolic extracts of leaf and root possessed marked inhibitory activity expressed as percentage inhibition, that is, 57% and 53%, respectively. Anti-inflammatory potential exhibited by ethanolic extracts of plant parts is leaf = 68.30 > root = 48.80 > stem = 10.70% and compared with percentage inhibitory potential of standard drug, diclofenac sodium which caused 77.87% oedema inhibition (Malik et al. 2003).

Sophora japonica

Sophora japonica (Hoe-in Vietnamese) belongs to Fabaceae family, is a medium-size deciduous tree, it is commonly found in China, Japan, Korea, Vietnam and other countries. The plant has a lot of bioactivities and is used in the medicinal industry.

Phytochemicals

To date, 153 compounds have been extracted from *Sophora japonica*, including flavonoids, isoflavonoids, triterpenoids, alkaloids, mineral elements and amino acids.

Flavonoids

Flavonoids comprise the major family of compounds identified in *Sophora japonica,* with 39 flavonoids and related glycosides. Because of their beneficial biological effects, they have been increasingly studied in recent decades in China. To date, kaempferol, quercetin, and their derivatives, including kaempferol, kaempferol 3-O-β-rutinoside, kaempferol 3-O-β-D-glucopyranosyl-(1- 2)-β-D-glucopyranoside-7-O-α-L-rhamnopyranoside, kaempferol 3-O-α-L-rhamnopyranosyl-(1-6)-β-D-glucopyranosyl-(1-2)-βD-glucopyranoside, quercetin, tamarixetin, rutin, isorhamnetin 3-O-β-D-rutinoside, and japonicasins A and B, are best known for their antioxidant, hemostatic, antitumor, antibacterial, and anti-inflammatory effects (He et al. 2016).

Isoflavonoids

Isoflavonoids comprise a class of flavonoid phenolic compounds, many of which are biologically active, abundantly present in plants. The literature review indicates that isoflavonoids are the major and widely studied group of secondary metabolites found in *Sophora japonica*. To date, 41 isoflavonoids have been isolated from the flowers, buds, pericarps, and other parts of *Sophora japonica*. It is worth noting that these isoflavonoids, and especially genistein and its analogs, have been identified as the bioactive components contributing to the wide range of biological properties of *S. japonica* including its anti-inflammatory, anti-osteoporotic, antihyperglycemic, and antiplatelet activities. In fact, the therapeutic effects of genistein on syndromes associated with female postmenopause, malignant cancers, and cardiovascular diseases have been confirmed by modern research (He et al. 2016).

Triterpenoids

Phytochemical investigations have shown that triterpenoids and their derivatives, especially the characterized olean-12-ene3β, 22β-diol, are generally present in the flowers, buds, and seeds of *S. japonica*. Before 2015, 17 compounds were isolated and identified from *Sophora japonica.* However, few bioactive triterpenoids have been reported recently (He et al. 2016).

Alkaloids

Although alkaloids are the characteristic components of the genus Sophora, only four kinds of alkaloids have been purified and characterized from *Sophora japonica*. They are matrine, sophocarpine, N-methylcytisine, and cytosine (He et al. 2016).

Other Compounds

Besides those bioactive compounds, *Sophora japonica* also contains 14 kinds of amino acids, phenols, phenolic acids, etc. (He et al. 2016).

Pharmacological Aspects

Anti-Inflammatory Activity

In vitro, the ethanol extract of *Sophora japonica* contains a high concentration of phenolics and flavonoids, it exhibits the production of both NO and TNF-α (Zhang et al. 2011).

Antibacterial Activity

In vitro, the ethanol extracts from flower buds of *Sophora japonica* exhibits significant antibacterial activity against *Staphylococcus aureus, Propionbacterium acnes*. It also inhibits *Escheria coli* and *Klebsiella pneumoniae*.

Antioxidant and Radical Scavenging Activity

Wang et al. demonstrated the antioxidant activity of *S. japoni*ca extract using DPPH and hydroxyl radical scavenging assay. The result shows that IC50 values of 14.46 and 1.95 respectively (Wang et al. 2006). Besides those activities, the extract of *Sophora japonica* also has antitumor activity, antiobesity activity, antihyperglycemic activity, whitening activity, antiplatelet activity and antifertility activity.

Hibiscus sabdariffa

Hibicus sabdariffa, of Malvaceae family, is commonly grown in Central and West Africa, South East Asia and elsewhere. The plant is an erect annual herb, the botanical features of which have been described by Mahadevan and Kamboj (Mahadevan and Kamboj 2009).

Phytochemicals

Hibicus sabdariffa contains protein, fat, carbohydrates, fibre, vitamin C, β-carotene, calcium, and iron (Da-Costa-Rocha et al. 2014).

The main bioactive compounds of *Hibicus sabdariffa* relevant in the context of its pharmacological are organic acids, anthocyanins, polysaccharides and flavonoids (Da-Costa-Rocha et al. 2014).

Pharmacological Aspects

Effects on Smooth Muscles

Hibiscus sabdariffa extracts mainly induced the endothelium-dependent relaxant effect in the isolated thoracic aorta of rats, via stimulation of NOS enzyme by the Pi3-K/Akt pathway. It was suggested that this was due to polyphenols. The nonendothelium dependent relaxation is a direct smooth muscle activation and results in the activation of smooth muscle potassium channels (Da-Costa-Rocha et al. 2014).

Antibacterial, Antifungal and Anti-Parasitic Activity

Water extracted from the Hibiscus sabdariffa extract inhibits the growth of methicillin-resistant Staphylococcus aureus, Klebsiella pneumoniae, Pseudomonas aeruginosa and Acinetobacter baumannii (Da-Costa-Rocha et al. 2014).

Antioxidant Activity

The antioxidant activity of the extract is due to its strong scavenging effect on reactive oxygen and free radicals, inhibition of xanthine oxidase activity, protective action against tert-butyl hydroperoxide (t-BHP)-induced oxidative damage, protection of call from damage by lipid peroxidation, inhibition in Cu^{2+}-mediated oxidation of LDL and the formation of thiobarbituric acid reactive substances (TBARs), inhibition of the formation of malondialdehyde content (100–300mg/kg), reduction of glutathione depletion, increase of the liver and decrease blood activity of superoxide dismutase and catalase while in the liver it increased superoxide dismutase, catalase and glutathione and decreased malondialdehyde. The effects were observed for both water and ethanolic extracts from flowers of Hs, as well as from the seeds or leaves. Besides, the extracts also have hepatoprotective activity, renal effects/diuretic effect, cancer-preventive activity, lipid metabolism-anticholesterol effects, anti-obesity activity, etc. (Da-Costa-Rocha et al. 2014).

Baeckea frutescens

Baeckea frutescens is a small shrub belonging to the family *Myrtaceae,* distributed from Southeast Asia to Australia. The Chinese use the roots of *B.frutescens* to treat rheumatism or snakebites. Today, many active and bioactive compounds have been identified from the plant.

Phytochemicals

Dai et al. have been identified 55 components in the essential oil of *Baeckea frutescens* in Vietnam. Ubiquitous terpene compounds were the main classes of compounds identified in the oil, comprising of 19.5% monoterpene hydrocarbons, 16.4% oxygenated monoterpenes, 45.4% sesquiterpene hydrocarbons and 17.4% oxygenated sesquiterpenes. The major constituents were identified as α-humulene (19.2%), β-caryophyllene (17.3%) and baeckeol (13.8%). Other less predominant compounds were terpinen-4-ol (3.7%), δ-cadinene (3.3), γ- terpinene (3.1%), α-pinene (1.8%), p-cymene (1.6%), α-terpineol (1.6%), α-terpinene (1.2%), α-terpinolene (1.1%), β-bourbonene

(1.1%) and (E)-nerolidol (1.0%) while the rest had content lower than 1.0% (Dai et al. 2015).

Pharmacological Aspects

Antimicrobial and Antioxidant Activity

The ethanol extract of *Baeckea frutescens* shows higher antioxidant activity than water extract. In addition, the ethanol and water extracts are also active to inhibit some bacterial strains. The highest antibacterial activity of the *Baeckea frutescens* extracts was observed against bacterial strains of *E. coli* and *S. typhi*, and is thought to be due mainly to the presence of the phenolic compounds. The antioxidant and antimicrobial activities of these extracts were positively correlated with their total phenolic and flavonoid contents. Therefore, *Baeckea frutescens* has been shown to have remarkable antioxidant and antibacterial properties as a natural source of antioxidants for use in pharmaceutical applications (Nisa et al. 2017).

Inhibit Copper-Induced Low-Density Lipoprotein Oxidation Activity

This effect has been proved by using a modified thiobarbituric acid reactive substances (TBARS) method (Kamiya and Satake 2010).

Cytotoxic Activity

The potent selective cytotoxic effect of *Baeckea frutescens* leaves hexane extract against MCF-7 cancer cells has been established. *Baeckea frutescens* extracts selectively suppressed cancer cell's glucose uptake and subsequently induced cancer cell death. These findings suggest a new role of *Baeckea frutescens* in cancer cell metabolism (Shahruzaman et al. 2019).

PROSPECTS AND FUTURE APPLICATION OF AROMATIC PLANTS IN VIETNAM

The aromatic plants in Vietnam are very plentiful and diverse. This is a valuable source of raw materials for the domestic pharmaceutical industry. But at present, these plants are not been fully researched and proven or have not been applied effectively. All the aromatic plants and the information about their phytochemicals and pharmacological review mentioned are proved their potential for development into drugs and health care products. But the number of studies and evidence of some plants and effects are not enough and need more investigation. Moreover, scientists and pharmaceutical companies should join hands and focus on potential effects to develop and produce new drugs or health care products for the people. Besides those plants, there are a lot of plants which has not been fully mentioned.

Conclusion

In conclusion, the aromatic plants in Vietnam contain a number of bioactive compounds such as flavonoids, terpenoids, amino acids, minerals, vitamins, etc. The main activity is antioxidant, anti-inflammatory, antibacterial, anticancer, hypoglycemic, etc. The scientist and pharmaceutical companies need to join hands to research and develop the product from these valuable materials.

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Chapter 13

PHYTOREMEDIATION POTENTIAL OF AROMATIC PLANTS FOR HEAVY METALS

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ABSTRACT

Pollution caused by the toxic heavy metals is leading to a substantial environmental hazard. It has impacted water bodies due to release of industrial effluent and soil due to waste dump sites causing a significant danger to humankind and has resulted in global concern. Phytoremediation includes the utilization of suitable plants to eliminate toxic contaminants from effected soil sites and water bodies by phytoaccumulation, delivering the heavy metals in the rhizospheric area balancing out the metals through roots and consequently moving them to the aerial parts. As aromatic plants do not play a direct role in food chain, so it holds an additional advantage over food crops for phytoremediation purposes. Aromatic grasses have certain unique characteristics like fast growth and are perennial, relatively high biomass production along multiple harvests. Economic value of aromatic plants is high because of essential oils extracted from them, making this idea sustainable production and phytoremediation in the longer run. The present chapter focuses on aromatic plants as reasonable option for use in different phytoremediation techniques. A detailed study of phytoremediation, its need, and its types along with an analysis of aromatic plants in phytoremediation is also summarised.

Keywords: phytoaccumulation, phytostabilization, phytoextraction, rhizofilteration and essential oils

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INTRODUCTION

Toxic heavy metals have become a cause of concern in the recent past. The unprecedented expansion in regions of contaminated waste dump sites and number of water bodies because of harmful heavy metals is a major concern around the world. Soil and water are indispensable natural assets and holds significance for humankind. Life in rural massively rely upon these natural assets. In any case, excessive presence of toxic heavy metals in the ecosystem and its accumulation is a significant danger to humankind and resulted in a global concern (Pandey et al. 2015).

Plants need some metal ions like Cu, Fe, Mn and Zn for sustaining its growth and development as well as for carrying out metabolism. Also, these metal ions are additionally assuming a significant part in the number of physiological cycles, for example, in photosynthesis, respiration and as a cofactor (Chaffai and Koyama 2011). Some metals which do not have any growth significance for plants are As, Cr, Hg, Cd, Pb and Se (Dabonneet al. 2010). Considerable amount of these metals can result in plants developing oxidative stress, which occurs due to various metabolic changes. One such change is the decrease in proline and glutathione production. It authoritatively affects sulfhydryl gathering of proteins and negatively impacting movement of antioxidant enzymes (Valkoet al. 2005). When plants accumulate these toxic heavy metals, it results into the generation of ROS. ROS are reactive oxygen species formed due to anaerobic metabolism and are toxic by nature. They affect structural integrity of cell by attacking unsaturated fat present on cell wall. Also they initiate lipid peroxidation (Patra et al. 2020).

Over the time, researchers have developed many physicochemical methods and some biological techniques for removing toxic heavy metals and remediating the affected soil and water bodies. Physicochemical techniques for remediation are not effective because of monetary and environmental limitations. Because of limitations of other techniques phytoremediation has been considered a superior technique. The previous years have seen an expanding accentuation on the phytoremediation of heavy metal pollution through interdisciplinary research across the world (Pandey et al. 2019).

Phytoremediation process harness utilization of particularly selected plant species to clean soil and water. It is achieved by phytoaccumulation, in which heavy metals are delivered to rhizospheric area and then roots transport it to aerial parts of plants. After the plant completes its development process, the biomass containing heavy metals is reaped which results into the elimination of pollutants from the contaminated soil or water bodies. Biomass thus obtained is treated by decimating or utilized by reprocessing it (Prasad and Freitas 2003).

Food crops were used conventionally for phytoremediation processs of soil polluted by heavy metals. Performing phytoremediation using food crops can prompt the biomagnification of heavy metals in fauna and human diaspora. Thus researches have recommended phytoremediation of affected sites using aromatic plants. As it is a sustainable way with an additional economical benefit of obtaining essential oil (Patra et al. 2020). Aromatic plants are a gift of nature to humanity, with the potential to produce secondary metabolites like phenols, flavonoids, alkaloids and terpenoids. These compounds are extensively used in the formulation of herbal medicine due to their inherent pharmacological activity. They have anti-microbial, anti-mutagenic, anti-inflammation, anti-atherosclerosis and anti-apoptosis property. In today's world, herbal medicine has a profound role in daily healthcare.

Aromatic plants are named so because of the astonishing odour they exhibit due to the presence of essential oils. Essential oils produced by them are used in various customary goods like perfumes and cosmetics, pesticides and culinary products. As these plants and their products are not part of food chains so the chances of bioaccumulation of heavy metals are negligible (Pandey and Singh 2015).

In this chapter, we discussed and analyzed in detail phytoremediation and its importance in present environmental challenges of heavy metal contamination, types of phytoremediation, and reasons for preferring aromatic plants for the purpose. An elaborative study of mechanisms used by different aromatic plant species and future possibilities of improvement in current methods of phytoremediation is also presented.

PHYTOREMEDIATION AND SIGNIFICANCE

With the ever-increasing population, the numbers of urban areas are also exponentially increasing. Large population requires large resources and food supplies. This puts immense pressure on nature and case degradation of soil and water due to the application of improper agricultural practices and waste disposal.

These ill-operations muddle the conditioning of soil by assimilating toxic heavy metals which make soil and water unsuitable for agricultural use. Decreases in yield, oxidative damages like degradation of polyunsaturated fatty acids, leakage of ions, DNA damage and apoptosis are some major adverse effects related to heavy metals pollution. Due to their resilience towards biodegradation, heavy metals get piled up at higher concentrations and for a longer time putting greater risk to humans and environment. Toxic heavy metals like Chromium (Cr), Lead (Pb), Nickel (Ni), Cadmium (Cd), Mercury (Hg), Arsenic (As), etc. are repeatedly dumped into environmental system due to several anthropogenic activities. Toxic heavy metals found in industrial effluent are Cr, Cd, Cu, Ni, Pb, As and Zn. A substantial amount of toxic heavy metal polluted water from industry is added making it ill-suited for environmental sustainability (Gunarathneet al. 2020).

A concentration of 5-gram or more present per cubiccentimeter present at any area is commonly considered as a toxicity deciding factor for heavy metals (Jauhariet al. 2017).

