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# Phytochemical and ethnopharmacological overview of endangered *Homalomena aromatica* Schott: An aromatic medicinal herb of Northeast India

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Northeast India falls under the Indo-Burma mega biodiversity hotspot and is considered one of the richest repositories of aromatic and medicinal plants in the World. The region is also known for its rich ethnic diversity comprising about 130 major tribes and 300 sub-tribes or groups. Each ethnic tribal community utilizes wide varieties of plant species as food and medicine. However, of late, this rich plant diversity of the region has been threatened mainly due to ever increasing pressure of anthropogenic interferences including large scale *jhuming* and unsustainable collection of forest resources from its natural habitats. *Homalomena aromatica* Schott.is one such aromatic medicinal herb found in this region. The rhizomes are known to possess medicinal properties like antiinflammatory, analgesic, antidepressant, antiseptic, sedative, antispasmodic, treating joint pain, and skin infections. The rhizomes contain an essential oil having mainly sesquiterpenoids group that is used for blending of most oriental perfume. It has a high demand in perfumery and cosmetic industries. The spent material after oil extraction is largely used in *Dhup* manufacturing. However, despite its importance, conservation of this herb is one of the major challenges confronting the region. Large-scale indiscriminate collection directly from its natural habitat has endangered this species. This review presents a comprehensive overview of ethnomedicinal uses and phytochemical composition of the essential oil of *H. aromatica*. It also highlights the economic potential and future research directions towards conservation and utilization of *H. aromatica.*

**Keywords:** Essential oil, *Homalomena aromatica*, Rhizome, *Sugandhmantri*.

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## Introduction

The Northeastern region of India comprises of eight states namely Arunachal Pradesh, Assam, Mizoram, Manipur, Meghalaya, Nagaland, Tripura, and Sikkim. The total geographical area of the region is 2,62,230 km$^2$ and lies between 21° 34′ N to 29° 50′ N latitude and 87° 32′ E to 97° 52′ E longitudes[1].The entire region falls under the Indo-Burma mega biodiversity hotspot and is considered one of the richest repositories of aromatic and medicinal plants in the World. It has the richest plant diversity in India supporting about 50 % of India's biodiversity[1]. The immense variety of the climatic, edaphic, and altitudinal variation in Northeastern India has resulted in a great range of ecological habitats[2]. About 50 % of the total 17,500 flowering plants hail from this region, and 40 % of them are endemic[3]. Due to its high biodiversity and rich traditional knowledge, this region has been a priority for leading conservation agencies of the world[4]. The region is also known for its rich ethnic diversity comprising about 130 major tribes and 300 sub-tribes or groups[5]. Each ethnic tribal community utilizes wide varieties of plant species as food and medicine[6]. However, of late, this rich plant diversity of the region has been threatened mainly due to ever increasing pressure of anthropogenic interferences including large scale *jhuming* and unsustainable collection of forest resources from its natural habitats.

*Homalomena aromatica* Schott. is a terrestrial, evergreen, perennial, aromatic medicinal herb belonging to the family Araceae (Plate 1). It can grow up to a height of 40-45cm with short and erect stem. The leaves are 20-35 cm long and 15-25 cm broad with long petioles and sheathing below. Leaf blades are ovate, often cordate or sagittate. The flowers are

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Plate 1—*Homalomena aromatica* Schott.

unisexual lacking perianth, ovaries partially 2-4 loculed, ovules many, parietal, stigma sessile, each ovary usually with a single, clavatest aminode, anther cell short, synandria of 2-4 fused stamens, anthers attached basally, filaments short, stout, locules dehiscing extrorsely by splits[7,8].The dry rhizomes of *H. aromatica* are known in trade as '*Sugandhmantri*'. The rhizomes are known to possess medicinal properties like antidepressant, analgesic, antiseptic, antiinflammatory, sedative, antispasmodic, treating joint pain, and skin infections[6,9-12]. The rhizome contains an essential oil containing mainly the sesquiterpenoids group and is used for blending of most oriental perfume. The essential oil has a high demand in perfumery and cosmetic industries. After extraction of the essential oil, spent material is widely used in *Dhup* manufacturing. However, despite its importance, conservation of this herb is one of the major challenges confronting the region as this herb is being exploited as a forest product without conservation and or cultivation measures. More than 400 MT of dry rhizomes are collected from Barak Valley of Assam and other parts of the region every year and are transported outside the state, mainly to Kannauj, Kanpur, Delhi, Kolkata, and Mumbai[8,13]. Indiscriminate large-scale collection of *H. aromatica* directly from its natural habitat has endangered this herb[10,14]. The continued unabated indiscriminate collection might lead to the extinction of this unique and valuable species from its place of origin.

