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## **Green Pesticides Handbook Essential Oils for Pest Control**

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### **Mentha Oil**

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# 4

## Mentha Oil

Hamir Singh Rathore, Shafiullah, and Raveed Yousuf Bhat

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### 4.1 Introduction

*Mentha* is an aromatic herb plant having pleasant odor leaves. In Japan, it is known by the name *Pudina*. In India, it is also known by the name *Pudina*. The native place of *Mentha* is Japan. So, *Mentha* is also known as Japanese mint. Peppermint oil is extracted from *M. piperita* of the Labiatae family and is also known as brandy mint and balm mint. This cooling and refreshing essential oil is used in aromatherapy to stimulate the mind, to increase mental agility, and to increase focus, while cooling the skin, reducing redness, and calming irritation and itchiness. It furthermore helps to ease spastic colon, migraine, headaches, sinus, and chest congestion, and boosts the digestive system.

#### 4.1.1 Origin of Peppermint Oil

It is a native of the Mediterranean, but is now also cultivated in Italy, the United States, Japan, and Great Britain. It is a perennial herb that grows up to 1 m (3 feet) high and has slightly hairy serrated leaves with pinkish-mauve flowers arranged in a long conical shape.

It has underground runners by which it easily propagates. This herb has many species, and peppermint piperita is a hybrid of watermint (*M. aquatica*) and spearmint (*M. spicata*).

According to Greek mythology, the nymph Mentha was hotly pursued by Pluto, whose jealous wife, Persephone, trod her ferociously into the ground, whereupon Pluto then turned her into an herb, knowing that people would appreciate her for years to come.

It has been cultivated since ancient times in Japan and China. Evidence of use was found in Egypt in a tomb dating back from 1000 BC.

#### 4.1.2 Different Species of Mint

There are 25 species of mint, and at least 14 different varieties are growing in South Africa [1]. These include unusual ones such as “Black Peppermint,” “Basil Mint,” “Mint Julep,” and “Slender Mint” (also known as “Aussie Mint”), as well as the better known peppermint, and the fruity ones, such as apple, pineapple, ginger, and eau de cologne mint. There are also several other hybrid species of mint.

Some species [1], with their characteristics and uses, are summarized in Table 4.1.

#### 4.1.3 Commercial Cultivars

Commercial cultivars [2,3] may include Dulgo pole, Zefir, Bulgarian population, Clone 11-6-22, Clone 80-121-33, Mitcham Digne 38, Mitcham Ribecourt 19, Todd’s#x2019, and Todd’s Mitcham, a *Verticillium* wilt-resistant cultivar produced from a breeding and test program of atomic gardening at Brookhaven National Laboratory from the mid-1950s.

A number of cultivars have been selected for garden use: *Mentha* × *piperita* “Candy mint” (stems reddish) [4]; *Mentha* × *piperita* “Chocolate Mint” [5–7]; *Mentha* × *piperita* “Citrata” (includes a number of varieties, including eau de cologne mint [8], grapefruit mint, lemon mint [9], and orange mint); *Mentha* × *piperita* “Crispa” (leaves wrinkled) [10]; *Mentha* × *piperita* “Lavender Mint” [11]; *Mentha* × *piperita* “Lime Mint” [12,13]; and *Mentha* × *piperita* “Variegata” [14].

#### 4.1.4 Difference between *Mentha*, Peppermint, and *M. piperita* Essential Oils

*Mentha* oil (*M. arvensis*) is also commonly known as the Japanese mint oil. It has a high menthol content and a very good “cooling” effect associated with it. *M. piperita* is commonly known as “peppermint” in the West. It gives a milder and warm-smelling essential oil. Peppermint oil is obtained from var. *Mentha piperita*, which is a hybrid species developed in India, and it is a crossing between the above two with a higher menthol content than the common *M. piperita*. The reason for this distinction is that most of the peppermint oil being sold in the market is from the hybrid variety of *M. piperita* (with a higher menthol content). Therefore, if somebody wants the warmer-smelling peppermint, one has to go for *M. piperita*.