Accumulation of heavy metals above the allowed limit can unfavourably influence human wellbeing. There is an urgent need to put our focus on such issues before it becomes impossible to turn back the natural equilibrium.Current practices for heavy metal remediation such as chemical precipitation, activated carbon and resin are costly, and generate secondary by-products. As a result, researchers and authorities have focused on phytoremediation, a plant-based technology, to remediate heavy metal from contaminated sources.

Landmeyer (2011) described Phytoremediation as the application of plant-controlled interactions with groundwater and organic and inorganic molecules at contaminated sites to achieve site-specific remedial goals. Plants have the property of removing toxic elements like chemicals and metals from the environment. They achieve this by absorbing them via roots and later on accumulating through translocation to various parts (Schnooret al. 1995).

Phytoremediation can be carried out *in situ*, whilst maintaining natural conditions of surroundings. As soon as the plant comes in contact with toxic heavy metals, it initiates various processes at cellular and molecular level to detoxify pollutants. These systems include discrete plant parts and continue through a pretty much usual pathway of take-up, transport, sequestration, and detoxification of toxins (Pathak et al. 2020). In addition, plant and microbial relationships in the rhizosphere along with plant chelator-based sequestrations play a vital role in phytremediation. As toxic heavy metals are found in soil, the ingestion of these contaminants by plants is the essential step in remediation. For improved ingestion of metal ions, plants discharge supplements, organic compounds, oxygen, and humidity in the soil which modifies environmental conditions suitable for microbial action. This improves the resilience of plants toward toxins and simultaneously making the heavy metals bioavailable for ingestion by the plant root cells (Sharma et al. 2013).

Roots are the site for the accumulation of heavy metals as they are in direct contact with heavy metals. Transport of toxic heavy metals is aided by transmembrane carriers (Tangahuet al. 2011). Some plants are hyper-accumulators and can complete the ingestion process faster because of the over-expression of metal carriers. Further, the toxic heavy metals are sent out from roots to the upper region of the plant through symplastic development and inside xylem vessels (Krämer 2010).

Plants use sequestration and detoxification as defence technology against harmful metals. The cell wall, Golgi bodies and vacuoles are used by plant cells for significant heavy metal sequestration. In cell wall suberin and gelatin, binds with heavy metals before sequestering them (Chen et al. 2013). Sequestration inside Golgi bodies and vacuoles is another way for confining toxic heavy metals and different molecular and biochemical aggravations caused by them inside cells. Antioxidants and metal chelating agents are also deployed in the cytoplasm by plant cells for neutralizing the toxic effect caused by metal ions as part of detoxification. A few transcriptional and translational changes are additionally used for detoxification techniques by plant cells (Rodriguez-Hernandez et al. 2015).

DIFFERENT TYPES OF PHYTOREMEDIATION

Phytoremediation involves different techniques that are used based on the nature of pollutants, level of contamination and type of contaminated area. These types are: Phytoextraction, Phytostabilization, Phytovolatilization, Rhizofilteration and Phytodegradation.

Phytoextraction

Phytoextraction is a very well-known technique utilized for eliminating toxic heavy metals from polluted land sites and water bodies. It is sustainable and economically viable in contrast with other types of phytoremediation. This technique assists accumulation of heavy metals in roots and shoots (Patra et al. 2019). Heavy metal contaminants are concentrated in the plant biomass using a favourable plant species. The species like *Alyssum* sp., *Arabidopsis* sp., *Arundo* sp., *Brassica* sp., *Thlaspi*sp., and *Typha* sp. have been reported to remediate heavy metals in large amount (Barceló and Poschenrieder 2003). The accomplishment of phytoextraction relies on many components including the physico-chemical status of soil, the bioavailability of metals, and environmental factors. Phytoextraction has qualities of quick development, rich biomass, easy cultivation, simple harvesting process, resistant to harsh environmental conditions and for preventing bioaccumulation into the food chain, it should be non-edible (Alì et al. 2013). The advantages of it include-1) it is a green technology. 2) *In situ* treatment of waste dumping site. 3) Easy restoration of the excavation site. Vetiver is a suitable aromatic plant for this technique.

Phytostabilization

In this technique of phytoremediation, plants are used to balance out pollutants. This balancing out is done by immobilizing transient toxic heavy metals in the contaminated site through roots. It brings rhizosphere into action of preventing or forestalling draining of heavy metals to groundwater and decreasing the bioavailability of the contaminants in the biosphere. Phytostabilization neither destroy nor fundamentally eliminate toxins from the soil but focus predominantly around balancing out contaminations in the soil around the rhizosphere (Cristaldi et al. 2017). First step involved in this process is adsorption which takes place on root surface, followed by sequestration inside roots, and chelation or precipitation of metal ions with antioxidants in the root area (Gunarathneet al. 2020).

Phytovolatilization

Heavy metals which are volatile in nature are volatilized and released in the atmosphere by the plants through phytovolatilization. This process starts with the absorption of toxic elements by roots. After that, these elements are translocated to shoots via vascular tissues and then to foliage. Through various metabolic processes, toxic metals are converted to less toxic gaseous forms and later released into the air via the transpiration process. Among toxic metals As, Hg, and Se are remediated from the contaminated area (Khalid et al. 2017). Phytovolatlization is also used for various other pollutants like VOCs, organic compounds containing chlorine-like tetrachloroethane and trichloromethane from the contaminated soil and water (Lee 2013). Although it removes toxic metals from the polluted site but they are not eliminated from the environment, only converted into less toxic gaseous form. The major drawback of this technique is heavy metal can find their way back through recycling and getting precipitated back to soil and water.

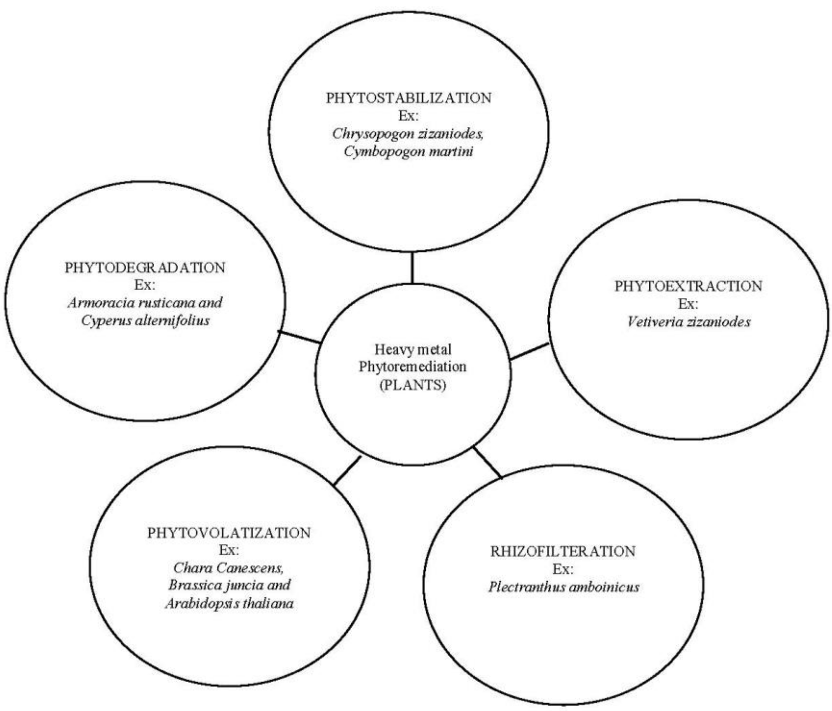

Figure 1. Types of phytoremediation.

Rhizofilteration

It is an adsorption method primarily used for removing toxic heavy metals from aquatic ecosystems. It can use both terrestrial and aquatic plants but hydrophytes are mainly preferred. Plant roots help in clearing out heavy metals through adsorption and then precipitation. Metal contaminants get accumulated into the root tissue (Cristaldi et al. 2017). Radioactive pollutant like Uranium is removed by this method. Plants used for the purpose are obtained through hydroponics, which are later transferred to the waste water. A wetland is constructed to treat industrial waste discharge. It is very effective when contaminants are in low concentration (Gunarathne et al. 2020).

Phytodegradation

In rhizosphere, pollutants are degraded or transformed into less toxic compounds by either the plant itself or through external enzymatic action. Phytodegradation involves metabolic modification of toxic elements. It often uses microorganisms and enzymes involved are dehalogenases, oxygenases, reductases and peroxidases (Gunarathne et al. 2020). These enzymes have the capability to convert toxic pollutant into non toxic compound. This method is not useful when the pollutant is toxic heavy metal as they are indestructible. Phytodegradation is used in treating waste site and groundwater from organic pollutants which are hydrophobic in nature like various insecticides, pesticides, chlorine containing pollutants and few inorganic toxins too (Ghosh and Singh 2005).

AROMATIC PLANTS: A FIT FOR PHYTOREMEDIATION

Proper appropriation of effective plant species can be detrimental for the achievement level of phytoremediation projects. Finding a plant species which can convert toxic heavy metals to a beneficial element would be a first of its kind, which hasn't been achieved yet. Till now many species have been screened and identified which can perform phytostabilization, which requires plants with high tolerance level for metal ion concentration and minimum metal accumulation in harvestable parts. Selected plant should possess high economic value; end product must possess minimum toxic metal so that it can be disposed off and produces rich biomass which can be utilized for other pharmaceutical or commercial purpose.

Many plant species including medicinal and aromatic plants are grown for secondary metabolites which possess pharmaceutical importance. Aromatic plants are cultivated for essential oils. These oils are used in cosmetics and personal care products. Some are used for medicinal purpose too (Lubbe and Verpoorte 2011). As aromatic plants do not play a direct role in food chain this is an advantage over food crops for phytoremediation purposes. Over the past few years, research has been done for finding phytoremediation potential of sizeable number aromatic plants. The search for finding suitable plant has come down to specific families, whose members have shown encouraging results in successfully carrying out phytoremediation of toxic heavy metals. Name of these families are Asteraceae, Geraniaceae, Lamiaceae and Poaceae. Among the plant names aromatic grasses is a suitable candidate for the project. In addition to that, plants like Rosemary, Bamboo, Lavender, Indian Borage, Mentha and Ocimum also seemed to be a good choice.

For *in situ* remediation of waste disposal sites, aromatic grasses had been recommended. Aromatic grasses have certain unique characteristics that are best suited for the purpose. These characteristics include very fast and perennial growth, relatively high biomass production along with multiple harvests. Their root system is very profuse and they show rapid and easy propagation. Tolerance level to various stress conditions such as drought, temperature, different level of pH and heavy metal toxicity, is also high. Metal stabilization capacity is also relatively high in them. In addition to this livestock avoid their ingestion, which makes them less likely to enter into the food chain (Pandey et al. 2015).

Aromatic grasses produce essential oils that have high economic importance. With the steam distillation process, the chances of essential oils having toxic heavy metals are negligible (Lal et al. 2013). Essential oils extracted from aromatic plants, are still effectively used as immune stimulators, growth promoters, dietary supplements, flavouring agents and preservatives. Their role in aromatherapy is extensively beneficial.

The difference between demand and supply of essential oils is significant across the globe approximately 3900metric tons (Barbosa et al. 2009). As the development of human lifestyle progresses, this demand is on the rise. Essential oils have high worth due to their unique attractive aroma. They are highly demanded in the cosmetic and perfume industries. It has been apprehended that their total economic demand will be US$5 trillion at current prices in 2050. High commercial value makes the whole process of remediation viable as well as sustainable. Environmental and ecological impact of aromatic plants is quite remarkable. It has been reported in many studies that aromatic plants prevent soil erosion and quality enhancement. Their well-developed root system acts as a soil binder. Other advantages are carbon sequestration, conservation of biodiversity and quality enhancement of substrate (Zheljazkov et al. 2006).

In addition to phytoremediation, aromatic grasses are in any way highly desirable globally. And with more efficient techniques of essential oil production emerging, risks of heavy metal contamination could be taken care of (Pandey et al. 2019). So, it will be suitable to endorse aromatic plants for phytoremediation of toxic heavy metals from the contaminated site due to their capability to bring down the danger of bioaccumulation of toxic heavy metals and also checks soil disintegration all the while improving the soil and water quality.

DIFFERENT AROMATIC PLANTS FOR PHYTOREMEDIATION

Table 1 summarises various aromatic plants and their capability to phytoremediate toxic heavy metals. There are various characteristics of different aromatic plants which make them suitable for remediating toxic heavy metals from the contaminated area.

Rosmarinus officinalis

Its common name is rosemarywhich belongs to the family Lamiaceae and the native place is the Mediterranean region. It is a shrub of huge medicinal value due to its antibacterial property. Essential oils obtained from this plant show good results against microbes causing food spoilage. Valero and Salmero´n (2003) reported that rosemary oil is very effective against *Bacillus cereus.*

It is also used as a chemo preventive agent because of its antimutagenic properties. Oil produced from *Rosmarinus officinalis* is rich in antioxidants and is used by industries for perfumes, cosmetics, processed food, spices and energy stimulant products (Peng et al. 2005). It is drought resistant plant, so it grows easily in semi-arid regions having sandy soils. It also helps in erosion control as it can grow on rocky terrain too (Oluwatuyi et al. 2004). It had been reported by Murillo et al. (2005) that rosemary is highly effective to treat soils having organic waste and metal contamination. They successfully used it on the banks of de Guadiamar, a river in Spain contaminated with various trace elements, as a phytostabilizer. But with increasing concentration of heavy metals growth and oil production in rosemary is adversely affected.

The tolerance level of rosemary is quite effective for Cd, Ni, and Pb. It translocates very less amount of heavy metal to its aerial parts. Accumulation of metals like Pb, As, Sb, Cu, and Zn in the shoots was less than 1 as reported by Affholder et al. (2013). These metals were found in stems, leaves, and flowers but at lower concentration. It is an effective phytostabilizer as it immobilizes heavy metals in its roots and also acts as a bio-monitor of toxic metals in soil (Pandey et al. 2019). So overall, rosemary is a potential candidate for phytoremediation along with its economical importance which makes the whole process very much sustainable and viable.

Chrysopogon zizanioides

Common name- Vetiver; Family- Poaceae/Graminae; native place- India and tropical regions. It is a small herb with remarkable potential in phytoremediation along with water and soil conservation.Locally known as “Khus”, vetiver is used extensively by pharmaceutical industries, perfume and cosmetic industries for its essential oil obtained from roots. It has a very deep and well-developed root system which acts as an anchor to prevent soil erosion and aids in water retention. It can grow in drought areas as its root length extends from 3m to 6m. It can grow in both acidic and alkaline soil and also has tolerability for high salinity and sodicity. Shoot biomass is also found in a good amount. It is a plant species that can be used for every type of phytoremediation including Phytostabilization, Phytodegradation, Phytovolatilization, Phytoextraction and Rhizofilteration.

Vetivar has been found to have excellent capability for the accumulation of heavy metals like s Pb, Cr, Zn, Cu, Fe, Mn, etc. (Danh et al. 2011). Toxic heavy metals are present in both roots and shoots but roots accumulate more than shoots. Vetiver shows good growth when the soil was contaminated with uranium. This makes it a potential candidate for the remediation of radioactive components from the polluted site, given that it can tolerate harsh environmental conditions usually found in these sites (Hung et al. 2010). Chen et al. (2016) reported that Vetivar grown on coal dump sites helps in ecological restoration by accumulating toxic metals like Pb and Cd. It is also used for phytoremediation on various other mining sites like gold, iron and zinc mines where it acts as phytostabilizer for heavy metals like As, Zn, Ni and Mn (Guimarãeset al. 2016; Roongtanakiat et al. 2008; Chiu et al. 2006). In photosynthesis, photoassimilates are translocated to roots which ultimately lead to replenishing of organic carbon content of soil along with sequestration of atmospheric carbon oxides. Lavania and Lavania (2009) reported that Vetivar can potentially sequester atmospheric CO_2 up to 1kg into its roots on $1m^2$ surface area. Due to its properties like rapid growth and deep roots, Vetivar is cultivated in many areas for carbon sequestration and ecological rehabilitation.