A comprehensive overview of ethnomedicinal uses, pharmacological applications, and phytochemical constituents of essential oil of *H. aromatic* along with future research directions towards conservation and utilization has been highlighted in this review. This is perhaps the first review on *H. aromatica* Schott.

## Geographical prevalence

*H. aromatica* is a rhizomatous perennial herb and its distribution is restricted to Guangxi and Southern Yunnan region of China to Bangladesh through Northeast India, Laos and Northern Myanmar to Vietnam through Northern Thailand[15].There are about 140 species occurring in the tropical Asia and South America, of which 23 species are confined to South Asian region, 6 species are distributed within Indian boundaries, and 2 species are exclusively distributed in Northeast India (*H. aromatica* Schott. and *H. rubescens* Roxb.)[8]. Majority of the species occur in South East Asia, which may probably be the centre of origin of the genus[16]. In Northeast India, it is found in the lower altitudes of Assam, Arunachal Pradesh, Nagaland, Mizoram, Manipur, and Tripura[17,18]. The plant is usually found grown in hill slopes and foothill areas covered by forests and other vegetation with 40-60 % shade. It is best suited in sandy and sandy loam to clay loam with rich organic matter and acidic soil with pH ranging from 4.9-5.5. The plant is a sub-tropical species and grows best in warm and humid climate with annual rainfall ranging from 2000-3000 mm.

## Ethnomedicinal uses of *H. aromatica*

Plants are important part of our everyday diet; their constituents and nutritional value have been used in the amelioration of various ailments. The traditional ethnomedical knowledge has been passed on from generation to generation through trial and error method. World Health Organization has shown great interest in documenting the use of medicinal plants from tribes in different parts of the world[19]. Traditional herbal medicine is an important component of primary health care system in developing countries like India. They are considered to be safe, effective and inexpensive, for which there is a global trend for the revival of traditional herbal medicine[20]. Many tribes in Northeast India use *H. aromatica* as remedial agent for a wide spectrum of treatments (Table 1). Traditionally, the leaves and rhizomes of this plant are used as a paste in joint-

Table 1—Ethnomedicinal uses and biological activities of *H. aromatica*

Ethnomedicinal uses of *H. aromatica*

| S. No | Plant parts | Traditional uses | References |
|---|---|---|---|
| 1 | Leaves and rhizomes | Joint-pains, skin infections, common cold in infants, stomach problem, jaundice, stomach pain and diarrhea | 12 |
| 2 | Petiole | Used in curry as condiment for the pleasant scent | 15 |
| 3 | Rhizome | Mosquito repellent | *16, 21* |
| 4 | Rhizome | Injuries, fractures, joint and muscle pains, stomach pains, lumbago, intestinal parasites, liver and kidney problems, anti-inflammatory agent, stomach diseases | 24 |
| 5 | Whole plant | Muscle weakness, rheumatism | 23 |
| 6 | Rhizome | Asthma | 11 |
| 7 | Rhizome | Treatment of liver diseases | 25 |
| 8 | Rhizome | Perfumery and cosmetic | 10 |
| | Rhizome | Rhizome paste is given in stomach ailments. | 20 |

Biological activities of *H. aromatica*

| S. No | Functional properties | Plant parts | Solvent extract | Test organism | References |
|---|---|---|---|---|---|
| 1 | Antifungal activities | Rhizome | Hydrodistilled | *Curvularia pallescens* *Aspergillus niger* *Fusarium graminearum.* | 9 |
| 2 | Insecticidal activity | Rhizome | Hydrodistilled | *Odontotermes obesus* Rhamb | 9 |
| 3 | Hepatoprotective activities | Rhizome | Absolute alcohol | Rats | 25 |
| 4 | Antifungal activities | Rhizome | Hydrodistilled | *Trichophyton rubrum, Trichophyton mentagrophytes, Microsporum fulvum, Microsporum gypseum, Trichosporon beigelii Candida albicans* | 6 |
| 5 | Ulcero protective activities | Rhizome | Ethanol | Wistar rat | 26 |
| 6 | Antioxidant activity | Roots | Ethanol | | 15 |
| 7 | Larvicidal activity | Rhizome | Ethanol | *Aedes aegypti* | 22 |