#### 4.1.5 Etymology of *Mint*

Mint descends from the Latin word *mentha*, which is rooted in the Greek word *minthe*, personified in Greek mythology as Minthe, a nymph who was transformed into a mint plant [15].

TABLE 4.1

Different Types of Mint and Their Uses

Name	Characteristics	Used In
1. Garden mint ( <i>Mentha spicata</i> )	Most popular mint; deep green and very aromatic leaves with spearmint flavor	Mint sauce, jellies, cakes, cosmetics, natural insecticides, and medicines
2. Spearmint ( <i>Mentha spicata aquatic</i> )	Most popular mint; deep green and very aromatic leaves with more spearmint flavor	Mint sauce, jellies, cakes, cosmetics, natural insecticides, and medicines
3. Apple mint ( <i>Mentha suaveolens</i> )	Tall growing with hairy leaves and mauve flowers	Mint sauce, jellies, cooked vegetables, and salad
4. Basil mint ( <i>Mentha piperita</i> f. "Citrata")	Small leaves with basil mint aroma	Flavoring melon, tomatoes, and fruit salad
5. Black peppermint ( <i>Mentha × piperita</i> )	Dark brown, oval, strongly peppermint-scented leaves	Medicines especially for relieving indigestion and chest infections
6. Eau de cologne mint ( <i>Mentha piperita</i> "Citrata")	Large, round dark green leaves with an orange and purple tinge	Oils and vinegars
7. Chocolate mint ( <i>Mentha piperita</i> spp.)	Dark green-brown leaves with a chocolate peppermint flavor	Pudding, ice cream, and drinks
8. Ginger mint ( <i>Mentha gracilis</i> )	Variiegated gold and green ginger-scented leaves	Salads, teas, drinks, and floral decorations
9. Mint julep ( <i>Mentha spicata</i> "Julep")	Sweetly scented leaves and a striking fresh flavor	Beverages, as well as medicinally, and as a natural insect repellent
10. Pineapple mint ( <i>Mentha suaveolens variegata</i> )	Green and cream variegated leaves with a strong pineapple scent	Salads, fruit salads, and as a garnish
11. Ground cover mints, including slender mint ( <i>Mentha diemenica</i> "Aussie Mint"), lawn pennyroyal ( <i>Mentha pulegium</i> var.), and Corsican mint ( <i>Mentha requienii</i> )	Flat, low-growing ground covers that are ideal between paving, stepping stones, and walkways; they release their scent when trod upon	Foodstuffs
12. Ant and flea repellent mint (penny royal— <i>Mentha pulegium</i> )	Upright growing	Repellents
13. Garden mint ( <i>Mentha spicata</i> ) and spearmint ( <i>Mentha spicata aquatic</i> )	Clusters of mauve flowers; crushed leaves release a strong peppermint fragrance	Repellent to ants and fleas

Mint leaves, without a qualifier like "peppermint" or "apple mint," generally refer to spearmint leaves.

In Spain and Central and South America, mint is known as *mentha*. In Lusophone countries, especially in Portugal, mint species are popularly known as *hortelã*. In many Indo-Aryan languages, it is called *pudīna*.

The taxonomic family Lamiaceae is known as the mint family. It includes many other aromatic herbs, including most of the more common cooking herbs, such as basil, rosemary, sage, oregano, and catnip. As an English colloquial term, any small mint-flavored confectionery item can be called a mint [16].

In common usage, other plants with fragrant leaves may be called "mint," although they are not in the mint family.

Vietnamese mint, commonly used in Southeast Asian cuisine, is *Persicaria odorata* of the family Polygonaceae, collectively known as smartweeds or pinkweeds.

Mexican mint, marigold, is *Tagetes lucida* of the sunflower family (Asteraceae).