Bambusa Species

Its common name is bamboo which belongs to the familyPoaceaeand the native place is believed to be the South Asia, East Asia and Southeast Asia. It is a group of perennial wood grass that is traditionally used in many anthropogenic activities in India, China, and Indonesia since ancient times. It is used in house construction, food dishes, decoration and handicrafts. Bamboo oil is extracted from its seeds and is rich in antioxidants and antimicrobial agents and contains a high amount of protein content. It is a part of trial medicines in India. It is being used to treat skin ailments, various other diseases and is very valuable for cosmetic and pharmaceutical industries (Vasu et al. 2014). Nath et al. (2015) reported carbon sequestration and storage values of many bamboo species from 30 to 121 tons per hectare. Bamboo plants show vegetative and rapid growth and can be grown on both soils and in hydroponic system. They have a physiological property of integration with each other which helps in growing dense forests giving them the ability to reduce environmental stress.

Bian et al. (2018) used Mosa bamboo and Phyllostachys praecox for treating industrial waste water and found that they can accumulate toxic metals like Cd, Zn and Cu without affecting its biomass yield. Moreover, metal components were mostly found in roots and rhizomes. Shukla et al. (2011) found that *Dendrocalamusstrictus* can accumulate Cd, Ni, Cr and Pb in higher concentrations. Moso bamboo can show growth under high Pb concentration due to its strong root system but it can cause oxidative stress effective nutrient uptake and biomass yield (Liu et al. 2015). Bamboo plants have a high translocation factor for heavy metals which makes it desirable for phytoextraction. Many strategies can be deployed to manage oxidative stress and improving the accumulation of toxic heavy metals like intercropping with hyperaccumulator plants, selecting tolerant species and using chelating agents (Bian et al. 2019).

***Plectranthus amboinicus* (*Coleus ambionicus*)**

Its common name is Indian Borage, Mexican mint and French thyme which belongs to the familyLamiaceae having the native place as India, Latin America and Europe. It is a perennial herb with a distinct aroma. It is used in ayurvedic medicines, food seasoning, beer production and cosmetics.They are widely used as an ornamental plant and also cultivated for its essential oil used by pharmaceutical industries (Kaliappan and Viswanathan 2008). They have hairy roots along with lateral branches making them a potential candidate for rhizofilteration.

Ignatius et al. (2014) found that *Coleus ambionicus* can grow in high Pb concentration and a wide range of nutrient deficiency. Lead was reported to be accumulated in rhizosphere with minimum translocation to shoots when grown hydroponically using a nutrient film technique system. This makes its economical value intact and a convenient candidate for the removal of toxic metals from polluted soil region and water bodies. Begum and Singanan (2019) reported that this plant species has a good potential for the accumulation of toxic heavy metals like Cd, Zn and Cu when grown on highly contaminated soil. Their study showed that it can accumulate 5.44 mg/kg Cd and 3.86 mg/kg Zn when used in phytoremediation of soil containing a high concentration of toxic heavy metals. Considering its high economic value and high heavy metal accumulating efficiency, this plant is suitable for remediating contaminated sites using safe biomass disposal methods.

Table 1. Aromatic plants used for heavy metal bioremediation

S. No.	Heavy Metal Abated	Plant Name	Features	References
1.	As, Cu, Pb, Zn and Sb	*Rosmarinus officinalis*	Plant show less than 1 bioaccumulation factor	Affholder et al. (2013)
2.	As, Cr, Cd, Pb, Hg and Se	*Mentha piperita*	Good growth in medium concentration of these heavy metals.	Kumar and Patra (2012)
3.	Ar	*Pteris vittata*	Phytoextraction.	Yang et al. (2016)
4.	Mn, Pb, Zn, Cd	*Acorustatarinowii, Alocasia cucullata, Cyperusalternifolius, Echinodorusamazonicus, Echinodorusbaothii, Hydrocotyle vulgaris, Scirpus triqueter and Veronica serpyllifolia, Eleocharis geniculate* and *Panicum repens*	*Acorustatarinowii* is also known as Tillers of Grass-leaved sweetflag; *Veronica serpyllifolia* common name is thyme leaved speedwell and *Echinodorusamazonicus* is known as Amazon sword.	Yang et al. (2016)
5.	Pb, Zn, Cu, Ar, Cd, Ni, Sn	*Vetiveria zizanioides*	It showS phytoextraction as well as phyto-stabilization for certain heavy metals. It translocates some heavy metalsinto the shoots.	Pandey et al. (2019)
6.	Hg, Ar, Cd, Pd, Mn and Zn	*Chrysopogon zizanioides,*	It shows phytostabilization.	Pandey et al. (2019)
7.	Zn and Pb	*Arabis paniculata*	It belongs to the family of *Brassicaceae*.	Patra et al. (2020)
8.	Cu	*Commelina communis*	It belongs to the family *Commalinaceae*.	Patra et al. (2020)
9.	Cr	*Cymbopogon flexuosus and Bracharia mutica*	It belongs to the family *Poaceae*	Patra et al. (2020)
10.	Cr, Ni, Pb, Cd, Fe, Mn, and Cu	*Cymbopogon flexuosu*	It is also known as lemongrass. It show optimum growth in waste water.	Pandey et al. (2018)
11.	Pb, Zn, Cd	*Lavandula vera*	Plant has property of hyperaccumulation of many heavy metals	Angelova et al. (2015)
12.	Cd,Pb, Cu, Mn, Zn, Fe	*Lavandula angustifolia*	Plant has property of hyperaccumulation of many heavy metals	Pandey et al.(2016)
13.	Cd, Pb, Cr	*Salvia sclarea*	Plant has property of hyperaccumulation of many heavy metals	Angelovaet al. (2015); Chand et al. (2015)
14.	Cd, Pb, Cr	*Salvia officinalis*	Plant has property of hyperaccumulation of many heavy metals	Stancheva et al. (2014)
15.	Hg, Pb, Cu, Zn, Cd, Ni, Fe, As, Sb	*Rosmarinus officinalis*	Potential bio-monitor, and act as a hyperaccumulator and phytostabilizer.	Affholder et al. (2013)

S. No.	Heavy Metal Abated	Plant Name	Features	References
16.	Cd, Pb, Zn, Ni	*Matricaria recutita*, *Matricaria chamomilla*, *Chamomilla recutita*	Facultative metallophytes or metal excluders, Cd accumulating species.	Stancheva et al. (2014);Voyslavov et al. (2013)
17.	Cr,Cd, Pb, Ni, Cd: ionic and nanoparticle	*Ocimum basilicum*	Plant showed good results in phytostabilization process.	Stancheva et al. (2014)
18.	Cr, Pb, Ni, Cd, Cu, Zn	*Mentha arvensis*, *Mentha crispa*	Phytostabilizer	Malinowska and Jankowski (2017); Sa et al. (2015)
19.	Cd, Ni, Pb, Zn	*Pelargonium cultivars*	Phytotranslocation and Hyper accumulatorfor certain heavy metals	Chand et al. (2015); Manshadi et al. 2013
20.	Cr, Cd, Pb, Ni, Fe, Zn, Cu	*Cymbopogon martinii*	Phytostabilizer	Pandey et al. (2015); Pandey et al. (2016)
21.	Cr and Cd	*Cymbopogon* *Winterianus jowitt*	Phytostabilizer	Sinha et al. (2013)
22.	Cd, Ni, Cr, Cu, Hg, Pb	*Cymbopogon flexuosus*	Phytostabilizer	Jha and Kumar (2017)
23.	Pb, Cd, Zn and Ni	*Cymbopogon citratus*	Phytostabilizer	Hassan (2016); Lee et al. (2013)
24.	Cu, Pb, Sn, Zn	*Chrysopogon zizanioides*	Phytostabilizer	Gautam et al. (2017)
25.	Cu, Pb, Sn, Zn	*Vetiveria zizanioides*	Phytostabilizer	Ng et al. (2017); Van Minh and Van Khanh (2016)

Cymbopogon species

Its common name is Lemongrasses or oilgrasses which belongs to the family Poaceae and the native place is India. Various plants of genus *Cymbopogon* are used as cash crops by industries for their essential oils. Their leaves are used as an alternate for lemon in tea. *Cymbopogon martinii*, also known as palmarosa, yields palmarosa oil which has a sweet aroma and is used significantly in manufacturing soaps, insect repellants, cosmetics and perfumes (Hussain 1994). These plants can grow in xerophytic conditions due to their adapted leaf structures. They can grow in most of the different ecological conditions present worldwide except for arid and sandy coast areas (Pandey et al. 2019).

Cymbopogon yields more essential oil with wastewater as compared to normal water and the amount of toxic heavy metals present in the essential oil thus extracted, is negligible (Lal et al. 2013). For remediating industrial waste containing heavy metals like Zn, Pb and Cd, *Cymbopogon* is a good choice. It phytostabilizes toxic metals such as As, Al, Cr, Cd, Ni, Pb and Mn into and its roots and accumulates them too when present in higher concentration (Gautam et al. 2017). *Cymbopogon martinii* is a potential phytostabiliser of Cr, Ni, Pb and Cd in decreasing order, when grown on a site contaminated with tannery sludge (Pandey et al. 2015). Hydrodistillation process for extraction is sufficient for avoiding heavy metal contamination in essential oils.

CONCLUSION

The deposition and contamination of toxic metals in agrarian areas and water bodies prompt a genuine threat to living beings because of bioaccumulation of metals into the natural way of life. Traditional advances involve enormous expenditure for sole purpose of removing heavy metals from polluted areas. Phytoremediation is a suitable, dependable, prudent, eco-accommodating, sun oriented, maintainable, and promising procedure that can be applied for enormous scope destinations. Reclamation of polluted land and water bodies should be possible through "reasonable phytoremediation" utilizing environmentally and financially important plant species.

Aromatic plants are a real deal given their well established and ever-growing economic value and potential to act as a remediator of toxic heavy metals and other pollutants. They facilitate process of phytoremediation by making it feasible and sustainable. As there are various types of phytoremediation, various species of aromatic plants provide a plethora of options to choose from, depending upon the nature and environment of the polluted site. Phytoextraction had shown its effectiveness in removing toxic metals from the contaminated soil, while other strategies only temporarily manage the pollution caused by heavy metals. In treating the contamination of water bodies, Rhizofilteration is as effective as it could. And use of the nutrient film system along with it resulted in increased efficiency. Among numerous aromatic plants, Vetivar and Cymbopogon are a gem, because of their tolerance level and their adaptability, making them suitable for every type of phytoremediation method. Other species had also shown good results when used specifically. Overall, it is an idea that should be carried forward on a large scale worldwide.

Phytoremediation, while helpful, is, all things considered, has the challenge posed by heavy metals of bioaccumulation in the plants because of their indestructible nature. A more all-encompassing methodology, in this way, is desperately required to address this environmental hazard. This will require phytomanagement to establish a fully functional system. Hydroponics and aquaponics technique can be an area to go further. They could be used in collaboration with microorganisms which can enhance the efficiency of the process. The use of biopesticides and biofertilizers has shown good results, so integrating them in this phytoremediation strategy could help in reducing stress from the aromatic plants caused by pollutants. Mitigating a proper action strategy involving researchers, government agencies, industrialist and farmers for further analyzing and accessing the socioeconomic benefit is a step ahead. In implementing that plan and carrying forward this idea into results is the requirement of time.

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Chapter 14

BIOGENESIS AND CHEMOECOLOGY OF ESSENTIAL OIL, AROMATHERAPY AND CONSERVATION IN VETIVER

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ABSTRACT

Chrysopogon zizanioides (Roberty) or Vetiver is an important part of the family of Poaceae. Aroma present in plant is a complex mixture of low-molecular-mass volatile phytomolecules like phenylpropanoids, terpenoids and fatty acid derivatives. Essential Oil of *Vetiveria zizanioides* is extracted from its aromatic roots. It is used in aromatherapy, as it is useful in stress release, depression, anxiety, fatigue, insomnia, body pain, muscular aches, headaches and circulatory problems etc. Essential oil of vetiver is an anti-oxidant, works naturally to facilitate help in release of various types of inflammations. Vetiver essential oil (VEO) mainly contains Vetiverol, Khusimol, Vetivone, Khusimone, Khusinol, Acetate etc. Alpha-Vetivone, β-Vetivone, and Khusinol are the major constituents that cause the fragrance. In ayurvedic massages, Vetiver oil became an essential part that helps to strengthen the nervous system by reducing the stress, maintaining emotions and increase in immunity system. This chapter deals with Vetiver essential oil in order to better understand the plant chemoecology and bioactive phytochemicals that will be beneficial for environment, agriculture and human health.

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Keywords: Chrysopogon zizanioides, chemoecology, aromatherapy, secondary metabolites, sesquiterpenes, essential oil

1. INTRODUCTION

Aroma present in plant is a complex mixture of low-molecular-mass volatile phytomolecules like phenylpropanoids, terpenoids and fatty acid derivatives. The aromatic roots of *Vetiveria zizanioides* are used for extraction of Vetiver essential oil, also known as Khus oil. VEO is also mentioned as “Oil of Tranquility” and “The Earthy Fragrance” due to its calming, seductive and profoundly soothing aroma. Essential oil of vetiver is used as in aromatherapy as it is very helpful for soothing anxiety, sleeplessness, exhaustion, sadness, and stress. It is also used in many cosmetic and beneficial in tightening pores as well as in protecting the skin against the severe effects of environmental stresses, thereby demonstrating antiaging properties. Vetiver Essential Oil, used medicinally, acts as a natural antioxidant that facilitates relief from different kinds of irritation. It is reputed that its tonic properties reflect regenerative effects as they strengthen and sustain immunity system. It is also known for its antiseptic properties. Aromatherapy is a significant access for healing that promotes health and well-being by using natural plant extracts, which is known as essential oil therapy sometimes. Aromatherapy medically utilizes herbal essential oils to enhance the health of the body, mind, and spirit. It improves physical as well as mental health. In the field of science and medicine, aromatherapy has gained more recognition recently. *Richard Axel and Linda B. Buck* were awarded the Nobel Prize for Physiology or Medicine in 2004 for their discovery of odour receptors and the structure and development of the olfactory system. They found a wide family of genes consisting of some thousands of distinct genes that give rise to an equal number of types of olfactory receptors. These super families of receptors are located on olfactory receptor cells which, is present in olfactory epithelium cell of nasal in a small area and help in detecting the odour molecules that are inhaled. During struggle to concentrate on a mission or stay alert to what’s happening around, Vetiver oil will make the brain to feel more conscious. Worldwide Khus or Vetiver is cultivated for its root essential oil, which is a complex combination of sesquiterpene alcohols and hydrocarbons. Cheaha et al., 2016 reported that vetiver oil enhanced alertness and function of nervous system in animal. Essential oil of Vetiver is present in secretory cells localized in the first cortical layer outside the endodermis of mature Vetiver roots (Figure 1).

Figure 1. *Vetiveria zizanoides* field view and its roots.

2. Biogenesis and Chemoecology of Vetiver Essential Oil

Vetiver root oil is very complex in composition and therefore very complicated with more than hundred sesquiterpene constituents and their derivatives. Main chemical constituents in vetiver essential oil are *Sesquiterpenes hydrocarbons***,** *Sesquiterpene Alcohol derivatives,* (Vetiverol, Khusimol), S*esquiterpene Carbonyl derivatives* (Vetivone, Khusimone), and *Sesquiterpene Ester derivatives* (Khusinol acetate). The major constituents that are known to influence the aroma are *α-Vetivone, β-Vetivone,* and *Khusinol* (Ramanujam et al., 1964; Smith et al., 2012). The major compound in vetiver essential oil includes firstly, (Sesquiterpene hydrocarbons) clovene, cadenene, amorphine, aromadendrine, junipene, secondly, (Sesquiterpene alcohol derivatives) vetiverols – khusimol, epiglobulol, spathulenol, khusinol, thirdly, (Sesquiterpene carbonyl derivatives) vetivones – vetivone, khusimone and lastly (Sesquiterpene ester derivatives) khusinol acetate. The most important components used in vetiver oil have the highest boiling points (Lavania et al., 2000 and 2009). In a recent study, metabolic engineering of (+)-zizaene biosynthesis in *E. coli* strains were reported. The biosynthetic pathway engineering included the over expression of the MEV pathway to increase the supply of FDP, the evaluation of promoters to effectively express *zizaene synthase*, and the engineering of multi-plasmid strains with multiple copies of ZS to raise the supply of ZS. In addition, optimization of the conditions for fermentation and evaluation of *E. coli* strains were analysed in order to improve the development of (+)-zizaene (Aguilar et al., 2019).

