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Regulation of essential oil production in plants

N.S. Sangwan, A.H.A. Farooqi, F. Shabih and R.S. Sangwan*
*Central Institute of Medicinal and Aromatic Plants [CIMAP], P.O. CIMAP, Lucknow, 226 015, India; *Author for correspondence*

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Abstract

This review provides a summary of the physiological dynamics and regulation of essential oil production, from the literature and available information on diverse volatile oil crops. Essential oil production is highly integrated with the physiology of the whole plant and so depends on the metabolic state and preset developmental differentiation programme of the synthesising tissue. Essential oil productivity is ecophysiologically and environmentally friendly. These and other aspects of the modulation of essential oil production are presented, along with a brief outline of the current concept of the relevant biosynthetic mechanisms.

Introduction

In the world today, the traditional food, forage and fibre crops are not the only plants of key agricultural and trade significance, but they also include plants whose secondary metabolites are valued for their characteristic aromatic or therapeutic attributes, or as main natural inputs to the proliferating perfumery and chemical industries. The aroma-yielding plants or their distilled volatile oils are known to have been, and in many cases, still are in use in various human activities, from religious ceremonies and adornments, to remedies and personal use, even before the recorded history of mankind. As active flavour and fragrant ingredients of perfumery and cosmetic concoctions, the demand for these oils is also rapidly increasing in hygiene and health care formulations (e.g. oils from thyme, mint, basil, eucalyptus etc. in toothpastes, mouthwashes etc.) including fringe medicines (e.g. aromatherapy). Also, some specific oil constituents, used as chiral auxiliaries in synthetic organic chemistry and microbial transformations of common structures to give highly functionalized substances of enhanced economic value, is another dimension of their commercial importance. The world trade in essential oils is expected to continue to expand tremendously in the foreseeable future, as a consequence of the growing number and preferences of consumers and the wider spectrum of the uses of these compounds. The agro-industrial uses constitute a key impetus to the present rate of inter-disciplinary research on essential oil plants, targeted towards increased production and quality enhancement of the oils.

The essential oil producing species are not restricted to any specific taxonomic group, rather they occur widely across the plant kingdom. Even within, for example, the angiospermic division of plants, the volatile oil plants are almost evenly distributed among the dicots and monocots of both temperate, as well as tropical habitat, covering a large number of families ranging from Gramineae (aroma grasses) to Rosaceae (roses). This scale of distribution of essential oil plants across the wide variety of plant taxonomic groups is paralleled by, (i) a variety of epidermal cellular structures producing and/or sequestering essential oils, and (ii) a myriad of quantitative and qualitative combinations of the chemical constituents of the volatile oils of these plants. In fact, it may not be out place to state that the biogenetic capability of essential oils or constituent secondary metabolite(s) may have evolved as early as the appearance of land plants. Rather, the recent discovery of the operation of a eubacteria type of metabolic pathway for the generation of building blocks (isopentenyl pyrophosphate) of essential oil terpenoids in the plastids of glandular trichomes of many essential oil plants, such as, mints, geranium, basil, thyme and chamomile etc. (Litchenthaler 1999) suggests the prokaryotic ances-

Table 1. Some of the commercially and industrially important essential oil crops popularly cultivated in different geographic regions of the world

Aromatic species	Family	English name	Usual major terpenes and/or phenylpropanoid component(s) of volatile oil
Mentha arvensis	Labiateae	Cornmint	Menthol, Menthyl acetate
Mentha piperata		Peppermint	Menthone, Menthol, isomenthone
Mentha spicata		Spearmint	Carvone, carveol
Cymbopogon winterianus	Poaceae	Citronella	Citronellal, citronellol, geraniol and their acetates
Cymbopogon flexuosus		Lemongrass	Citral, geraniol
Cymbopogon martinii		Palmarosa	Geraniol, geranyl acetate
Eucalyptus species	Myrtaceae		Eugenol, methyl eugenol
Rosa damacena	Rosaceae	Rose	Geraniol, rose oxide
Salvia officinalis	Labiateae	Sage	Camphor, thujone
Artemisia annua	Compositeae	Qinghasu	Artemisia ketone
Artemisia dracunculus		French tarragon	Methyl Chavicol
Ocimum basilicum	Labiateae	Sweet basil	Chavicol, Linalool
Pelargonium graveolens	Geraniaceae	Geranium	Geraniol, *L*-citronellol
Carum carvi	Umbellifereae	Caraway	Limonene, Carvone
Lavandula officinalis	Labiateae	Lavender	Geraniol, Linalool and their esters
Matricaria chamomilla	Asteraceae	Chammomile	Azulene
Santalum album	Santalaceae	Sandal wood	Santalol
Vetiveria zinzoides	Poaceae	Vetiver	Vetiverol
Origanum majorana	Labiateae	Sweet marjoran	Terpenen-4-ol, pinene
Melaleuca altenifoli	Myrtaceae	Tea-tree	Tepenen-4-ol, Terpinolene

try of the basis of the biogenetic pathway of mono- and sesquiterpenoid essential oils. This inheritance of the prokaryotic pathway of terpenoid biosynthesis might have occurred through the endosymboint eubacterium during the evolution of the eukaryotic progenitor cell for plants.

In general, terpenoids are a predominant constituent of plant essential oils, but many of these oils are also composed of other chemicals like phenylpropanoids. In fact, almost all essential oils are extremely complex in composition, with respect to the presence of a large variety of highly functionalised chemical entities, belonging to different chemical classes (monoterpenoids, sesquiterpenoids, phenylpropanoids etc.). These are further diversified as belonging to a variety of skeletal types (limonene, myrcene, terpenene, farnesene, eugenol etc.). Many of these oil constituents are present only in traces, or in insignificant proportions, and are rarely referred to in the gross essential oil trade, unless associated with a fine sensory evaluation of acceptability or disagreement. Thus, the regular types of aromatic species, their genetic variants and the essential oils extracted from them, are often recognised chemotypically, only on the basis of major skeletal types or the individual chemicals they contain. Nevertheless, sometimes even the minor oil constituents have major organoleptic roles to play. In fact, it is not a feasible task to define all the oil constituents, with respect to addressing the chemotaxonomic, biochemical and physiological aspects of their production. Some of the major volatile oil crop species, contributing significantly to the volume of global trade, are listed in Table 1, along with the chief constituent(s) of their essential oils.

The essential oils in these plants, contained in leaves and/or reproductive structures and sometimes in the stem and roots, are usually recovered by steam distillation of the relevant biomass. Commercially, these crops are traded as fresh or dried herbs or as the oil distilled from them, depending upon the locally available state of agrotechnology, or on the specific end uses. The list of such industrial aromatic plants and aromatically off-types of the domesticated aromatic plants is expanding as a consequence of newer collections, genetic improvements and agrotechnology developments for commercial cultivation as modern cash crops. To achieve better oil yields and more profitable economics of cultivation under diverse agro-climatic, seasonal and soil conditions, research efforts have been focused, not only on development of better cultivars, chemotypes and ecotypes, but also on discerning physiological modulations of