#### 4.1.6 Global Scenario

The native place of *Mentha* is Japan. After Japan, its cultivation spread to Argentina, Brazil, and China. In India, it came late, that is, after China. Now India stands in the top position regarding *Mentha* oil production and exports. Other countries, such as Brazil, China, and the United States, are also major producers and suppliers of *Mentha* oil. These countries also produce the by-products obtained in *Mentha* oil processing. However, China is among the biggest importers of *Mentha* oil. It does further refinement of the oil and preparation of its by-products, and then these products are supplied all over the world.

The total *Mentha* oil produced is derived from *M. arvensis* (75%), and it is mainly to produce menthol. Of the total *M. arvensis* oil produced, India contributes 73%, China 18%, and other countries 9%. The consumption *Mentha* produced is 30%–40% in India, followed by China, the United States, and European countries.

Total production of the oil is 75%–80% in India, 18% in China, and the remaining in Brazil and the United States. The total production and consumption of the oil has been found to be steady over a period of time. Recently, the global output was further enhanced. The total output from India alone is estimated to be 35,000 tons in 2009–2010. The export of mint products such as menthol flakes, menthol crystals, and mint oil is increasing day by day. This increase is due to the increasing demand for *Mentha* oil products abroad. The major countries for Indian export are Argentina, Brazil, France, Germany, Japan, the United Kingdom, the United States, and others.

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#### 4.2 Botany of the *Mentha* Plant

All mints require the same kind of growing conditions: moist and rich soil in a partially shaded spot. The plant dies down in winter but will come up again in spring. Most varieties are rampant growers that will smother other plants around them, and so they should be grown on their own, in pots or in pots that are sunk into the ground. This makes it easier to lift the pots and trim off the runners. Mint will grow from root cuttings, and it is a good idea to make or buy new plants every year, as they will start to lose their vigor.

##### 4.2.1 *Mentha piperita* L. Emend. Hudson

*M. piperita* L. Emend. Hudson is currently one of the most economically important aromatic and medicinal crops. It is commonly known as peppermint, brandy mint, candy mint, vilayt ipudina, or paparaminta.

The plant is a strongly scented, perennial, glabrous herb and is 30–90 cm in height. The square stems are usually reddish-purple and smooth. The leaves are short, 2.5–5 cm long, oblong-ovate, and serrate. The flowers are purple-pinkish and appear in the summer months. The sowing of the crop starts in January and continues until March, and it is harvested during May–June. In India, during this period there are sunny days and a hot season, and plants give a good yield of oil. The *Mentha* oil is extracted from the leaves by processing and steam distillation. In India, during May–June dried plant-based fuel (plant material including *Mentha* plant) is also available for steam distillation. Monsoon starts in July, and in the rainy season, the percentage of oils falls and steam distillation becomes costly. The plant has runners above- and belowground, and propagation takes

place through these runners. It is originally a native of Asia, Europe, Canada, and the United States, and has been naturalized in several parts of India. It is cultivated in Japan, India, China, Europe, America, Australia, South Africa, Brazil, and some other countries. The leaves and flower tops are collected as soon as flowers begin to open, and are dried as a crude drug for their oil and peppermint [17,18]. The arrival of the oil at the physical market starts in May and extends until November. Generally, two or three cuttings can be done for one crop.

#### 4.2.2 *Mentha longifolia* L.

It is commonly known as wild mint (English); kruisement balderjan (African); koenaya-thaba (southern Sotho); inixina, inzininiba (Xhosa); and ufuthana lomhlanga (Zulu) [19–22]. Because of its strong mint smell and taste, this herb is grown in kitchen gardens, as well as in pots, where it is used in foodstuffs and as a medicine. As discussed above, there are different mints—different species, many hybrids, and special selections that are grown all over the world. Almost all the species are water lovers and are usually grown in wet and damp places.