In India, two different vetiver morphotypes were described, which is North Indian and South Indian style. The northern type showed increased activity of genes associated with flavonoid and terpenoid biosynthesis, i.e., ERF, MYB, bHLH, WRKY and bZIP. Analysis of gene expression analysis showed that genes were upregulated in sesquiterpene biosynthesis pathway (Chakrabarty et al., 2015). Whole genomic and transcriptomic sequences have become available in many model organisms over the last several years, which have significantly enhanced knowledge of the nature of physiological processes in higher plants like Vetiver. Chakrabarty et al., 2015 reported transcriptome analysis of North and South Indian type vetiver to know the role of genetic makeup on oil quality and root morphology. In another study, numerous genes reported by George et al., (2017) during drought and salt stress to be upregulated in *Chrysopogon zizanioides*. This includes genes encoding dehydration responsive proteins, peroxidases, Late Embryogenesis Abundant (LEA) proteins, enzymes scavenging Reactive Oxygen Species (ROS), transporters, enzymes in the flavonoid biosynthetic pathways, protein kinases, ethylene receptors etc. There were 108 genes found to be responsive to both salt and drought stress in both tissues. In a recent study, the complete and annotated chloroplast genome sequences of *Chrysopogon zizanoides* reported by Sigmon et al., (2017) that include three Sunshine, Capitol, and Huffman non-fertile cultivars and two fertile accessions from Punjab and Allahabad from northern India sites. Non-fertile accessions of vetiver grass have been used for environmental remediation and erosion control in many parts of the world but fertile plants can turn into harmful weeds. Unique polymorphisms are important to differentiate between non-fertile and fertile plants therefore; cp genomes of both were sequenced. Total 28 polymorphisms, which include 14 SNPs, 11 microsatellites, 2 small indels, and one micro inversion, were reported in the sterile Sunshine from fertile accessions of vetiver. This study is very useful and helps in conservation of germplasm. The microRNAs are small non-coding RNA molecule that plays an important role in metabolism and regulate post-transcriptional gene expression. They typically bind to their target mRNAs' 3'-UTR (untranslated region), and repress protein production by destabilizing mRNA and translational silencing. Recently, Mishra et al., (2020) reported *in silico* study of miRNA identification in *Vetiveria zizanioides* from both leaf and root sequences through bioinformatics. Total 80 miRNA were identified with 25 miRNA families in leaf and 31 in root. The miR169 and miR5021 were reported to regulate most of the targets in leaf and root. Some miRNA like miR2102, miR854 and miR5658 regulate terpenoid metabolism as well as primary metabolism like photosynthesis (miR5021 and miR854) etc. in Vetiver. The sesquiterpene (+)-zizaene is the direct precursor of khusimol, the main fragrance constituent of the vetiver essential oil. Improved production and i*n situ* recovery of Sesquiterpene (+)-Zizaene from metabolically-engineered was done by using E. coli (Aguilar et al., 2019).This research provides additional information for the incorporation of terpene bioprocesses by *in situ* product recovery, which could be extended to industrializing fragrant molecules in other terpene studies. *Vetiveria zizanioides* L. Nash is considered to be an effective remedy for the heavy metal phytoremediation. In *V. zizanioides* plantlets, an arsenic (As) accumulation, translocation and tolerance investigation were performed by Singh et al., (2017) upon exposure to specific arsenic concentrations (10-200 µM). The up-regulation of the antioxidant enzyme activities of superoxide dismutase (SOD), ascorbate peroxidase (APX), guaiacol peroxidase (GPX), catalase (CAT) and glutathione s-transferase (GST) showed increased tolerance to plants against arsenic induced oxidative stress.

In many tropical regions, cultivation of Vetiver grass has been done for controlling soil erosion by water as well as for removing many heavy metals from soil that is contaminated (Dalton et al., 1996). In one of the studies, in the Vetiver root microbial population through culture-based and culture-independent approaches were characterized, and explored the possibility of the root-associated bacteria being involved in the metabolism of Vetiver oil. The results of this study shed also a new light on the ecological significance of the association between Vetiver and its root-associated bacterial community (Del Giudice et al., 2008).The results indicated a large phylogenetic range of bacteria, including a-, b- and g-Proteobacteria, Gram-positive bacteria with a high G+C content, and microbes belonging to the community of Fibrobacteres/Acidobacteria. Root-associated bacteria showed that by using essential oil sesquiterpenes as a carbon source, most of them were able to expand and metabolize them, releasing a large number of compounds usually contained in commercial Vetiver oil into the medium reported by Del Giudice et al., (2008).

3. Vetiver Essential Oil Applications in Aromatherapy

Aromatherapy is a traditional method that utilizes herbal essential oil from aromatic plants that help in the treatment of physical as well as mental health. In the field of science and medicine, aromatherapy has gained more recognition recently. In aromatherapy, Vetiver essential oil (VEO), extracted from vetiver grass, has been used, as it is proposed to have calming, anti-anxiety and sedative effects. Vetiver essential oil contains many properties that help in aromatherapy (Moate 1995). In a trial investigation in mice showed that the inhalation of vetiver essential oil significantly reduces rearing activity in an open field test, indicating a sedative effect (Thubthimthed et al. 2003). In another research the anticonvulsant activity of vetiver root ethanol extracts in mice was also shown (Gupta et al., 2013). However, there are no published studies about the actions associated with anxiety following VEO inhalation. Essential oil can be used in three main ways: inhalation, skin absorption, and ingestion (Woronuk et al., 2011). The lungs and nasal mucosa will absorb essential oil into the bloodstream, taking the active compounds into the central nervous system. In addition, essential oil also activates the olfactory pathway and then transmits the impulses to an emotional core, the limbic system. Cheaha et al., (2016) showed that Vetiver essential oil can minimize mental stress and increase alertness, so it makes sense that it might work to concentrate on a task and block out all sensory feedback for people with ADHD. Attention deficit hyperactivity disorder (ADHD) is a mental health disorder that can be cured using vetiver oil aromatherapy as a treatment. But further research is required to clearly confirm that vetiver essential oil will function in the treatment of ADHD. Meanwhile, other essential oils have been shown to be helpful for ADHD.

Vetiver essential oil (VEO) has been used for stimulation in aromatherapy. The goal of this research was to investigate the effects of VEO on an anxiety-related behavioral model (the elevated plus-maze, EPM) and amygdala-related immediate-early gene c-fos, known to be involved in anxiety. Overall, the findings indicate that VEO's anxiolytic properties could be correlated with altering neuronal activity in the cell (Saiyudthong et al. 2015).

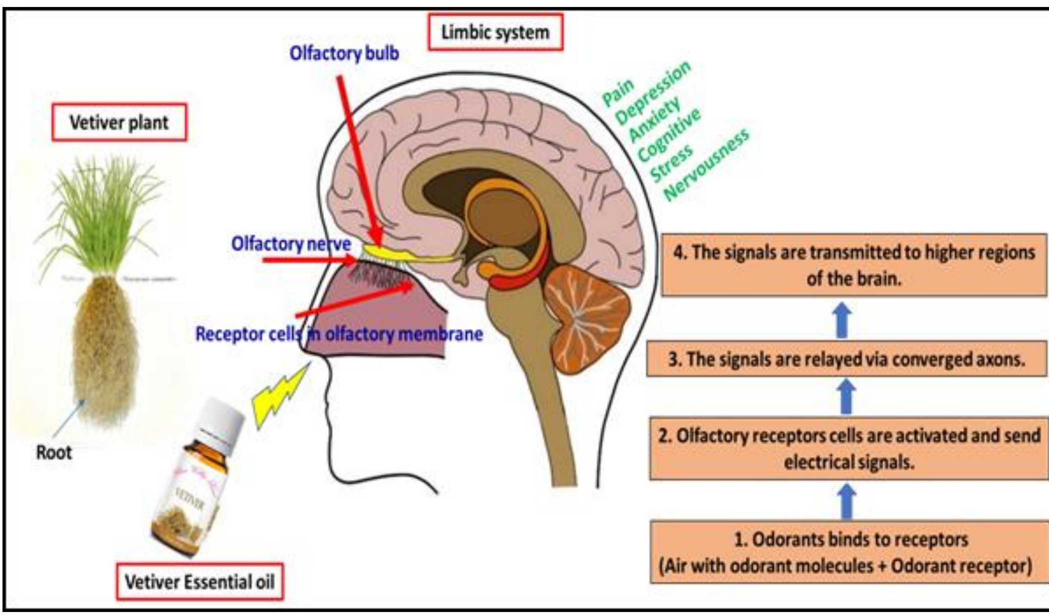


Figure 2. How aromatherapy works using essential oil (Vetiver) on human brain.

It is a tonic for the nerves, therefore is called a nervine, since it takes care of the nerves and keeps them in good health in Essential Oil of Vetiver. It also heals the damage done by shock, anxiety, tension, etc., to the nerves. In addition, it helps to eradicate nervous problems, infections, epileptic and hysterical attacks, nervous and neurotic disorders such as Parkinson's disease, loss of limb coordination, etc. Vetiver Essential Oil is a well-known sedative. It sedates nervous irritations, diseases, seizures, and emotional outbursts such as frustration, anxiety, epileptic and hysterical attacks, restlessness, nervousness, etc. In addition to various culinary drinks and aphrodisiacs, a calming infusion is made with vetiver essential oil, used to relax and recover from extreme pressures. Help to overcome situations of shock, fear, high levels of stress, panic, etc. Animal studies concluded that inhalation of vetiver oil improved alertness and brain activity. Vetiver oil may help your brain feel more conscious if alertness is required more to concentrate on a task or remain alert to what's happening around us. In a study, it showed that vetiver root has antioxidant properties. Antioxidants scavenge your body's systems for toxins and which are called "free radicals," which disrupt body's processes and contribute to the signs of aging. (Figure2) Using skin creams that contain vetiver oil, or using it in its pure essential oil form, may give you an antioxidant boost (Luqman et al., 2009)**.** Therefore, Vetiver may become an essential part of any cosmetic or stress reliever product.

4. Role of Vetiver Grass for Conservation of Soil and Water

Vetiver zizanioides, known for its function in silage, soil and water conservation, is a perennial herb of the Poaceae family. In a recent report, the resources of *Vetiver zizanoides* associated nitrogen-fixing bacteria were identified. Vetiver-related nitrogen fixers have shown great diversity and may have a potential application for grass forage and agriculture (Zhao et al., 2009).Vetiver grass can be used on the steep slopes of arid regions where erosion is extreme, to prevent erosion, because it has proven effective in holding the soil. Vetiver can accumulate heavy metals, particularly lead (shoot 0.4% and root 1%) and zinc (0.4% and root 1%) (shoot and root 1%). Many heavy metals are thus deposited in roots therefore it is appropriate for Phyto stabilization and phytoextraction with the addition of chelating agents. Vetiver is also able to consume and facilitate organic waste biodegradation (2, 4, 6-trinitroluene, phenol, ethidium bromide, benzo[a]pyrene, atrazine). While Vetiver is not as successful in heavy metal accumulation as in some species, very few plants have a wide range of tolerance to extremely adverse climate conditions and growing medium (soil, sand, and railings) combined as vetiver into one plant as mentioned in the literature. All these unique characteristics make vetiver a plant of choice for the phytoremediation of heavy metals and organic waste stated by Lavania et al., (2004). Soil erosion is the way to extract topsoil, which consisted of various organic soils and nutrients (Pardini et al., 2003); so critical nutrients were removed due to this enormous soil erosion (Polyakov et al., 2008). As a result, productivity decreased per capita land capacity. Babalola et al., (2003) and Barton et al., (2004). Vetiver helps to reduce soil erosion in fields and retains soil moisture. It is also a significant component of maintenance projects in drainage channels that may need irrigation-engineering work, have several environmental applications and provide inexpensive and effective solutions to soil degradation, loss of soil fertility, recharge of groundwater, improvement of water quality and reconstruction of sites in relation to industry and intensive trade in the future (Wolde, 2015). Vetiver has been shown to have tremendous potential to be used for phytoremediation. Vetiver is able to minimize the movement and transport of heavy metals by keeping them in the microenvironment of the rhizosphere. Phytoremediation is considered to be an effective, affordable and environmentally compatible approach for the remediation of heavy metals. Land and water bodies are very susceptible to heavy metal contamination surrounding mines in semi-arid and arid zones. Another example of areas needing restoration and soil decontamination is abandoned mined sites. The concerns of toxic heavy metal emissions have been discussed by Nanpham et al. in 2001 (Table 1).

Table 1. Agricultural and non-agricultural relevance of *Vetiveria zizanioides*

Application Type	**Application**	**Various activities**
Agricultural applications	For generating breeding stocks	Mulching and Composting
	Developing green feed	Animal feed Insecticides Pesticides Allelochemical
Non-Agricultural applications	landscaping	Farm boundaries and slopes designing with support
	Decorative hedge	Field boundaries
Environmental protection	Preventing soil erosion	Soil and water conservation Slope support Disaster management
	Soil health improvement	Absorption of heavy metals Wastewater treatment
As fragrance	Various sesquiterpenes	Various perfumes toiletries, soaps, candles, herbal shampoos
As therapeutic agent	Health drinks	Root drinks
		As an antioxidant
Small scale industries	Agro based industries making diverse products based on handicrafts	thatch, compost, mulch, mushroom medium, animal fodder, bouquet
Industrial applications	Different sesquiterpenes and their derivative products	Perfumery industry Cosmetic industry Food industry
As chemical adjuvant in chemoecology	As an attractant	Varied chemological activities

5. Future Prospects

The uses of vetiver essential oil are lesser known, but it has many an important property. To understand how vetiver essential oil affects your brain and the rest of your body when it is applied topically or inhaled. More knowledge and research is still required. To know about t the properties of vetiver oil related to its soothing and relaxing anxiety, trigger more alertness in a tired brain, and protect from tick bites that may cause other health issues. The genome analysis of vetiver provides a basic model for understanding of biosynthesis and gene regulation of other aromatic plant species. Therefore, this plant is providing a model plant system for medicinal as well as for aromatic plant species. Vetiver could be planted in non-farming zones for soil conservation and to prevent soil erosions for riversides and slopes furthermore, it could be utilized in chemo-ecological perspectives with superior and improved varieties with suitability towards different ecological regimes. Here at CSIR-CIMAP various improved and elite varieties are available with higher yields and suitability towards different agro climatic zones. The water protection could be devised with certain changes by reducing the moisture loss and simulating with climatic conditions, perhaps this will provide additional benefits to the farmers, growers and industries. This will again use for roads sides and to support foothills by combining the fertile and non-fertile varieties as per the requirement ecological niche modelling and benefits in terms of generating employment and by increasing profit ratios. Further the output from the research will nurture this crop for more valuable outputs and applications related to aroma chemicals for treating various disease and disorders with the advancements in Aromatherapy utilizing its precious essential oil chemical constituent along with its earthy soothing fragrance (Table 2).

Table 2. Industrially important aromatic plants developed at CSIR CIMAP CSIR-Central Institute of Medicinal and Aromatic Plants, Lucknow U.P. (India), 226 015

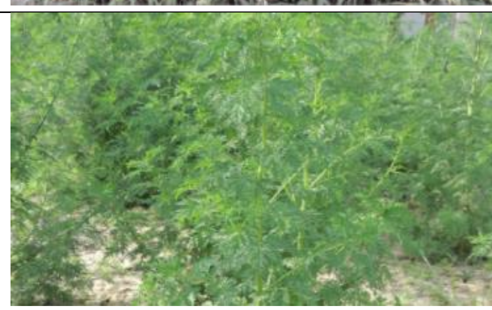
S. no.	Aromatic plants	Plant image
1.	Scented Rose (*Rosa damascena, R. gallica, R. centifolia, R. moschata*)	

Table 2. (Continued)

S. no.	Aromatic plants	Plant image
2.	Geranium (*Pelargonium graveolens* L.)	
3.	Field mint/Corn mint (*Mentha arvensis* L.)	
4.	Peppermint (*Mentha piperita* L.)	
5.	Sagewort, Worm wood (*Artemisia annua*)	

S. no.	Aromatic plants	Plant image
6.	Patchouli (*Pogostemon cablin* Benth)	
7.	Citronella (*Cymbopogon winterianus*)	
8.	Tulsi (*Ocimum basilicum* L.)	
9.	Tulsi (*Ocimum gratissimum* L.).	
10.	Tulsi (*Ocimum sanctum* L.)	