pains and skin infections; the aroma of the rhizomes is traditionally used for treating common cold of infants. Its rhizome serves as a good source of nutrition and is used for treating stomach problem, jaundice, stomach pain, diarrhoea, and asthma[8,12,20]. Petiole of the plant is also used in curry as condiment for the pleasant scent by the people of this region[15]. Its rhizomes are aromatic stimulant; found to possess high larvicidal activity against mosquito; and have blackflies repellent properties[16,21,22]. The extract of the whole plant is also used in treating muscle weakness and rheumatisms[23].The herb is also used as blood purifier, cure for allergic eruption, treatment of boils in ear, in curing deafness, treatment for dandruffs, and healing of wounds in women after child birth[8].The rhizomes are also used in Chinese medicine for myriad treatments viz., injuries, fractures, joint and muscle pains, stomach pains, lumbago, intestinal parasites, liver, kidney etc.In Vietnamese folk medicine, the rhizomes are used as a tonic drug, an antiinflammatory agent, and also for the treatment of stomach diseases[24]. Though ethnomedicinal uses of *H. aromatica* have been reported by various workers, due to the existence of diverse cultures with varied traditional knowledge, proper documentation with reference to each ethnic group might unearth new findings. Hence, proper documentation for conservation of indigenous knowledge is extremely important in drug discovery. In addition, phytochemical and pharmacological studies should be carried out to support and validate the folkloric use of this plant.

## Pharmacological studies

### Biological activity

The therapeutic potential of *H. aromatica* oils is due to their aromatic stimulant and high antimicrobial property (Table 1). The essential oil has been reported to have antifungal activity against *Curvularia pallescens*, it was found to be highly effective in controlling the mycelial growth of *Aspergillus niger* and *Fusarium graminearum*, and was also highly toxic against white termite (*Odontotermes obesus* Rhamb.)[9]. More recently, antifungal activity against dermatophytes and yeasts has also been reported for the use of *H. aromatica* essential oil for curing various skin ailments by ethnic people. The essential oil showed high antimicrobial activity against *Trichophyton mentagrophytes, T. rubrum, Microsporum gypseum, M. fulvum, Candida albicans*, and *Trichosporon beigelii*[6]. Though traditionally, the rhizome is known to possess medicinal properties for liver diseases, but hepatoprotective activities of *H. aromatica* oil in acute and chronic animal models have been reported recently[25]. More in-depth investigations are required to fully provide scientific evidence for its use in human. Similarly, a study has reported the ulcero protective property in *H. aromatica* extract when tested in animal models[26]. Essential oil of *H. aromatica* is known to possess a wide spectrum of medicinal properties and most of these are based on traditional knowledge. However, scientific validations are required to provide substantial evidences so as to fully exploit *H. aromatica* in pharmaceutical industries. Most of the reports used crude extract for bioactivity study, therefore, more investigations are needed to separate and isolate compounds with respect to their biological activity.

#### Antioxidant activity

Essential oils possessing antioxidant activity are of great interest because they may preserve foods from the toxic effects of oxidants[27]. In a study, it was observed that the *H. aromatica* root extract exhibited high antioxidant activity indicating a possible use as an alternative to the synthetic antioxidants available in the market[15]. A thorough evaluation of antioxidant activity of *H. aromatica* and their mechanism of action would be of great benefit.