##### 4.2.2.1 Description

*M. longifolia*, or wild mint, is a fast-growing perennial herb that has creeps along an underground rootstock. It reaches up to 1.5 m height in favorable climatic conditions; usually it goes to 0.5–1 m, and it remains shorter in dry conditions. It is strongly aromatic; its leaves are formed in pairs opposite each other along the square-shaped stem. The soft, lanceolate leaves (long and narrow with a sharp point) are between 45 and 100 mm long and 7.20 mm wide. The leaves are usually coarsely hairy and the edges sparsely toothed. The color of leaves varies from light and dark green to gray. The small-sized flowers of *M. longifolia* are crowded into spikes at the tip of the stem. The flowers of this wild mint vary in color from white to mauve throughout the summer months.

Two mint species, *M. longifolia* and *M. aquatica* (wild water mint), are indigenous to South Africa. Both are commonly found in marshes and along streams from the cape through Africa and Europe.

*M. longifolia* is identified by its stalkless leaves and white to mauve flowers that are grouped in a long spike. The leaves of *M. aquatica* (aquatica means living in water) are broader and more egg shaped, and its flowerheads are roundish whorls (approximately 25 mm in diameter), with pink or mauve flower clusters formed one above another. There are three subspecies: (1) *wissi* (cape velvet mint), which has long and thin gray-green leaves with an unpleasant aromatic smell; (2) *capensis* (balderjan), which possesses a strong peppermint scent; and (3) *polyadena* (spearmint).

##### 4.2.2.2 Growing *Mentha longifolia*

It is worth finding a place in the garden for the wild mint in order to achieve a strong fragrance and many uses. It is easy to grow, as it is a fast grower with underground runners and heavy feeders, and it is a water lover. To encourage new fresh growth, mint should be cut back often. The mints grow in semishade and full sun. They may be grown in pots but need to be repotted every year or two in new compost-rich soil. It is better to provide small leaks while keeping the mint moist. Many crops of mint may be obtained by cutting back often, and this process encourages new fresh growth of the plant. Mint plants are

easy to multiply by division, as the small piece of healthy rootstock quickly grows into a new clump with regular water and compost, and cuttings of young actively growing shoot roots are easily possible throughout the year.

The large mint family, Lamiaceae, with about 250 genera and 6700 species, includes many well-known herbs and garden plants, such as lavender, sage, basil, rosemary, and mint. *Mentha* (Latin for “mint”) is a cosmopolitan genus with about 20–30 species that are mainly found in temperate regions. Being a very easy hybridization of mint species, it is quite difficult to identify a particular species of mint. Therefore, the same common name is given to different plants, or the same plant may have different names in different areas and languages. For example, *M. longifolia* is known as horse mint in England, as its leaves are usually unpleasantly scented [23]. *M. spicata* is also known as spearmint; it is not indigenous to South Africa, but it is often found as a garden escape in wet areas. This exotic mint is a very popular herb and has been cultivated in Europe since ancient times. Its origin has been lost, but it has been naturalized throughout the world in different forms [23].

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### 4.3 Ecology

In the flowering season, bees and butterflies are attracted to the wild mint. Peppermint typically occurs in moist habitats, including stream sides and drainage ditches. Being a hybrid, it is usually sterile, producing no seeds and reproducing only vegetatively, spreading by its rhizomes. If placed, it can grow anywhere, with a few exceptions [24,25].

Outside of its native range, areas where peppermint was formerly grown for oil often have an abundance of feral plants, and it is considered invasive in Australia, the Galápagos Islands, New Zealand [26], and the United States.

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### 4.4 Toxicology

The toxicity studies of the plant have received controversial results. Some authors reported that the plant may induce hepatic diseases (liver disease), while others found that it protects against liver damage that is caused by heavy metals [27,28]. In addition, the toxicities of the plant seem to vary from one cultivar to another [29] and are dose dependent [27,30].