Table 2. (Continued)

S. no.	Aromatic plants	Plant image
11.	Rosemary (*Rosmarinus officinalis*)	
12.	Palmarosa (*Cymbopogon martini* [Roxb] Wats.)	
13.	Davana (*Artemisia pallens* Wall ex.DC)	
14.	Khus (*Vetiveria zizanioides* L.)	
15.	Chamomila (*Matricaria chamomilla*)	

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Chapter 15

CHEMISTRY AND BIOCHEMISTRY OF AROMA AND FLAVOR

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ABSTRACT

A wide number of species are part of the plant kingdom, giving rise to an abundance of biologically active molecules with different chemical phases. Over the course of hundreds of years, despite developments in the new clinical and pharmaceutical industries, the use of aromatic plants has become an integral part of daily life. They are currently products of dynamic beauty treatment, nourishments and teas, just as elective medications. Aromatic plants are part of a wide group of plants which are of economic significance. The interest in basic oils is growing, fragrance synthetic substances medications and pharmaceuticals in the world market since two decades. Aromatic plants have different characteristic aroma and flavour. This aroma and flavour is due to the presence of different chemical compounds in these aromatic plants. In different plant sections, there are some plant parts which comprises of aroma, i.e., fruit, seed, flower, peel, root, leafage, etc. The most popular essential oil bearing plants are mint, vetiver, citronella, palmarosa, geranium and so on. Those comprises of various biologically abuzz substances, essentially polyphenolic compounds, that have been exhibited to a variety of forms of action, for instance antimicrobial, cancer preventive, fungicidal, anti-parasitic, anti-afflicting etc. Recently, due to their characteristic natural properties and peoples' increased environment consciousness, the interest in these plants and their subordinates has been enhanced.

Keywords: aromatic plant, aroma, flavour, bioactive compounds, mode of action

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INTRODUCTION

Aromatic plants have been categorized for recognition and taxonomic purposes with medicinal plants; there is a much more feasible general grouping within the category of medicinal and aromatic plants. In order to investigate and use MAPs, the starting step is the identification of the plants and then their taxonomic classification. Prior to the study of plants, vision, scent and smell were exclusively based on sensations and contact without any scientific point of reference subsequently the primary reason for classification of aromatic plants. With the appearance of science and the discovery of large amounts of plants with identical morphologies, it became difficult to group them morphologically, as well as pressing for the need for a more standardized classification scheme where new organisms could be discovered in the future and thus different features, like as material attributes, was used by the classification structure. Subsequently, organic science helped by other professional accomplishments appears. In order to apprise promising insights owing to the development of fresh ones, exceptionally outstanding restorative chemo-cultivars and sweet-smelling taxa. Out of an aggregate of around 1500 types of fragrant documented plants, just there were a little over 500 species heavily focused under certain depth. Among the 50 species found as a mercantile source of volatile oils and fragrance synthetics, an absolute number of those with standard oils and fragrance synthetics are barely exceeded by the enormous scope of use. It is impossible to determine the actual number of species of aromatic plants or MAP materials in use in the world. First of all, this is because certain aromatic and medicinal plant materials are used in minute quantities and are therefore not listed in the trader's database. In addition, an aromatic or MAP product can come from many species, but it can still be traded under a trade name that vaguely identifies the specific origins of the various species. Lastly, many species are most frequently used at the local level, and their use is not fully known.

AROMA AND FLAVOR

Taste and smell unit of measurement the two most sensitive human senses. The nose can typically notice and distinguish doors at level that even trendy instrumentation is hard ironed to attain. The plants - particularly that of upper plants - provide a multitude of flavours and fragrances, either directly or indirectly, that impinges upon these senses. Through most of the time, and with the help of so many thousand species of plants, from that to provide them, Countless numbers of such perfumes have made their way into daily life through essential oils: into foods and beverages, and confectionery items; into private-use merchandise like shampoos, savours, deodorizers, tub ointments, toothpastes, soaps, and mouth rinses; into pharmaceutic formulations wherever square flavours measure extra to produce the merchandise addititium or public sphere or export in tobacco products The list is endless, such as air fresheners, laundry soaps, detergents, cleaning agents, etc.

Definition of Aroma

An aroma compound is a substance that has a scent or smell, commonly known to as an odorant, scent, perfume. It must be sufficiently volatile to be transported to the sensory organs in the upper part of the nose for a chemical compound to have a scent or odour.

Definition of Flavour

Flavour is the sensory perception of food or other material that is mainly defined by the senses of taste and smell that are chemical. As such with natural or artificial flavourings, the taste of the food may be changed. The multiplicative effect of the flavour and flavour of food is known as flavour. When treated, processed or stored, as in coffee, milk, and cooked meats, the taste and aroma of food usually declines. However the taste of food is improved by processing in some exceptions, such as cheese is matured, wine is aged, or meat is aged.

Important Chemical Compounds Present in Aromatic Plants and Their Chemical Structures with Mode of Actions

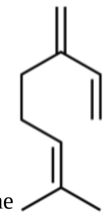
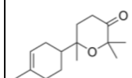
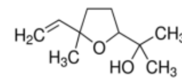
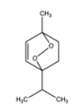
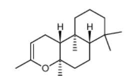
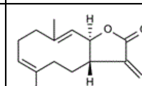
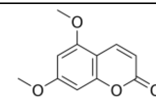
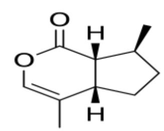
There are different groups of compounds with diverse properties. Examples of only certain chemicals with structures and therapeutic benefits have been reported. Through exhaustive analysis of the structure of volatile oil by GC-MS (gas chromatography and mass spectrometry), various compounds can be identified. Mostly a useful mixtures of terpenoids such as borneol, linalool, menthol, geraniol, α-terpineol, citronnillol, thujanol, and a variety of aliphatic hydrocarbons with a low molecular weight such as phenols (gaiacol, eugenol, carvacrol and thymol,) and aromatic aldehyde (cuminal, phellandral and cinnamaldehyde) has been found.

Table 1. Plant parts use for extraction of Secondary metabolites from Aromatic Plants

Plants	Family	Useful Parts	Uses	Secondary Metabolites	Reference
Mint (*Mentha piperita*)	Lamiaceae	Leaves	Carminative, spasmolytic, against tumour, hostile to diabetes, against nociceptive and so on.	Hesperidin, rosmarinic acid,didymin, buddleoside, diosmin	Zhao et al. (2018)
Lemongrass (*Cymbopogon flexuosus*)	Poaceae	Leaves	Lemongrass used as Anti-inflammatory, analgesic, anti-fungal	Citral, geranium, geranyl acetate,nera, β-myrcene	Boukhatem et al. (2014)
Citronella (*Cymbopogon nardus*)	Gramineae	Leaves	Citronella used Cosmetics and anti-inflammatory agents For the management of pests. Potent antitumor and chemopreventive drug	Citronella, cadinene, methyl isoeugenol, geranyl acetate, citronellyl propionate	Wibowo 2018.
Vetiver (*Vetiveria zizanioides*)	Poaceae	Roots	Vetiver is applied straight forwardly to the skin for assuaging pressure, just as for enthusiastic injuries and stun, lice and repulsing bugs. It is al so used for arthritis, stings, and burns	Sesquiterpenes and their derivatives	Jindapunna Pat 2018.
Geranium (*Pelargonium graveolens*)	Geraniaceae	Leaves	As an ingredient in perfumes and cosmetics, geranium oil is commonly used. The fundamental oil is additionally utilized in fragrance based treatment to treat various medical issues. In fragrant healing, fundamental oils are breathed in utilizing a diffuser, or weakened with transporter oils and applied to the skin for alleviating.	6-Octen-1-ol, 3,7-dimethyl, Linalool L, Citronellol, Geraniol,	Hsouna, 2012
Patchouli (*Pogostemon cablin*)	Lamiaceae	Leaves	Patchouli oil is an essential oil that comes from the leaves of the patchouli plant. It's often used for things such as skin conditions, relieving stress, or controlling appetite. You can apply the diluted oil to your skin or use it for fragrance based treatment.	Pogostol, Seychellene, patchouli pyridine, Limonene, Pinene, 1-alpha, 5-alpha-epoxy alpha-guaiene	Chakrapani, 2013

Plants	Family	Useful Parts	Uses	Secondary Metabolites	Reference
Rosemary *(Rosmarinus officinalis)*	Lamiaceae	Whole plant parts.	Rosemary is being used to enhance memory, diarrhoea (dyspepsia), joint pain linked to arthritis, loss of hair, and other disorders, although most of these applications are not confirmed by any good scientific evidence. Rosemary is used as a spice in nourishment items. The leaf and oil are used in nourishments and the oil is used in Rosemary is used as a spice in nourishment items. The leaf and oil are used in nourishments and the oil is also being used.	carnosol, carnosic acid and rosmarinic acid (mostly the poly-phenolic diterpenes)	Swamy 2009
Lavender (*Lavandula angustifolia*)	Lamiaceae	Flower, Stem	The lavender flower and oil are used to manufacture medicine. For uneasiness, fatigue, and a sleeping disorder, lavender is commonly used. It is also used for depression, dementia, pain after surgery, and many other disorders, although many of these applications are not confirmed by any good scientific evidence.	Ocimene, Cineol, Camphor, Linalool, Linalyl acetate, Terpinen-4-ol	Prusinowska, 2014

Table 2. Different class of chemical compounds with characteristics, chemical frameworks and therapeutic properties

	Class of Chemical Compounds	Example/Characteristics	Chemical frameworks	Therapeutic properties
1	Hydrocarbon	They contain only carbon and hydrogen molecules. Mono terpene(C10), Sesquiterpene (C15) &Ditiperne (C20) are categoriziation of Terpenoid. It may be monocyclic or tricyclic or aromatic. Example: Farnesene, Thujane, myrcene, Sabinene, Fenchane,. (+) – limonene, (-) –α-pinene.	 Myrcene	Antibacterial, Antiviral, Antitumour, Deconngestant, Stimulant, Heptatoprotectant
2	Oxides	Strongest odorants -1-8 cineole is the most common oxide present in Eos given its wide occurrence in many Eos. Example: Linalool oxide, Ascaridol, Bisabolone oxide, Sclareol oxide.	  Bisabolone Oxide Linalool oxide   Ascaridol Sclareol oxide	Expectorant, Anti-inflammatory, Stimulants
3	Lactones	They are of relatively high molecular mass. Generally found in oils being pressed. Example: Costuslactone, Aesculatine, Citroptene, Nepetalactone, Dihydronepetalactone.	  Costuslactone Citroptene  Nepetalactone	Ativiral, Antimicrobial, Analgesic, Antipyretic, Sedative, hypotensive

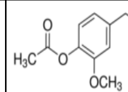
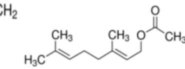
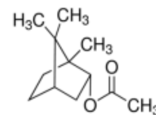
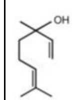
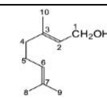
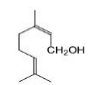
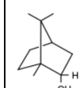
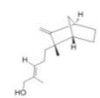
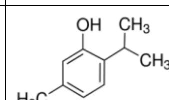
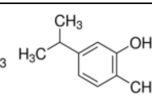
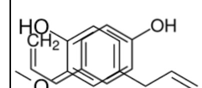
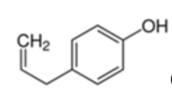
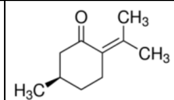
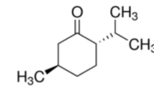
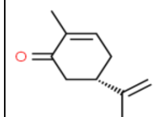
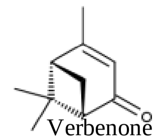
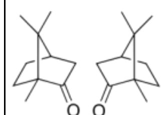
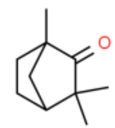
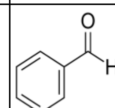
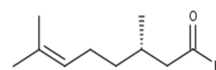
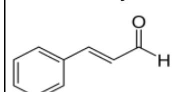
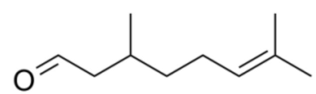
	Class of Chemical Compounds	Example/Characteristics	Chemical frameworks	Therapeutic properties
4	Esters	In several Eos, commonly found. The scent is sweet, giving Eos a nice smell. Example: Geranyl acetate, Eugenol acetate, 3,7, Dimethycota-1,6 dien-3-yl-acetate and 4,7,7 Trimethyl-3-bicyclo (2.2.1) heptanyl.	 Eugenol acetate  Geranyl acetate  Bornyl acetate	Stimulating, Anaesthetic, and Antifungal medicine, Anti-barbed, Antispasmodic
5	Alcohols	Apart from their strong fragrance, without any recorded contraindications, they are EO constituents with the most therapeutic advantages. Example: Borneol, Santalol, Linalool, (+)-Citronellol, Geraniol, Menthol, Nerol.	 Linalool  Geraniol  Nerol  Borneol  Santalol	General anesthesia, anti-inflammatory, antiparasitic, antiseptic, spasmolytic, balancing, toning
6	Phenols	Among the most reactive are these aromatic components. They are extremely dangerous and cause discomfort, particularly to the skin and mucosal. While their properties are more prominent, they are related to alcohols. Generally at room temperature, they are crystals. Example: Thymol, Carvacrol, Eugenol, Chavicol.	 Thymol  Carvacrol  Eugenol  Chavicol	Spasmolytic antimicrobials. Anesthetic, irritant, activating immunostimulation

Table 2. (Continued)

	Class of Chemical Compounds	Example/Characteristics	Chemical frameworks	Therapeutic properties
7	Ketones	Not so popular in the majority of Eos, not as flavours or fragrances of particular significance. Not so popular in the majority of Eos, not as flavours or fragrances of particular significance. They are relatively stable and are not metabolized easily by the liver due to their stability. In certain instances, such as Thujone and Camphor, neurotoxic and abortifaccients can be. Example: Pulegone, Menthone, Carvone, Camphor, Verbenone, Fenchone, Thujone.	 Pulegone  Menthone  Carvone  Verbenone  Camphor  Fenchone	Mucolytic, Cell recovery, Sedative, Antiviral, Nerotoxic, Analgesic, Digestive, Spasmolytic.
8	Aldehydes	Common EO components. They are unstable and are oxidized easily. Many of them can cause irritation to mucous membranes as well as skin sensitization, A soft, fun fruity smell characterises them and can be found in spices such as cinnamon and cumin. Example: Benzaldehyde, Citronellal (citronellal), Myrtenal, Citronellal, Cinnamaldehyde and Citral (geranial and neral).	 Benzaldehyde  Citronellal  Cinnamaldehyde  Myrtenal  Citronellal	Antimicrobial Medicine, Antipyretic, Antiviral, Soothing, Hypocholesterolemic, Spasmolytic, Narcotic, Tonoc, Vasodilators.

BASIL

Aroma Profiles and Chemical Compounds of Basil

Four key essential oil chemotypes of basil were classified by Lawrence (1988): (i) methyl cinnamate-rich, (ii) methyl cinnamate-rich, (iii) two enantiomers of terpene alcohol-rich, (iv) Estragole-rich, and also many subordinate types based on more than 200 studies of O-isolated essential oils. The main compounds responsible for typical basil fragrance were Basilicum and they suggested classification into five forms of chemotherapy, i.e., linalool/trans-methyl cinnamate, methyl chavicol chemotype, linalool/-trans-alpha-bergamotene, linalool and linalool chavicol (Lee et al. 2005). cinnamate (<1 to 52%), germacrene D (1.13 to 5.17%), linalool (1.9-85 percent), methyl chavicol (<1 to 90%), methyl eugenol (0 to 68%), t-cadinol (3.12 to 8.73%) and 1,8-cineole (<1 to 20%), are the most commonly encountered compounds (Grayer 1996; Koutsos 2009; Srivastava 2018; Ozcan and Chalchat 2002; Pandey et al. 2014; Chenni et al. 2016; Simon et al. 1999). Species of Ocimum, other than O. Bacilium, display superior variation in chemical forms and chemical composition (Dudai et al. 2020). A few of these species are rich in various phenylpropanoid collections, some have distinct characteristics of monoterpenoids, and some are rich in sesquiterpenes although it is possible to make certain generalisations extremely variable. High concentrations of camphor are accumulated *by O. kilimandscharicum,* O. high levels of p-cymene, and thymol or exalted levels of alpha-bergamotene, O. β-bisabolene and O are accumulated by tenuiflorum. Varieties of Americanum show great flexibility in the selection of citral or methyl.