### Phytochemical composition of the essential oil

The rhizomes of *H. aromatica* are rich source of essential oil extensively used in pharmacological applications, perfumery and cosmetic industries. Sesquiterpenoids are the main components in the rhizome oil. A consolidated list of phytochemical constituents identified in *H. aromatica* is presented in Table 2. In addition, IUPAC name, molecular formula, molecular weight, element analytical calculation and their chemical structures were calculated and drawn using Chembiodraw (Fig. 1). The earliest study on the chemical analysis of essential oil reported the presence of 36 constituents in *H. aromatica* oil; the major compounds were found to be linalool (49.9 %), α -cadinene (23.2 %), terpenolene (4.5 %), limonene (4.3 %), dihydrocuminaldehyde (4.2 %), camphene (3.8 %), linalyl acetate (2.2 %) and α -pinene (1.1 %) [29]. In another study, about 37 compounds were reported where linalool (71.2 %) was the major constituents while the other components such as terpene-4-ol (4.6 %), linalyl acetate (3.3 %), δ-3-carene (1.3 %), α-terpineol (1.2 %) were present in lower percentages[17]. In addition, several sesquiterpene alcohols namely lβ,4β,7α-trihydroxyeudesmane, homalomenol A, and homalomenol B, oplopanone, oplodiol and bullatantriol have been reported from the roots of *H. aromatica*[24]. These structures were elucidated by spectroscopic investigations and chemical transformations. Consequently, HPLC and GC-MS analysis of *H. aromatica* rhizome oil showed the presence of 39 components accounting for 96.9% of the total essential oil; the major component was identified as linalool (62.1 %), followed by terpinen-4-ol (17.2 %), α-terpineol (2.4 %), γ -terpinene (1.9 %), α-cadinol (1.5 %), geraniol (1.4 %), nerol (1.4 %), α-terpinene (1.0 %), spatulenol (1.0 %) and T-cadinol (1.0 %). Comparing the percentage in either type of analysis, a higher percentage (87.5 %) was obtained in HPLC studies as compared to GC[9]. Similarly, in a study on *H. aromatica* collected from Bangladesh was investigated, linalool (69.5 %), 4-terpineol (7.6 %), 2-furanethanol-5-ethenyItetrahydro-α, α-5-trimethyl (5.7 %), α–methyl-α–(4-methyl-3-pentenyl}- oriranemethanol (5.3 %) and 3, 7-octadiene-2,6-diol-2, 6-dimcthyl (2.8 %), α-cadinol (2.7 %), and 1, 2-dimethylbenzene (1.0 %) were reported as the main compounds in this essential oil[31]. Similarly, about 30 compounds from rhizome oil accounting for 88.7 % of the oil were determined by GC/MS[16]. More recently, the yield of the oil in rhizome has been reported to be 0.64 % on dry weight basis with linalool (58.3 %), terpinen-4-ol (16.7 %), α-terpineol (1.8 %). α-eadinol (1.7 %), spathulenol (1.5 %), and cryptone (1.4 %) as the main compounds. In another study, about 55 chemical constituents were reported from the rhizomes, of which T-muurolol (5.32 %), viridiflorol (3.69 %), α-selinene (2.19 %), M-cymene (2.19 %) and γ -Muurolene (1.81 %) were identified and reported for

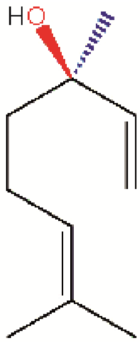
Table 2—Phytochemical constituent of essential oil in leaves and rhizome of *H. aromatica*[6,9,16,17,24,29,30]