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### 4.5 Extraction of Peppermint Oil

Peppermint oil is extracted from the whole plant aboveground just before flowering. The oil is extracted by steam distillation from the fresh or partly dried plant, and the yield is 0.1%–1.0% [31]. Supercritical fluid extraction (SFE) has been performed [32], and the



results obtained have been compared with those obtained by hydrodistillation (HD). The extraction was carried out under two conditions: SFE-1 and SFE-2. Higher concentrations of menthone, menthol, 1,8-cineole, and piperitone, and lower concentrations of methyl acetate,  $\alpha$ -caryophyllene, and  $\alpha$ -cadinene were obtained by SFE-1 than by SFE-2. Oxygenated monoterpenes, which are responsible for the peppermint fragrance, come out to 79.2% by SFE-1 and 74.4% by SFE-2. Sesquiterpenes were distilled out only 7.7% by SFE-1 and 11.6% by SFE-2. Hydrodistillation gave a higher concentration of terpene acetate (12.5%), while SFE-1 gave a 12.0% concentration of terpene acetate. A recently developed technique, microwave hydrodiffusion and gravity, has been used for the extraction of peppermint oil [33]. It is much faster than conventional hydrodistillation.

Gill et al. [34] have carried out experiments to study the kinetics of *Mentha* oil extraction from *Mentha* leaves (*Mentha arvensis* L.), and quality analysis was carried out for the oil extracted. The oil was extracted from *Mentha* leaves at three different moisture contents of 74.30% (fresh leaves), 42.30% (shade dried), and 19.35% (sun dried) using the hydrodistillation method. Various physicochemical tests were carried out on the oil extracted. The results revealed that the hydrodistillation process took more time for oil extraction and oil recovery was less. Various physicochemical properties, such as acid value, refractive index, specific gravity, saponification value, and solubility in water, did not show significant variations with respect to oil extracted by differently pretreated *Mentha* leaves.

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#### 4.6 Consumption and Export

India's domestic consumption of *Mentha* oil is hovering in the range of 8,000–10,000 tonnes, with an annual growth of around 7%–8%, while the export demand ranges from 18,000 to 22,000 tonnes (inclusive of menthol, menthol crystals, and mint oil), growing by 10%–12% annually.

India is the largest exporting country for *Mentha* oil. Mint products, including mint oils, menthol crystals, and menthol powder, are the single largest product group in the export basket, accounting for 22%–27% of spices exported from India. Mint products are exported to the United States and China, and these two countries together account for more than 53% of total mint exports. The other major buyers are Singapore, Germany, the Netherlands, and Japan.

The slowdown in major consuming markets such as the European Union and the United States adversely affected export of value-added spices, including mint products like mint oils, menthol crystals, and menthol powder, from 2007 to 2009 [35].

The export of mint products in 2009–2010 was 19,000 tonnes valued at 1189.72 crore, against 20,500 tonnes valued at 1420.25 crore in 2008–2009. Per the latest release by the Spices Board of India, mint exports in April to August 2010 surged by 2% to 723.95 lakhs, against 595.57 lakhs reported last year in the same period. In 2010, a strong demand was seen in the international market as the export prices of *Mentha* bold were quoting at around \$20–\$20.50 per kilogram, against \$16 per kilogram reported May 2010. Traders are estimating that the total export of 2010–2011 is nearly 22,000 tonnes; in 2009–2010 it was 19,000 tonnes. Export from India has crossed the level of around 10,000 tons per annum, and that is likely to increase in the coming years.



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## 4.7 Analysis

Chromatographic profiling of peppermint oil has been made by using gas chromatography with a flame ionization detector [36–39]. Quantification, as well as identification, of *Mentha* oil is difficult due to the fact that its components, like menthol, menthone, and methyl acetate, consist of several stereoisomers. For example, menthol has three chiral centers, for a total of eight stereoisomers, which makes the chromatographic separation difficult. This problem was resolved by using gas chromatography–mass spectrometry (GC/MS) [40]. Visible fluorescence analysis of *Mentha* oil has been reported [38,41]. The results obtained show that the same group of organic compounds dominate in the oils of peppermint and spearmint, while different compounds are present in Japanese mint oil. Estimation of menthone, menthofuran, and methyl acetate in peppermint oil has been reported by using capillary gas chromatography equipped with a dual flame ionization detector and dual injector [42]. Gas liquid chromatography has been used for the estimation of pulegone [43], which was found to be unresolved by gas chromatography. In fact, pulegone has a retention time that is very similar to that of menthol and isomenthol. It is either very near to that of menthol, with a consequent overlap, or very similar to those of isomenthol and some sesquiterpene hydrocarbons (cadinene and caryophyllene) [39].