Biosynthesis

The most important oil of Tulsi (Basil) is extracted from its glandular cells which are popularly known as trichomes residing on the periphery of the foliages (Gang et al. 2001 and Werker et al. 1993). There is very little knowledge of the biogenesis and evolution control of compound accountable for the flavour consistency of garden-fresh and processed medicinal plants (Wang 1999) and its essential oils with regard to the widespread use and value of sugared Tulsi (Basil) and its extraction oils which is known as essential oil. Two main classes of compounds responsible for basil fragrance are phenylpropanoids and terpenoids. The two distinct basil chemotypes, phenylpropanoids, eugenol and methyl chavicol, are bio incorporation in collateral pathways arising since the similar forefather, L, d-phenylalanine (Dudai et al. 2020) (Figure 1). Gang et al. (2002) observed that eugenol chemotype Tulsi (Basil) contains p-coumaroyl-Coenzyme-

A: cyclitol and a cyclohexanecarboxylic acid p-coumaroyl-CoA: 5-O-shikimate p-coumaroyltransferase (CST) activity and p-coumaroylshikimate 3'-hydroxylase (CS3'H) p-coumaroyl-Coenzyme-A activity (Figure 1), Eugenol biosynthesis mediated by these enzymes, while the encoding genes were extracted mere with the latter enzyme. Another emergent gene in the route way, chavicol synthase (EGS), with its formation and techniques of action ascertain by X-ray crystallography (Louie et al. 2007), was also identified by Basil (Koeduka et al. 2006). The biosynthesis of cinnamic acids are generated from the shikimic acid pathway and controlled by diverse groups of biocatalytic reactions through metabolic process (Dixon et al. 1992). Most cinnamic acids are obtained from phenylalanine through the chemical change of L-phenylalanine ammonia-lyase (Figure 2).

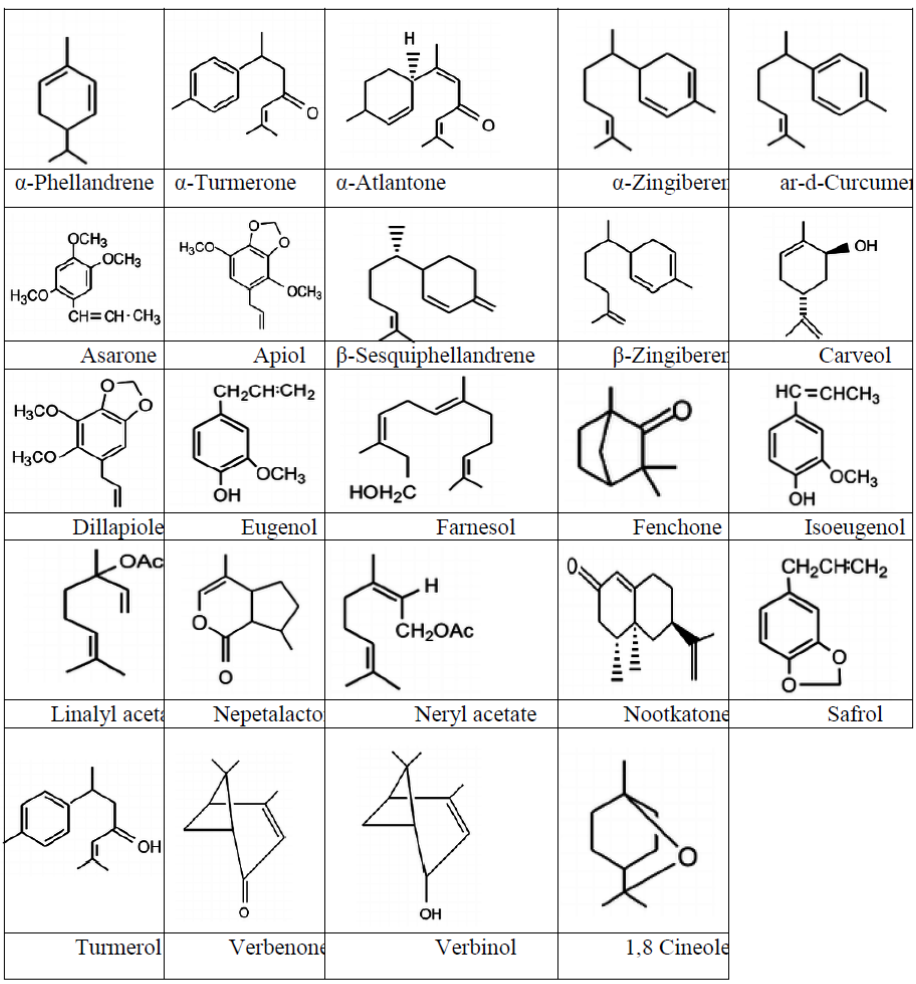


Figure 1. Chemical structures of essential oil constituents of Basil.

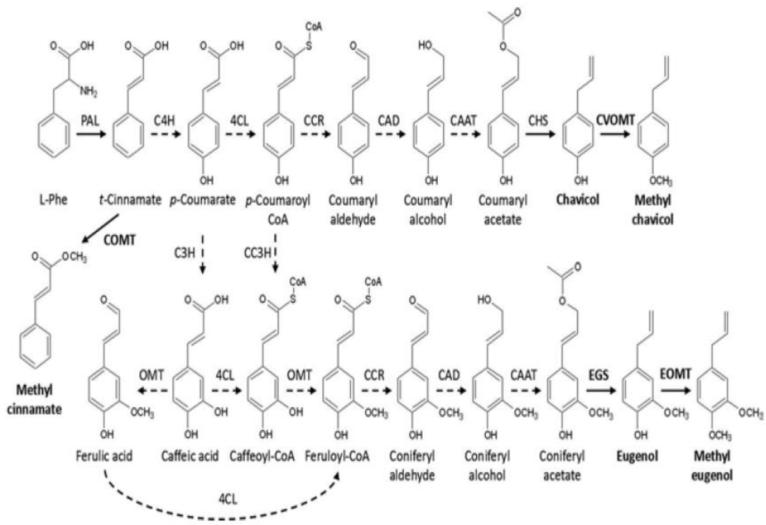


Figure 2. Suggested biosynthetic routes for biosynthesis of phenylpropanoids in basil. Strong arrows reflect reactions that have been seen in basil. Enzymes identified by their encoding genes from basil are represented by bold enzyme names. Names of bold compounds indicate fugitive present in the important oil of basil. Shikimic acid p-coumaroyltransferase, PAL L-phenylalanine ammonia-lyase, C4H cinnamate 4-hydroxylase,4CL p-coumarate CoenzymeA ligase, CADscinnamyl alcohol dehydrogenases, CAAT coniferyl alcohol acetyl transferase, EGS t-anol/isoeugenol, EOMTeugenolO-methyltransferase, CS3'H p-coumaroyl-CoA 3'-hydroxylase, CCR cinnamaldehyde:NADP+ oxidoreductase (CoA-cinnamoylating), CST p-coumaroyl-CoA: CHS chavicol synthase, CVOMT chavicolO-methyltransferase, EGS eugenol synthase, A.

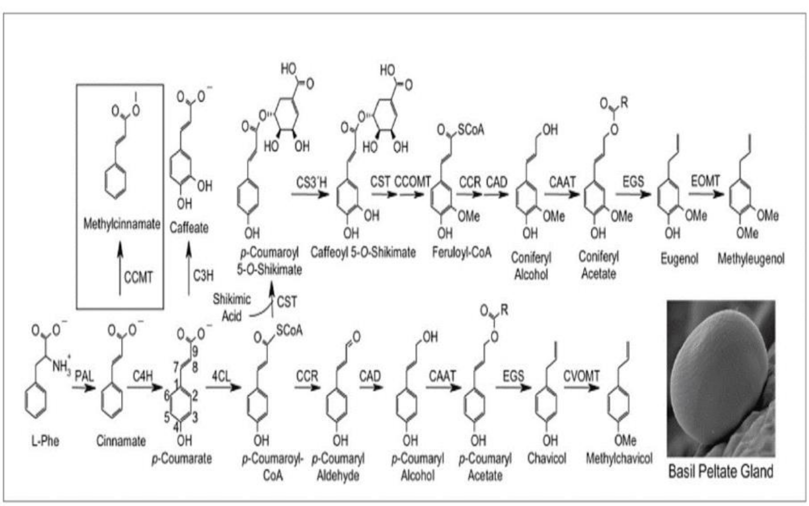


Figure 3. The enzyme abridgement for PAL, L-phenylalanine ammonia lyase; CCMT, cinnamate carboxyl methyltransferase; C4H, Cinnamic acid 4-hydroxylase; 4CL, p-coumaroyl CoA ligase; C3H, coumarate-3-hydroxylase; CST, p-coumaroyl shikimate transferase; CS3'H, p-coumaroyl 5-o-shikimate 3'-hydroxylase isoform 1; CCOMT, ca-coumarate 3-hydroxylase; p coumaroyl shikimate transferase; CST, p-coumaroyl shikimate transferase; CCT, acetyl transferase coniferyl alcohol, EOMT, O-methyl transferase eugenol; CVOMT, O-methyl transferase chavicol; CAAT, EGS, eugenol (and chavicol) synthase; (Kapteyn et al. 2007).

Central part of the enzymes, PAL, is in the regulation of phenylpropanoid plant production with a pivotal role (Achnine et al. 2004; Iijima et al. 2004).

LAVENDER

- Lilac (lavender) and *Lavandula hybrida* (lavandin) belongings of Lamiaceae and to the subfamily of lavandula, comprising more than thirty different species. (LisBalchin 2002). In appearance and aromatic consistency, the different Lavandula species differ (Upson and Andrews 2004).
- Spike lavender – *Lavandula latifolia* Medik.
- True lavender – *Lavandula officinalis* Chaix
- The hybrids of those two species, Lavandin,

The essential oils of lavender are commonly used as nice fragrances in the production of perfumes, soaps, comestibles flavours and several products, also used as antimicrobial agent. For industrial perfumery, Lavandin essential oil is intended; detergents and air fresheners are used to provide scent, For perfumery, beauty products, massage therapy and medicinal uses, lavender essential oil is intended (Guenther 1954; Lis-Balchin 2002; Cavanagh and Wilkinson 2002).

Aroma Profiles and Chemical Components of *Lavender*

The most important oils of lavender are contained in special type of cell which is known as glandular trichomes, located on the periphery of foliage and blooms. Monoterpene hydrocarbon, 50-60 of which have been identified, are the main components. Essential oil properties and fragrance are decided by a small number of prominent molecules which are present in each species distinctively (Woronuk et al. 2011). The most abundant monoterpenes in common varieties of lavender are linalool and linalool acetate (Lane 2010). The formation of essential oil is calculated primarily by the prototype of the plant (Table 3). For the production of 250 kg essential lavender oil, slightly more than 1000 kg lavender oil is needed (Gallotte et al. 2020). Lavenders are less productive than Lavandins (100 kg of essential oil/ha vs. 15-40 kg of essential oil/ha for lavender).

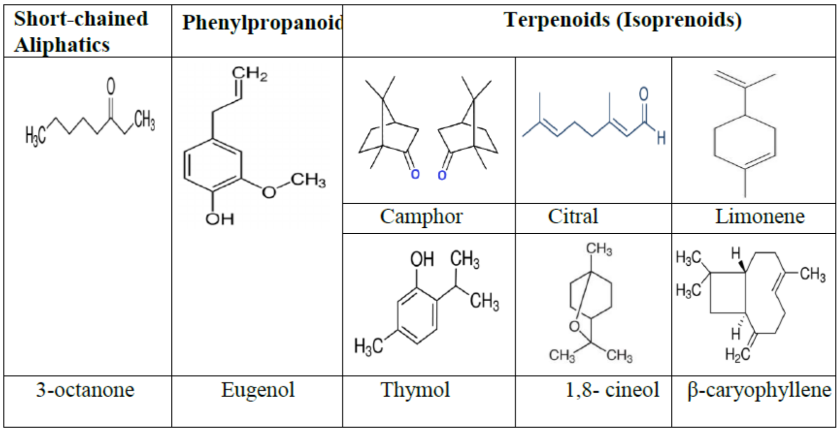


Figure 4. Chemical structures of essential oil constituents of lavender.

Table 3. Important substances of the lavender oils from some of the significant *Lavandula* sp.

Species	**Important substances**	**Reference**
Lavandula viridis L	Camphor and 1,8 cineole	Nogueira and Romano (2002)
Lavandula stoechas L	Fenchon, camphor, myrtenyl acetate and 1,8-cineole	Giray et al. (2008)
Lavandula pinnata L.fil.	α- and β-phellandrene	Figueiredo et al. (1995)
Lavandula pedunculata (Miller) Cav	1,8-cineole and Camphor	Zuzarte et al. (2010)
Lavandula×intermedia	Camphor, Linalool acetate, 1,8-cineole and Linalol.	Desautels et al. (2009)
Lavandula latifolia Med.	β-linalool, Eucalyptol and Alcanfor	Munõz-Bertomeu et al. (2007)
Lavandula angustifolia Mill.	Linalool acetate and Linalol	D'Auria et al. (2005)

Biosynthesis

The main fractions of lavender essential oils are monoterpenes and sesquiterpenes. In case of other plant monoisoprenoids, sesquiterpenes, delta3-Isopentenyl diphosphate (IPP) and its radical isomer di-methylallyl-di-phosphate (DMAPP), which are synthesized from two separate tracks, are synthesised by fixation of the ecumenic five-carbon harbinger (Figure 1). In the cytosol IPP are synthesised by MVA pathway from three acetyl-Coenzyme A molecules, while in the plastids from pyruvate and glyceraldehyde-3-phosphate (G3P) (also referred to as the 1-deoxy-D-xylose-5-phosphate (DXP) pathway) it is produced by the 2-methyl-D-erythritol-4-phosphate (MEP) pathway (Dudareva et al. 2005; Rodriguez-Concepción and Boronat 2002). Monoterpenes, some sesquiterpenes and photosynthesis-related isoprenoids are extracted from the MVA pathways and MEP pathway, are extracted from certain sesquiterpenes, sterols and the mitochondrial ubiquinone side chain (Lichtenthaler 1999). Flux via MEP is partly mediated by the very first enzyme of this pathway,-deoxy-D-xylulose-5-phosphate synthase (DXS). 3-hydroxy-3-methylglutaryl-CoA synthase (HMGS) and 3-hydroxy-3-methylglutaryl-CoA reductase (HMGR), respectively, catalyse the foremost and second leap of the MVA pathway. Recent findings indicate the metabolic interchange between the two pathways, in the face of subcellular compartimentalization of MEP and MEV pathways (Cusidó et al. 2007; Dudareva et al. 2005).

ROSEMARY

Rosmarinus officinalis L. (rosemary) could be a currently, familiar odoriferous plants origin to the Europe & Africa (Bagci et al. 2017) are grown globally (Jardak et al. 2017). It also has antimicrobial effects, essential oil (EO) synthesized from rosemary foliage is routinely used as a potluck conservative agent and also as a therapeutic agent (Borges 2018) and as the most profitably important tribe in the Lamiaceae family of the subfamily Nepetoideae. In Mediterranean preparation, rosemary is commonly used for seasoning food and as a most regarded medicinal plant in kinsfolk's medicines as well as pharmacy, beauty and phytocosmetics (Hammer and Junghanns 2020).