| S. No. | Compound Name | IUPAC Name | Molecular formula | Molecular weight | Anal. calculated for element (%) |
|---|---|---|---|---|---|
| 1. | Linalool | (R)-3,7-dimethylocta-1,6-dien-3-ol | $C_{10}H_{18}O$ | 154.2 | C=77.87, H=11.76, O=10.37 |
| 2. | α –cadinene | (1S,4aR,8aR)-1-isopropyl-4,7-dimethyl-1,2,4a,5,6,8a-hexahydronaphthalene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |
| 3. | Terpenolene | 1-methyl-4-(propan-2-ylidene)cyclohex-1-ene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 4. | Limonene | (S)-1-methyl-4-(prop-1-en-2-yl)cyclohex-1-ene | $C_{10}H_{16}$ | 133.23 | C=88.16, H=11.84 |
| 5. | Dihydrocuminaldehyde | 2,5-dihydroxy-4-isopropylbenzaldehyde | $C_{10}H_{12}O_3$ | 180.20 | C=66.65, H=6.71, O=26.64 |
| 6. | Camphene | (1R,4S)-2,2-dimethyl-3-methylenebicyclo[2.2.1]heptane | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 7. | Linalyl acetate | (R)-3,7-dimethylocta-1,6-dien-3-yl acetate | $C_{12}H_{20}O_2$ | 196.29 | C=73.43, H=10.27, O=16.30 |
| 8. | α -pinene | (1R,5R)-2,6,6-trimethylbicyclo[3.1.1]hept-2-ene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 9. | Terpine-4-ol | (R)-1-isopropyl-4-methylcyclohex-3-enol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 10. | lβ, 4β, 7α-trihydroxyeudesmane | (1R,4S,4aR,6S,8aR)-6-isopropyl-4,8a-dimethyldecahydronaphthalene-1,4,6-triol | $C_{15}H_{28}O_3$ | 256.38 | C=70.27, H=11.01, O=18.72 |
| 11. | γ -terpinene | 1-isopropyl-4-methylcyclohexa-1,4-diene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 12. | α-cadinol | (1R,4S,4aR,8aR)-4-isopropyl-1,6-dimethyl-1,2,3,4,4a,7,8,8a-octahydronaphthalen-1-ol | $C_{15}H_{26}O$ | 222.37 | C=81.02, H=11.79, O=7.20 |
| 13. | Homalomenol A | (1R,3aR,4R,7S,7aR)-3a,7-dimethyl-1-(2-methylprop-1-en-1-yl)octahydro-1H-indene-4,7-diol | $C_{15}H_{26}O_2$ | 238.37 | C=75.58, H=10.99, O=13.42 |
| 14. | Oplopanone | 1-((1S,3aR,4R,7S,7aS)-4-hydroxy-7-isopropyl-4-methyloctahydro-1H-inden-1-yl)ethanone | $C_{15}H_{26}O_2$ | 238.37 | C=75.58, H=10.99, O=13.42 |
| 15. | Oplodiol | (1S,4R,4aR,8aR)-7-isopropyl-1,4a-dimethyl-1,2,3,4,4a,5,8,8a-octahydronaphthalene-1,4-diol | $C_{15}H_{26}O_2$ | 238.37 | C=75.58, H=10.99, O=13.42 |
| 16. | Bullatantriol | (1S,3aR,4R,7S,7aR)-1-(tert-butyl)-3a,7-dimethyloctahydro-1H-indene-4,7-diol | $C_{15}H_{28}O_2$ | 240.38 | C=74.95, H=11,74, O=13.31 |
| 17. | α-terpineol | 2-(4-methylcyclohex-3-en-1-yl)propan-2-ol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 18. | Nerol | (Z)-3,7-dimethylocta-2,6-dien-1-ol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 19. | α -Terpinene | 1-isopropyl-4-methylcyclohexa-1,3-diene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 20. | Spatulenol | (1aR,4aR,7S,7aR,7bR)-1,1,7-trimethyl-4-methylenedecahydro-1H-cyclopropa[e]azulen-7-ol | $C_{15}H_{24}O$ | 220.35 | C=81.76, H=10.98, O=7.26 |
| 21. | T-cadinol | (1S,4S,4aR,8aR)-4-isopropyl-1,6-dimethyl-1,2,3,4,4a,7,8,8a-octahydronaphthalen-1-ol | $C_{15}H_{26}O$ | 222.37 | C=81.02, H=11.79, O=7.20 |
| 22. | 4-terpineol | (R)-1-isopropyl-4-methylcyclohex-3-enol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 23. | α–methyl-α–(4-methyl-3-pentenyl}-oriranemethanol | 6-methyl-2-(oxiran-2-yl)hept-5-en-2-ol | $C_{10}H_{18}O_2$ | 170.25 | C=70.55, H=10.66, O=18.80 |
| 24. | 7-octadiene-2,6-diol-2, 6-dimcthyl | (E)-2,6-dimethylocta-3,7-diene-2,6-diol | $C_{10}H_{18}O_2$ | 170.25 | C=70.55, H=10.66, O=18.80 |
| 25. | 1, 2-dimethylbenzene | o-xylene | $C_8H_{10}$ | 106.16 | C=90.51, H=9.49 |
| 26. | Cryptone | (S)-4-isopropylcyclohex-2-enone | $C_9H_{14}O$ | 138.21 | C=78.21, H=10.21, O=11.58 |
| 27. | δ –cadinene | (1S,8aR)-1-isopropyl-4,7-dimethyl-1,2,3,5,6,8a-hexahydronaphthalene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |
| 28. | T-muurolol | (1S,4S,4aR,8aS)-4-isopropyl-1,6-dimethyl-1,2,3,4,4a,7,8,8a-octahydronaphthalen-1-ol | $C_{15}H_{26}O$ | 222.37 | C=81.02, H=11.79, O=7.20 |
| 29. | Viridiflorol | (1aR,4S,4aS,7R,7aS,7bS)-1,1,4,7-tetramethyldecahydro-1H-cyclopropa[e]azulen-4-ol | $C_{15}H_{26}O$ | 222.37 | C=81.02, H=11.79, O=7.20 |
| 30. | M-cymene | m-cymene | $C_{10}H_{14}$ | 134.22 | C=89.49, H=10.51 |
| 31. | γ -Muurolene | (1S,4aS,8aR)-1-isopropyl-7-methyl-4-methylene-1,2,3,4,4a,5,6,8a-octahydronaphthalene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |
| 32. | *cis*-linalool oxide | 2-((2R,5S)-5-methyl-5-vinyltetrahydrofuran-2-yl)propan-2-ol | $C_{10}H_{18}O_2$ | 170.25 | C=70.55, H=10.66, O=18.80 |