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## 4.8 Chemical Composition

The chemical components of peppermint oil are menthol, menthone, 1,8-cineole, methyl acetate, menthofuran, isomenthone, limonene,  $\beta$ -pinene,  $\alpha$ -pinene, germacrene-d, trans-sabinene hydrate, and pulegone.

The constituents reported in the International Pharmacopoeia [37,44] are limonene (1.0%–5.0%), cineole (3.5%–14.0%), menthone (14.0%–32.0%), menthofuran (1.0%–9.0%), isomenthone (1.5%–10.0%), menthyl acetate (2.8%–10.0%), isopulegone (maximum 0.2%), menthol (30.0%–55.0%), pulegone (maximum 4.0%), and carvone (maximum 1.0%). The ratio of cineole content to limonene content should be a minimum of 2.

The following composition with minor details has also been reported in the literature: the major constituent is volatile oil, of which the principal component is usually (–) menthol, together with menthol stereoisomers such as (+) neomenthol and (+) isomenthol. Other monoterpenes include menthone (10%–40%), methyl acetate (1%–10%), menthofuran (1%–10%), cineol (eucalyptol, 2%–13%), and limonene (0.2%–6%). Monoterpenes like pinene, terpinene, murcene,  $\beta$ -caryophyllene, piperitone, piperitenone, piperitone oxide, pulegone, eugenol, menthone, isomenthone, carvone, cadinene, dipentene, linalool,  $\alpha$ -phellendrene, ocimene, sabinene, terpinolene,  $\gamma$ -terpinene, fenchone, p-menthane, and  $\beta$ -thujone are also present in small quantities [45,46].

About 85 constituents of the oil have been identified, and a further 40 are unidentified. Composition of the oil varies from place to place, as it depends on temperature, photoperiod, nutrition, salinity, water stress, plant age, harvesting, and planting time [47]. Flavanoids like luteolin and its 7-glucoside (cynaroside), menthoside, isorhoifolin, and others, including a number of highly oxygenated flavones, have been reported [48,49].

Phenolic acids, including caffeic, chlorogenic, and rosmarinic acids and pseudotannis derived from them, are reported to be present. Triterpenes in microamounts, including squalene,  $\alpha$ -amyrin, urosolic acid, sitosterol, and other constituents, azulene, and minerals are also present [50].

Peppermint oil possesses a greater antihydrolytic effect than commercial preservatives, such as butylated hydroxytoluene [51].

Scavroni et al. [52] have evaluated the effects of biosolid levels on the yield and chemical composition of *Mentha piperita* L. essential oil. Mint plants were grown in a greenhouse in pots containing the equivalent of 0, 28, 56, and 112 tonnes/ha biosolids. Three evaluations were made at 90, 110, and 120 days after planting (DAP). The oil was extracted from the dry matter of shoots by hydrodistillation, and composition was determined by GC/MS. Oil production was slightly affected by the biosolid, increasing when plants were grown with 28 tonnes/ha, a condition that did not result in quality improvement. Methyl acetate was the component obtained at the highest percentage in all treatments. At 90 DAP, plants showed a higher percentage of menthol. Under these conditions, plant harvesting is recommended at 90 DAP, a period in which the menthol level was higher.