Aroma Profiles and Chemical Compounds of Rosemary

Compounds are contained in the volatile fraction of rosemary EO, with higher mass percentages of the following: camphor (12 to 20%), alpha-pinene (10 to 43%), and eucalyptol (14 to 64%), (Silvestre 2019). Alpha-terpineol (12 to 24%), alpha-pinene (15 to 26%), bornyl acetate (1 to 5%), camphor (10 to 25 percent), borneol (1 to 6%), camphene (5 to10%) and 1, 8-cineole (20 to 50%), are the main compounds of rosemary essential oil, widely used for their germicidal impact. For the presence of the limonene, β-pinene, β-caryophyllene and myrcene in the oil an exclusive odour is form. For example, the phenolic blends, carnosic corrosive and carnosol, are primarily responsible for rosemary's unique cancer prevention agent action. They offer a slightly harsh taste to rosemary and affect the age of off-flavours. Their unmistakable properties of cancer prevention agents have made rosemary an extremely encouraging plant material and essential for the food industry for drug store and beauty care products. In rosemary, the carnosic corrosive and carnosol content varies widely. It is found that carnosic corrosive content varies from 3 mg/g to 50 mg/g on dry weight basis and 0.2 to 0.4 percent carnosol content (Birtić et al. 2015; Hidalgo-Fernández et al. 1998; Richheimer et al. 1996; Schwarz and Ternes 1992).

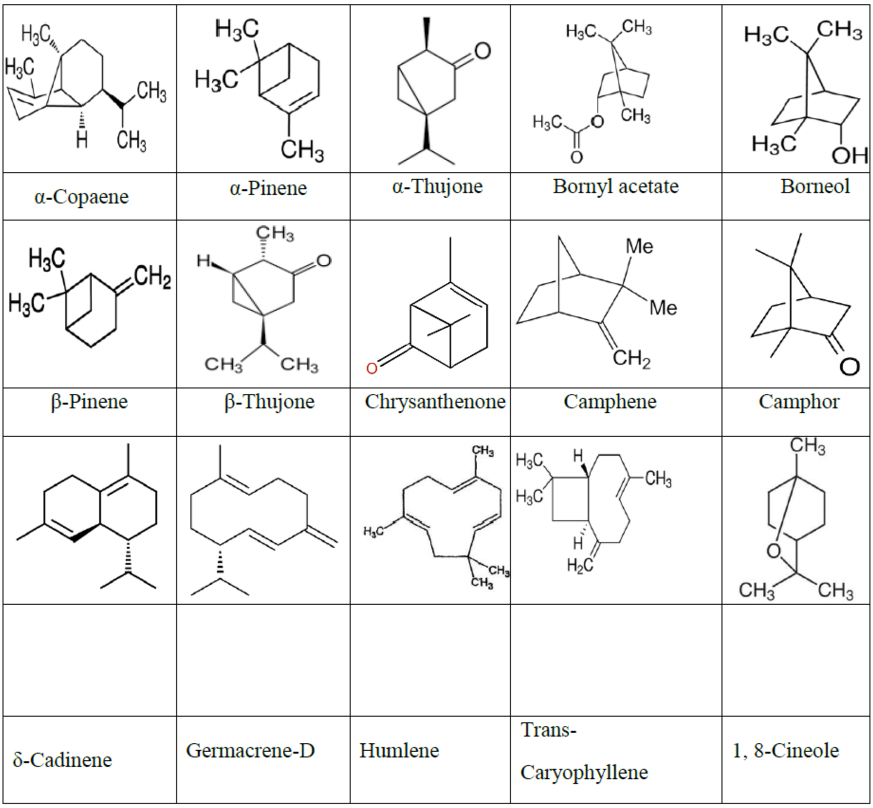


Figure 5. Chemical structures of essential oil constituents of Rosemary.

Biosynthesis

In the mevalonate pathway, diterpenes, consisting of the repeating 5-carbon backbone skeleton, isoprene unit(s) is extracted biosynthetically (Habtemariam 2016). Isopentenyl pyrophosphate (IPP,1) and dimethyl lallylpyrophosphate (DMAPP,2) are the two known isoprene building blocks that polymerize to form the precursor of 20-carbon diterpene (4isopreneunits) by head-to-tail fashion called dimethyl lallylpyrophosphate (DMAPP, 2). By means of transformations including aromatization, cyclization, rearrangement and a sequence of reaction leaps resulting from phosphate group impairment, including carbonium ion removal, construction of subgroups of diterpene the GGPP results in. The rosemary identified so far is the abietane type class of diterpenes (5-7) comprised of six-membered tricyclic ring systems, one of which is aromatic (Bruckner 2014). Biosynthetically, it is understood that abietane-type diterpenes derive from the immediate predecessor, subclass labdane. Variegated intrinsic products that have been exhibited to contain mingles of unprecedented fashion and biological significance are the labdane group of diterpenes alone (Habtemariam 2016).

LEMONGRASS

Cymbopogon citratus L. is an associated aromatic perennial plant with long slender, leaves of the Poacae family. It’s equally distributed and widely used for medicinal properties throughout the tropical regions of South and Central America. Citratus tea to alternative beverages, attributable to its chemistry characteristics, as well as style, distinctive sourish smell, colour, strength, and intensity, whereas several others consume *C. citratus* tea or simmering for physiological reasons. *C. citratus* is additionally extra to non-alcoholic beverages and baked foods as a flavourer and a preservative in confections and cuisines.

Aroma Profiles and Chemical Compounds of Lemongrass

Cymbopogon citrates leaf contains a high composition of essential oil. It includes citronellol (cymbopogon and cymbopogon), citral, myrcene, geraniol, and alpha-oxobisabolene (a combination of terper-noids and geraniums). On the basis of plant species and geographical location (12-15 percent of Western Indian lemongrass grass, 10 to 13% of East Indian) their content varies depending (Ranitha et al. 2014). Citralis is essential in the plant’s flavour formation (Ranitha et al. 2014 and Costa et al. 2013). Major ingredients such as decanal (0.25%), selina-6-en-4-ol (27.8%), 3.7-dimethyl-1,3,6-octatriene (0.58%), neointermediol (7.2%), alpha-cadinol (8.2%), eudesma-7(11)-en-4-ol (5.3%), naphthalene (0.79%) and methyl heptenone (1.2%), were reported (Costa et al. 2013 and Vahid et al. 2013). Recent studies have reported the existence of cubebol (4.7%), humulene (4%), elemol (41%), and β-eudesmol (45%) (Halabi, 2014), citral diethyl acetal, citralacetate, (Bharti 2013 and Kumar 2013), acetate, geranyl citronella, verbenone, sabinene, (Soares 2013), 8-dien-2-olcis (17.34%), limonene (19.33%), mentha-1(7), mentha-2, 8-diene-1-ol tranella, mentha-1(7) (Soares 2013).

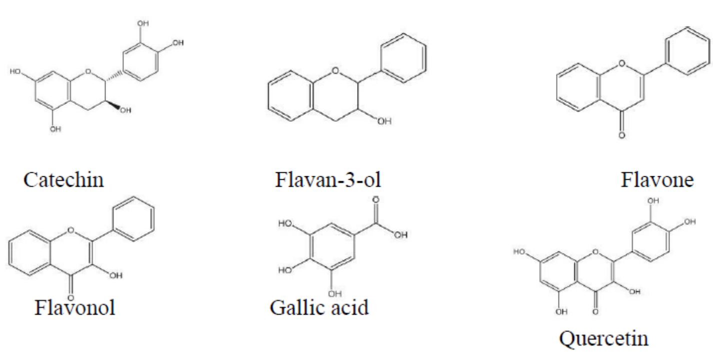


Figure 6. The structures of *C. citratus* flavonoids and phenolic compounds Biosynthesis.

Biosynthesis

Biosynthesis of monoterpenes has been a focal point since long (Banthrope et al. 1980; Croteau 1981). Various approaches were adopted with the advent of technology, including the use of radioactive compounds (Luthra and Ganjewala 2007). Despite the fact that these endeavours gave huge bits of knowledge, basic oil biosynthesis in lemongrass couldn't be altogether fathomed and still has research gaps. The fundamental oil in lemongrass is basically a mixture of cyclic and non-cyclic monoterpenes which are primarily gotten from geranyl diphosphate (GPP) which goes about as the antecedent for monoterpenes biosynthesis (Gupta and Ganjewala 2015). The GPP is formed by the condensation of isopentenyl diphosphate (IPP) and dimethylallyl diphosphate (DMAPP) units. This IPP can either be synthesised in the plastid (MEP-pathway) or in the cytoplasm (MVA pathway). The IPP units produced by MVA-pathway could be moved to plastids for blending monoterpenes alongside other IPP units created through MEP-pathway. Therefore, essential oil biosynthesis in lemongrass leaves occurs either through cytoplasmic MVA pathway or through the plastidic-MEP pathway (Gupta and Ganjewala 2015).

Mevalonate Pathway

For the first step in acetate-MVA pathways, 2-acetyl-Coenzyme A molecules condense to generate acetoacetyl-Coenzyme A. This condensation is catalysed by acetoacetyl-Coenzyme A thiolase enzyme. In the second reaction step, acetoacetyl-Coenzyme A is further condensed into 3 hydroxymethylglutaryl-Coenzyme A (HMG-Coenzyme A) through HMG-CoA synthase with the addition of another acetyl-CoA molecule. By the HMG-CoA reductase HMG-CoA is reduced into mevalonate (MVA). Mevalonate plays a crucial role in the MVA pathway by acting as a precursor for the biosynthesis of IPP units.

Damask Rose

Rosa damascena Mill, called summer Damask rose, a bushy perennial ligneous plant, most celebrated decorative worldwide, in terms of perfumery and food, plants of the Rosaceae family virtually the full production in Balkan nation and Turkey, the 2 biggest producers of attar within the world, provision over 80–90% of this product to the trigintipetala Dieck (30-petalled rose), that vegetatively amplified for hundreds of years and historically used for preparation of attar, Concrete Rose, rose utmost and essence, that measure enclosed in first-rate fragrance product additionally as in product of the Health and pharmaceutical sectors (Douglas 1993; Mirali et al. 2012).

Aroma Profiles and Chemical Compounds of Damask Rose

Rose oil extracted from *R. damascena* f. sp. *trigintipetala*, a potent mix of more than 300 compounds. In the top perfumery market, this composition makes it indispensable and defines its ability in human and veterinary medicine. Chemical composition of the essential oil mainly comprised of hydrocarbon compounds, phenyl derivatives terpenic (Balinova-Tsvetkova et al. 1977; Ponomaryov et al. 1979; Kovats 1987; Pellati et al. 2013). Few number of sulphur-containing compounds has also been reported (Omata et al. 1991). Eight of its components - ethanol, nerol, heneicosane, citronellol, β-phenylethanol, heptadecane, geraniol, and nonadecane, refered by the International standard regulation (ISO 9842:2003) (Rusanov et al. 2020).

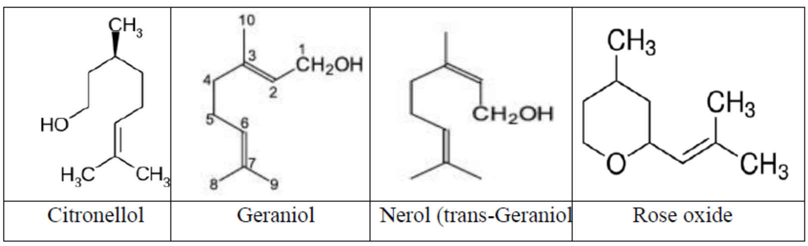


Figure 7. Chemical structures of essential oil constituents of damask rose.

Conclusion

There are no health effects or reactions in the supply of flavouring medicine. Aromatic has significantly and uncharacteristically increased the attribute of the first body care system. Square measure of aromatic plants applied as favouring vicergent in potluck and potable enterprises. In the cleaning products, pharmaceutics, maquillage, and soap industries they are also widely used. They are applied as bactericidal, fungistatic, anti-incendiary, cancer-opposed, anodyne and aseptic agents in human medicine. Now a day's studies into pharmacological medicine and photochemical screening of secondary metabolites have targeted interests in aromatic plants to find out their therapeutic efficacy and improve the assembly of essential oils and alternative compounds which are bioactive, for their medicinal activities in aromatic plants. There are also records of their applications in the food, pharmaceutical, cosmetic, beverage, soap and detergent industries. In order to enhance the phytochemical and medicine studies of aromatic plants vital factors, e.g., mode of propagation, synthesized methods and harvest time should be controlled and discussed. This will improve the composition of chemical science and bio-activities of the synthesized products of aromatic plants and in this manner increase their quantity.

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Chapter 16

FUTURE RESEARCH STRATEGIES

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ABSTRACT

Plant based essential oils play a major role as one of the important raw materials for many of the industries and also for securing consumer acceptability in the products used. Aromatic crops and its diversified products have huge potential in the markets owing to the demand for these plant based molecules and compounds which are considered safe and environmental friendly. These products are extensively used in pharmaceutical, cosmetic, nutraceutical, aromatherapy and agro-based industries. Their demand is expected to rise both in the domestic and international markets with the growing awareness against synthetics and inclination towards naturals. The future of aromatic plant sector is bright considering the existing market demand scenario coupled with strong research base and the technological skill involved in this sector. The chapter provides an overview of the present scenario, opportunities, recent trends and future strategies aromatic plant sector.

Keywords: essential oils, aromatic crops, nutraceutical, aromatherapy, perfumery

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INTRODUCTION

Aromatic plants includes the group of plants that are capable of producing aromatic compound which have importance in industries like perfumery, food, pharmaceutical, cosmetics, liqueur, etc. Such particularities in aroma are attributed to the presence of variety of complex chemicals, volatile, highly concentrated and odorous compounds known as essential oils. The essential oil secreting glands in plants are located in different parts of the plant in varying amounts. It may be present in flower buds, roots, foliage, bark, fruit, seeds, etc. and are accumulated in oil ducts, resin ducts, glands or trichomes (glandular hairs) of the plants (Baser and Demirci 2007). The essential oils represent the distilled essence of the active constituent compounds in plants. These oils tend to evaporate on exposure to air at ordinary temperatures and hence are referred to as volatile or ethereal oils (Joy et al. 2008). For aromatic plants, the extraction of essential oils can be done either through steam distillation, hydro-distillation, solvent extraction and more recently the super carbon dioxide extraction method (Nakatsu et al. 2000). In today's world of growing demand for organic products, the trade for these aromatic plant compounds has also recorded a positive trend.

Since the beginning of the human civilization, the sense of smell has played an important role directly or indirectly in lives of human beings. For instance, the sweetly scented flowers attract the insects and favours in cross pollination or the fruit maturity can be judged by the aroma that it emits and can be consumed. The knowledge of usage of essential oils as fragrance, medicine, in aromatherapy, healthcare systems has been known throughout Egypt, India, China, Arabia, Greece since the ancient times. With whatever knowledge they had, essential oils were extracted through distillation techniques. The use of essential oils gained popularity India under the Mughal emperors who had a great affinity for perfumes and flavours. Their gardens would also consist of sweetly scented flowers like *Jasminum* spp., *Michelia champaca* etc. (Joy et al. 2008).

Essential oils are no longer considered as a luxury product; rather it has become an important part in securing consumer acceptability in almost every day used products. There are nearly 300-400 chemical compounds which are responsible for the fragrance, flavour, medicinal and therapeutic effects of essential oils. It has been reported that more than 200-300 essential oils are commonly used while; another 800 different types are used occasionally. These oils are extracted from commercially cultivated crops (80%) and also from wild collections (20%) (Joy et al. 2008). The usage of essential oils for various purposes in daily life has been increasing. Flavour and fragrance industries consume about 90% of global essential oil production. Due to the characteristic flavour, fragrance, other biological and medicinal properties, essential oils are used in several industries such as, food industry as flavours; cosmetic industry for incorporation of fragrance in various products; pharmaceutical industry for its medicinal properties as anti-microbial, anti-inflammatory activity, anti-depressant, etc. (Burt 2004; Hussain et al.

2008; Patin et al. 2009; Teixeira et al. 2013). Essential oils are widely used for aromatherapy and in other alternative healthcare products. They also find its use as insect repellents (citronella, basil, eucalyptus, geranium, lemongrass and peppermint), and detergents (orange, lemon, bergamot and grapefruit).