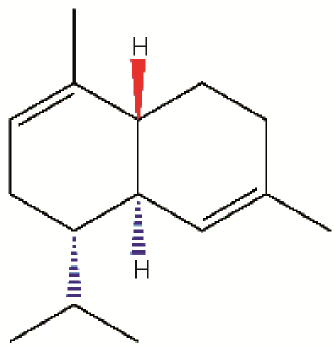
(*Contd*.)

Table 2—Phytochemical constituent of essential oil in leaves and rhizome of *H. aromatica*[6,9,16,17,24,29,30] (*Contd*.)

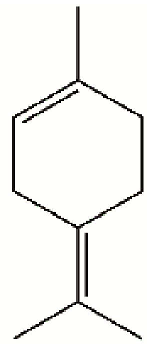
| S. No. | Compound Name | IUPAC Name | Molecular formula | Molecular weight | Anal. calculated for element (%) |
|---|---|---|---|---|---|
| 33. | *trans*-linalool oxide | 2-((2S,5R)-5-methyl-5-vinyltetrahydrofuran-2-yl)propan-2-ol | $C_{10}H_{18}O_2$ | 170.25 | C=70.55, H=10.66, O=18.80 |
| 34. | *cis*-p-menth-2-en,1-ol | (1S,4S)-4-isopropyl-1-methylcyclohex-2-enol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 35. | *trans*-p-menth-2-en,1-ol | (1R,4S)-4-isopropyl-1-methylcyclohex-2-enol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 36. | p-menth-2-en-1-ol | 4-isopropyl-1-methylcyclohex-2-enol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 37. | p-cymen-8-ol | 2-(p-tolyl)propan-2-ol | $C_{10}H_{14}O$ | 150.22 | C=79.96, H=9.39, O=10.65 |
| 38. | Cuminaldehyde | 4-isopropylbenzaldehyde | $C_{10}H_{12}O$ | 148.20 | C=81.04, H=8.16, O=10.80 |
| 39. | Carvone | (R)-2-methyl-5-(prop-1-en-2-yl)cyclohex-2-enone | $C_{10}H_{14}O$ | 150.22 | C=79.96, H=9.39, O=10.65 |
| 40. | Car-3-en-2-one | (1S,6R)-3,7,7-trimethylbicyclo[4.1.0]hept-3-en-2-one | $C_{10}H_{14}O$ | 150.22 | C=79.96, H=9.39, O=10.65 |
| 41. | Piperitone | (R)-6-isopropyl-3-methylcyclohex-2-enone | $C_{10}H_{16}O$ | 152.23 | C=78.90, H=10.59, O=16.51 |
| 42. | β-caryophyllene | (1R,9S,E)-4,11,11-trimethyl-8-methylenebicyclo[7.2.0]undec-4-ene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |
| 43. | α-humulene | (1E,4E,8E)-2,6,6,9-tetramethylcycloundeca-1,4,8-triene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |
| 44. | allo-aromadendrene | (1aR,4aS,7R,7aR,7bS)-1,1,7-trimethyl-4-methylenedecahydro-1H-cyclopropa[e]azulene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |
| 45. | α-muurolene | (1S,4aS,8aR)-1-isopropyl-4,7-dimethyl-1,2,4a,5,6,8a-hexahydronaphthalene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |
| 46. | α-calacorene | (S)-1-isopropyl-4,7-dimethyl-1,2-dihydronaphthalene | $C_{15}H_{20}$ | 200.32 | C=89.94, H=10.06 |
| 47. | Ledol | (1aR,4R,4aS,7R,7aS,7bS)-1,1,4,7-tetramethy-ldecahydro-1H-cyclopropa[e]azulen-4-ol | $C_{15}H_{26}O$ | 222.37 | C=81.02, H=11.79, O=7.20 |
| 48. | Humulene epoxide II | (1R,3E,7E,11S)-1,5,5,8-tetramethyl-12-oxabicyclo[9.1.0]dodeca-3,7-diene | $C_{15}H_{24}O$ | 220.35 | C=81.76, H=10.98, O=7.26 |
| 49. | *epi*-α-cadinol | (1R,4R)-4-isopropyl-1,6-dimethyl-1,2,3,4,4a,7,8,8a-octahydronaphthalen-1-ol | $C_{15}H_{26}O$ | 222.37 | C=81.02, H=11.79, O=7.20 |