Verma et al. [53] have evaluated the essential oil content and composition of menthol mint (*Mentha arvensis* L.) and peppermint (*M. piperita* L.) cultivars grown in the Kumaon region at different stages of crop growth. In menthol mint cultivars, that is, Kosi, Saksham, Himalaya, and Kalka, the essential oil content was found to vary from 0.3% to 1.2%, 0.42% to 1.1%, 0.38% to 1.0%, and 0.26% to 1.2% at different days after transplanting (DAT), respectively, while in cultivars Kukrail, CIM-Madhurus, and CIM-Indus of peppermint, it varied from 0.28% to 0.6%, 0.19% to 0.55%, and 0.17% to 0.37%, respectively, at different DAT. The menthol content in the menthol mint cultivars reached higher values at 120 and 150 DAT. In the case of peppermint cultivars, that is, Kukrail, CIM-Madhurus, and CIM-Indus, the menthol content varied from 32.92% to 39.65%, 34.29% to 42.83%, and 22.56% to 32.77%, respectively, during the crop growth. It was concluded that peppermint and menthol mint cultivars should be harvested in June (150 DAT) if the crop is sown in January and July–August (120–150 DAT) if the crop is sown in March, respectively, under the climatic conditions of the Kumaon region of the western Himalayas in Uttarakhand, India.

Peppermint oil has a high concentration of natural pesticides, mainly pulegone (found mainly in *Mentha arvensis* var. *piperascens*, and to a lesser extent [6530 ppm] in *Mentha*  $\times$  *piperita* subsp. *notho* subsp. *piperita*) [54] and menthone [55].

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## 4.9 Physical Properties

*Mentha* or peppermint oil is a colorless or pale clear liquid. It has a pleasant aroma and a pungent taste, followed by a cool aftertaste. It is 95% miscible in methanol, 99.5% in ethanol, 95% in warm ethanol, 95% in diethyl ether, and 95% in dichloromethane. It is practically insoluble in water. The following parameters have been reported in the International Pharmacopoeia [37]: relative density, 0.900–0.916; refractive index, 1.457–1.467; and acid value, maximum 1.4, determined on 5.0 g diluted in 50 ml of the prescribed mixture of solvent.

## 4.10 Pest Control

A renewed interest in the use of essential oils for insect pest control has originated from the need for pesticide products with a less negative environmental and health impact than that of highly effective synthetic pesticides [56–59]. Esmaili et al. [56] have assessed the fumigant toxicity of essential oil from *Mentha pulegium* on the adults of *Callosobruchus maculatus*, *Tribolium castaneum*, *Lasioderma serricornis*, and *Sitophilus oryzae*. An experiment was carried out at  $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$  and  $65\% \pm 5\%$  relative humidity (RH) in five concentrations and three replications in 24 hours, under dark conditions. The results demonstrated that mortality increased with the increase in concentration. The results indicated that the  $\text{LC}_{50}$  values at 24 hours after treatment were 97.3, 165.5, 419.2, and  $12.7 \mu\text{l/L}$  air for adults of *C. maculatus*, *T. castaneum*, *L. serricornis*, and *S. oryzae*, respectively. *S. oryzae* was more susceptible to *M. pulegium* than other pests. It was found that the plant essential oil *M. pulegium* had high potential in controlling different stored pests [60,61].