Table 1. Some important aromatic crops under cultivation in India

Crop	Scientific name	Family	Plant part used	Yield (kg/ha/yr)	Rs/kg essential oil
Lemongrass, Nimbu Ghas	*Cymbopogon flexuosus* L.	Graminae	Leaves	200-250	600-800
Palmarosa, Rosha Ghas	*Cymbopogon martinii* L.	Graminae	Leaves	175-250	2000-2500
Citronella Java	*Cymbopogon winterianus* L.	Graminae	Leaves	150-180	1000-1250
Menthol mint/ Japanese mint/ Corn mint	*Mentha arvensis* L.	Lamiaceae	Leaves and twigs	200-225	1000-1400
Indian Basil, Sweet Basil, French Basil	*Ocimum basilicum L.*	Lamiaceae	Inflorescence and twigs	100-125	800-1000
Vetiver	*Veteveria zizanioides* L.	Graminae	Roots	15-18	15,000-20,000
Patchouli	*Pagostemon patchouli* L.	Lamiaceae	Inflorescence and twigs	60-70	3000-3500
Desi Gulab, Chaiti Gulab, Damask Rose, Bulgerian Rose	*Rosa damascena* L.	Rosaceae	Flowers	1.5-2.0	2,00,000-2,50,000
Geranium or Rose Geranium	*Pelargonium graveolens* L.	Geraniaceae	Leaves and twigs	30-35	6000-7000
Lavender/ Lavendula/ True lavender	*Lavendula officinalis/ L. angustifolia* L.	Lamiaceae	Inflorescence and twigs	40-60	4000-5000

Global and Indian Scenario of Essential Oil Business

The demand for essential oil business has taken a major fillip owing to the changing lifestyle and fashion, preference for natural and organic care products, increasing popularity of aromatherapy (in massage, inhalation, bathing, etc.) therapeutic and health related benefits (Ahuja and Singh 2019). Another reason for its popularity is the ability of essential oils to help people overcome depression, anxiety disorder coupled with its calming properties which are very common in the recent times. Studies have reported that the largest consumer of essential oil products in USA followed by France, Germany, UK and Japan (Holmes 2005). The leading producers of essential oils across the globe are Brazil, China, India, Indonesia, Sri Lanka, Morocco, Tunisia, Egypt, Algeria, France, Canada and North America. Total area covered by aromatic crops is 600,000 ha of the 1 billion ha under agriculture area with over 1 million farms engaged in its production representing about 0.06% of the total farms worldwide (Barbieri and Borsotto 2018).

Out of total estimate of nearly 3000 essential oil bearing plants, 300 of these are reported to be commonly traded at the global level (CBI 2009). Only 50% of these plants are cultivated in the fields, while the rest are collected or harvested from wild populations. The global essential oil production was estimated to be 1, 50,000 tonnes in 2017 which has shown to be three times more since 1990 (45,000 tonnes). It is expected that the production will increase to 37,000 tonnes worth 10 billion US dollars (Barbieri and Borsotto, 2018). Rose oil, tea tree oil, lavender, citronella, patchouli, lemon grass and geranium are the major essential oils that are in demand and traded worldwide.

India shares around 21-22% in the value of essential oils worldwide and nearly 16-17% of global essential oil quantity (Shukla 2015). The actual area and production of aromatic crops in India is not available. However, the area and production under medicinal and aromatic crops in 2018 is 7.2 lakh ha with a production of 8.66 lakh MT, respectively. Rajasthan (56%) is having the highest area under medicinal and aromatics, but Madhya Pradesh (44%) is leading in production (Chowti et al. 2018; NHB 2018). The major essential oils produced in India are ajwain, corn mint, cumin, rose, sandalwood, rose, patchouli, citronella, lemongrass, ginger, etc.

OPPORTUNITIES

The production of aroma products is not enough to meet the growing demand, as the demand for naturally originated ones is on raise. Aromatic crops generate high returns per unit area, hence considered as low volume, high value crops. The cultivation of aromatic crops has moved on from being tagged as a minor crop to as one of the potential and alternative crop plants with maximum returns in a short span of time. The economic importance and value of aromatic and medicinal sector is expected to increase with the adoption of Intellectual Property Rights (IPRs) in the field of pharmaceuticals where reverse engineering would no longer be allowed. Ultimately, it will cause an increase in the price of the allopathic drugs/medicines and in turn more demand for plant based products and preparations. As a result of the growing interest in organic products, new opportunities have emerged for production and export of such plants and in developing curative drugs for a number of ailments which are considered safe and cost effective.

The major value added products produced from aromatic crops oils and oleoresins, specialty extracts and blends which has been used for preparation of different formulations and finished products in various industries. The Indian export basket has a potential for area expansion in the global market for giving opportunities to the marginal and small growers. The Indian trade also has acquired comparative advantages over other countries in terms of congenial climatic conditions and low labour costs for the production of aromatic crops. The Indian industries over the last decades have acquired knowledge through technological interventions for the production and processing of aroma produce (Joy et al. 2008).

The opportunity for cultivation of high value aromatic plants can play a major role in boosting the livelihood and income of the small and marginal farmers. While enhancing their skills and increasing their knowledge base on the advantages of aromatic plants and how they play an important part of modern day medicine, they are also provided with the opportunity to come up with a new product in the market assuring them of better price of the produce. Further, aromatic crops can be grown throughout the year in one season or the other which provides opportunity for a regular cash flow and employment opportunities for the farming community.

The use of essential oils in the field of agriculture as anti-repellent, anti-feedant, organic insecticide/herbicide and as growth booster is well known. However, only few of these plants have been proven to possess such properties while other crops are still yet to be investigated providing fascinating realms of further research. Adoption of advanced techniques of cell and tissue culture for production of secondary metabolites under controlled conditions also offers exciting opportunities for future research.

RECENT TRENDS IN AROMATIC CROPS

In recent years, the preferences of the products which are natural have increased due to their health benefits. In this context, most of the scientific studies have been focused on natural resources. Active principles of natural products can be obtained by different applications. These products are manufactured by the flavour and fragrance industries and used in food, perfumery, cosmetics, pharmaceuticals and aroma-therapy sectors. In conventional applications, these products or active compounds can be obtained by various methods such as, distillation, expression, extraction or separation from the plant matrix by some chromatographic techniques depending on the nature of the material. Nowadays, sophisticated techniques *viz*. Supercritical fluid extraction, Ultrasound assisted extraction, Microwave assisted extraction are employed in order to produce specialized extracts (Gayas and Kaur 2017). Some of these techniques may not necessarily be used for the commercial production of essential oils but are considered as valuable new applications for micro-analysis of essential oils from plants or other biological materials. Biological activity of constituents is another important parameter while carrying out the isolation from natural products. To find out the novel active principles of the essential oils instruments such as, GC-MS (Gas Chromatography Mass Spectrometry), NMR (Nuclear Magnetic Resonance), HPTLC (High-performance Thin Layer Chromatography) are used and this information serves as a guide for the scientist to identify these compounds in other aromatic crops.

Strategies to Improve the Cultivation of Aromatic Crops

Aromatic crops which are grown under forest cover and are shade tolerant can be incorporated with the agro-forestry system of cultivation which is an important strategy for promoting their cultivation and conservation. Several feasible approaches such as integrating shade tolerant aromatic crops at lower strata species in multistoried systems; cultivating short cycle aromatic as intercrops in existing stands of plantation tree-crops and new forest plantations, can be adopted.

1. The growing demand for aromatic crops makes them alternative remunerative crops to the traditional ones for smallholders in the tropics. Being underexploited species with promising potential, the aromatic crops require research attention on a wide array of topics ranging from propagation methods to harvesting and processing techniques, germplasm collection, genetic improvement to quality control and market trends.
2. Strategic plans for improving the post harvest aspects and value addition of aromatic crops right from its harvest till its transformation high value aromatic products, encapsulation of extractives and fixation of fragrant compounds.
3. To develop sustainable and profitable production systems, ensuring reasonable price for producers, implementation of trainings and demonstrations for crop production, timely transfer of technologies from lab to land, mechanization in production and processing, ensuring Good Agricultural Practice (GAP), promoting organic farming and crop insurance.
4. Collective efforts to bring down the cost of production per unit area, processing, and marketing which will provide better market opportunities and quality products. Bridging the gap in production and marketing is also necessary to make the products available at the consumers door step. e- Marketing channels will be a great boon to the essential oil manufacturers to bypass the agents and sell products directly to the consumers.
5. Medicinal and aromatic plant sector still remains unorganized and may lead to problems in quality of the products, safety as well as marketing channels. Further, being a high value potential crop, a strategy may be devised so as to

enable for processing and value addition on or close to the field itself and to allow for more equal distribution of benefits amongst the growers throughout the value chain

6. Joint forest management with farmers and contract farming with drug companies with buyback arrangement will promote cultivation of aromatic plants.
7. Shift in cultivation from traditional areas to non-traditional areas, identifying new areas of production, introduction of exotic aromatic plant species having high market potential like vanilla, rosemary, thyme, area expansion of high value crops like saffron that can boost the exports, establishment of export linkages (Joy et al. 2008; Rao et al. 2004; Solidaridad 2020).

CONCLUSION

Changing lifestyles, growing concerns for health, orientation towards organic products and its derivatives for a good health and healthy living, are some of the driving factors that have led to more and more people to use aromatic plant products (Bikash, 2005). The need of the hour is the joined efforts at the global and domestic level by the farming community, entrepreneurs, government agencies, non government organizations, scientists and researchers of universities for the widespread popularization and cultivation of aromatic plants to meet the demands of the domestic industry as well as for export. Taking advantage of the diverse climatic conditions, abundant bio-diversity and natural resource base, adequate infrastructure, trained manpower, India may look for achieving global leadership through export of quality produce and products from these aromatic crops.

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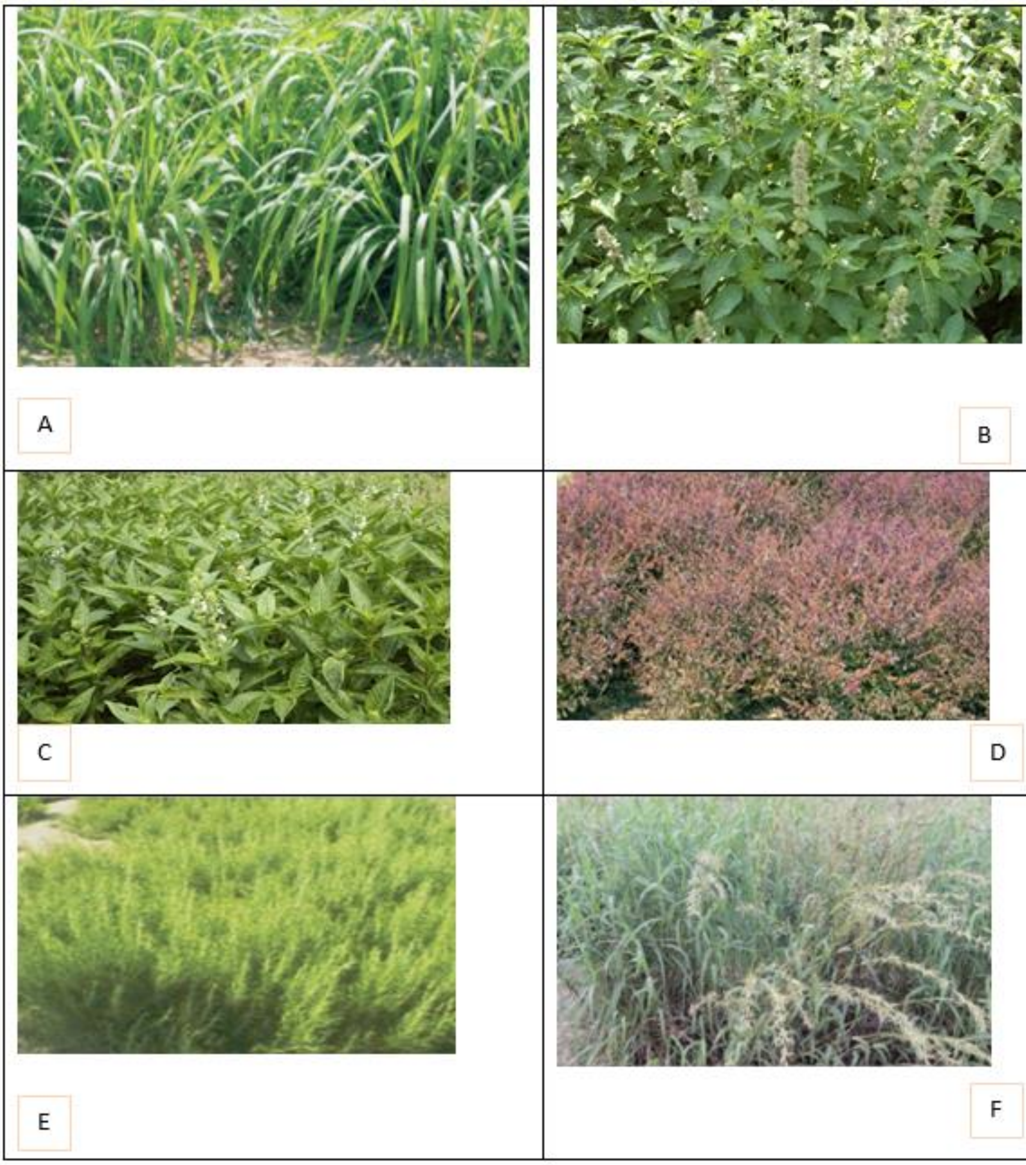
PHOTOGRAPHS OF SOME COMMON AROMATIC PLANTS

A: Scented Rose (*Rosa sp*) **B:** *Pelargonium graveolens* L. **C:** *Mentha arvensis* L.
D: *Mentha piperita* L. **E:** *Artemisia annua* **F:** *Pogostemon cablin* Benth



A: *Cymbopogon winterianus* **B:** *Ocimum basilicum* L. **C:** *Ocimum gratissimum* L.
D: *Ocimum sanctum* L. **E:** *Rosmarinus officinalis* **F:** *Cymbopogon martini* [Roxb]

A: *Artemisia pallens* Wall ex.DC **B:** *Vetiveria zizanioides* L. **C:** *Matricaria chamomilla*

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Prof (Dr.) Amit Baran Sharangi is one of the Professors of eminence in Horticulture and former Head, Department of Plantation, Spices, Medicinal and Aromatic crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya (Agricultural University), India. He is in the profession of teaching for twenty three years. He spent times in Prof. Cousen's lab in Melbourne, Prof Picha's lab in USA, Dr Dobson's lab in UK and continued research on herbs and spices. One of his papers has ranked among the top 25 articles in ScienceDirect. He has published about 84 research papers in peer-reviewed journal, 50 conference papers, 22 books from reputed publishers including Springer as well as several book chapters published from Springer Nature, Tailor and Francis, CRC Press, Nova Science Publishers (USA) and scores of popular scientific articles. Presently he is associated with over 50 international and national journals as editor in chief, associate editor, technical editor, editorial board member and active reviewer. Prof Sharangi has visited abroad extensively on academic mission and obtained several international awards viz., ENDEAVOUR Post-doctoral Award (Australia), INSA-RSE Visiting Scientist (UK), FULBRIGHT Visiting Faculty (USA), Achiever's Award (SADHNA), Marquis Who's Who (USA), Man of the Year-2015 (Cambridge, UK),Outstanding Scientist and Higher Education Leadership Award(Venus International Foundation), Bharat Ratna Mother Teresa Gold Medal Award-2020 (GEPRA), etc. He had a couple of invited lectures in UK, USA, Australia, Thailand, Israel and Bangladesh on several aspects of herbs and spices, chaired several scientific sessions, delivered a couple of key note addresses in seminar, webinar, e-conferences and associated with a number of research projects as Principal and Co-Principal Investigators having academic and empirical implications. He is an elected FELLOW of WB Academy of Science and Technology, (FAScT). He is also the Fellow of International Society for Research and Development (FISRD, UK), the Society of Applied Biotechnology (FSAB), Academy of Environment & Life Sciences (FAELS), International Scientific Research Organization for Science, Engineering and Technology (FISROSET), Scientific Society of Advanced Research & Social Change (FSSARSC), Society of Pharmacognosy and Phytochemistry (FSPP), International Society of Noni Sciences (FISNS). He is an active member of several science academies and societies like NASI, NABS, ISNS, IAHS (Formerly HIS), CWSS including the New York Academy of Science (NYAS),World Academy of Science, Engineering and Technology (WASET), African Forest Forum (AFF), to name a few.

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