| 50. | Hexadecanoic acid | tetradecanoic acid | $C_{14}H_{28}O_2$ | 228.37 | C=73.63, H=12.36, O=14.04 |
| 51. | α -thujene | (1R,5R)-5-isopropyl-2-methylbicyclo[3.1.0]hex-2-ene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 52. | Sabinene | (1R,5R)-1-isopropyl-4-methylenebicyclo[3.1.0]hexane | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 53. | β-pinene | (1R,5R)-6,6-dimethyl-2-methylenebicyclo[3.1.1]heptane | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 54. | Myrcene | 3,7-dimethylocta-1,6-diene | $C_{10}H_{18}$ | 138.25 | C=86.88, H=13.12 |
| 55. | α -phellandrene | (R)-5-isopropyl-2-methylcyclohexa-1,3-diene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 56. | δ-3-carene | (1S,6R)-3,7,7-trimethylbicyclo[4.1.0]hept-3-ene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 57. | *p*-cymene | p-cymene | $C_{10}H_{14}$ | 134.22 | C=89.49, H=10.51 |
| 58. | β -phellandrene | (R)-3-isopropyl-6-methylenecyclohex-1-ene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 59. | (z)-β-Ocimene | (Z)-3,7-dimethylocta-1,3,6-triene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 60. | (E)- β-Ocimene | (E)-3-ethyl-7-methylocta-1,3,6-triene | $C_{11}H_{18}$ | 150.26 | C=87.93, H=12.07 |
| 61. | Terpinolene | 1-methyl-4-(propan-2-ylidene)cyclohex-1-ene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 62. | Eucarvone | (2Z,4Z)-2,6,6-trimethylcycloocta-2,4-dienone | $C_{11}H_{16}O$ | 164.24 | C=80.44, H=9.82, O=9.74 |
| 63. | Geraniol | (E)-3,7-dimethylocta-2,6-dien-1-ol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 64. | Phellandral | (S)-4-isopropylcyclohex-1-enecarbaldehyde | $C_{10}H_{16}O$ | 152.23 | C=78.90, H=10.59, O=10.51 |
| 65. | Cuminol | (4-isopropylphenyl)methanol | $C_{10}H_{14}O$ | 150.22 | C=79.96, H=9.39, O=10.65 |
| 66. | Neryl acetate | (Z)-3,7-dimethylocta-2,6-dien-1-yl acetate | $C_{12}H_{20}O_2$ | 196.29 | C=73.43, H=10.27, O=16.30 |
| 67. | α-selinene | (2R,4aR,8aR)-4a,8-dimethyl-2-(prop-1-en-2-yl)-1,2,3,4,4a,5,6,8a-octahydronaphthalene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |
| 68. | Caryophyllene oxide | (1S,5R,7R,11R)-7,12,12-trimethyl-2-methylene-6-oxatricyclo[9.2.0.05,7]tridecane | $C_{16}H_{26}O$ | 234.38 | C=81.99, H=11.18, O=6.83 |
| 69. | α -Terpinolene | (S)-2-(4-methylcyclohex-3-en-1-yl)propan-2-ol | $C_{10}H_{18}O$ | 154.25 | C=77.87, H=11.76, O=10.37 |
| 70. | α -Terpene | 1-isopropyl-4-methylcyclohexa-1,3-diene | $C_{10}H_{16}$ | 136.23 | C=88.16, H=11.84 |
| 71. | γ-cadinene | (1R,4aS,8aS)-1-isopropyl-7-methyl-4-methylene-1,2,3,4,4a,5,6,8a-octahydronaphthalene | $C_{15}H_{24}$ | 204.35 | C=88.16, H=11.84 |