Khani and Asghari [62] have tested essential oils extracted from the foliage of *M. longifolia* (L.) and *Pulicaria gnaphalodes* Ventenat (Asterales: Asteraceae), and flowers of *Achillea wilhelmsii* C. Koch (Asterales: Asteraceae) in the laboratory for volatile toxicity against two stored product insects, the flour beetle, *T. castaneum*, and the cowpea weevil, *C. maculatus*. The chemical composition of the isolated oils was examined by gas chromatography–mass spectrometry. In *M. longifolia*, the major compounds were piperitenone (43.9%), tripal (14.3%), oxathiane (9.3%), piperitone oxide (5.9%), and d-limonene (4.3%). In *P. gnaphalodes*, the major compounds were chrysanthenyl acetate (22.38%), 2L-4L-dihydroxy eicosane (18.5%), verbenol (16.59%), dehydroaromadendrene (12.54%),  $\beta$ -pinene (6.43%), and 1,8-cineol (5.6%). In *A. wilhelmsii*, the major compounds were 1,8-cineole (13.03%), caranol (8.26%),  $\alpha$ -pinene (6%), farnesyl acetate (6%), and p-cymene (6%). *C. maculatus* was more susceptible to the tested plant products than *T. castaneum*. The oils of the three plants displayed the same insecticidal activity against *C. maculatus* based on  $\text{LC}_{50}$  values (between  $1.54 \mu\text{l/L}$  air in *P. gnaphalodes* and  $2.65 \mu\text{l/L}$  air in *A. wilhelmsii*). While the oils of *A. wilhelmsii* and *M. longifolia* showed the same strong insecticidal activity against *T. castaneum* ( $\text{LC}_{50} = 10.02$  and  $13.05 \mu\text{l/L}$  air, respectively), the oil of *P. gnaphalodes* revealed poor activity against the insect ( $\text{LC}_{50} = 297.9 \mu\text{l/L}$  air). These results suggest that essential oils from the tested plants could be used as potential control agents for stored product insects.

### 4.10.1 Antimicrobial Activity

The peppermint oil exerts antidermatophytic activity against (+) and (–) strains of *Nannizzia fulva* and *N. gypsea* [63]. It also shows antibacterial activity against *Staphylococcus aureus*, *Streptococcus pyogenes*, *Escherichia coli*, *Bacillus subtilis*, and *Proteus vulgaris* [64,65]. It possesses repellent activity against *T. castaneum*, and it is a moderately effective fumigant of both *C. maculatus* and *T. castaneum* [66]. It has a moderate antimyotic property against *Aspergillus fumigatus*, *Candida albicans*, *Geotrichum candidum*, *Rhodotarlula rubra* [67], *Phytophthora cinnamini*, *Pyrenochaeta lycopersici*, and *Verticillium dahlia* [68]. Peppermint oil has shown antifungal activity against *Aspergillus niger*, *Alternaria alternata*, and *Fusarium* sp. by the agar well diffusion method [68].

### 4.10.2 Larvicidal and Mosquito Repellent

Oil of *Mentha piperita* L. (peppermint oil), a widely used essential oil, was evaluated for larvicidal activity against different mosquito species [69]—*Aedes aegypti*, *Anopheles stephensi*,

and *Culex quinquefasciatus*—by exposing third-instar larvae of mosquitoes in enamel trays (6 feet 4 inches) filled to a depth of 3 inches with water. The oil showed strong repellent action against adult mosquitoes when applied on human skin. The protection obtained against *Anopheles annularis*, *Anopheles culicifacies*, and *C. quinquefasciatus* was 100%, 92.35%, and 84.5%, respectively. The repellent action of *Mentha* oil was comparable to that of mylol oil consisting of dibutyl and dimethyl phthalates.

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#### 4.11 Conclusion

*Mentha piperita* oil possesses diversified potential in the areas of food, cosmetics, medicines, and pest control [70]. It has been proven helpful in symptomatic relief of the common cold. It may also decrease symptoms of irritable bowel syndrome and decrease digestive symptoms such as dyspepsia and nausea. It is used topically as an analgesic and to treat headaches. It may also be used as an insecticide, repellent, fumigant, and fungicide in stored foodstuffs. Although *Mentha piperita* oil is on the Food and Drug Administration's (FDA) generally recognized as safe (GRAS) list, more research work is needed, as this herb has a few side effects. It can cause heartburn or perianal irritation and is contraindicated in patients with bile duct obstruction, gallbladder inflammation, and severe liver damage. Caution is required in patients with gastrointestinal (GI) reflux, and its products may not be used directly under the noses of children due to the risk of apnea.

This plant is now well acclimatized and cultivated in different countries, including India. This oil enjoys strong export potential. Its various formulations, for example, Pudín Hara for gastrointestinal disturbances like flatulence and indigestion and Itch Guard for skin disorders, are commercially available.

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