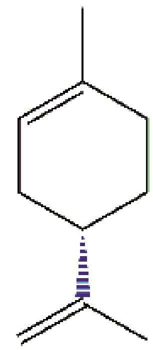

Linalool
**1**



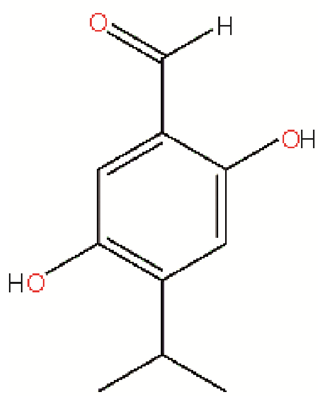

α-Cadinene
**2**



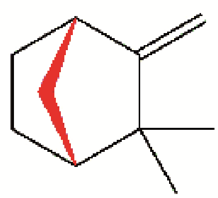
Terpinolene
**3**



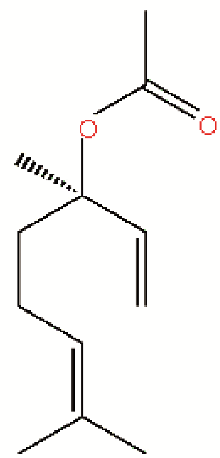
Limonene
**4**



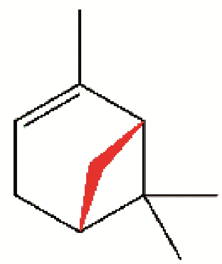

Dihydrocuminaldehyde
**5**



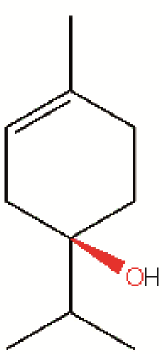
Camphene
**6**



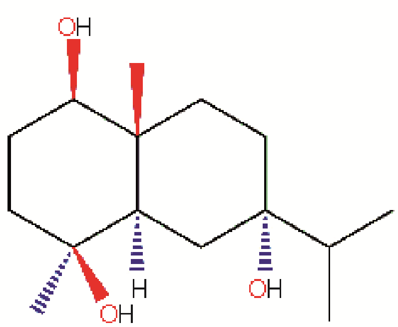

Linalyl acetate
**7**



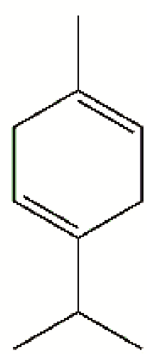
α-Pinene
**8**



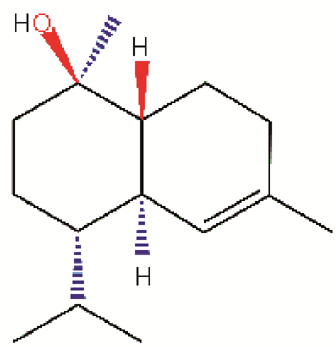

Terpinen-4-ol
**9**




1β, 4β, 7α-Trihydroxyeudesmane
**10**

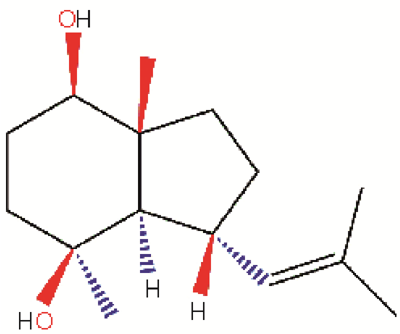


γ-Terpinene
**11**

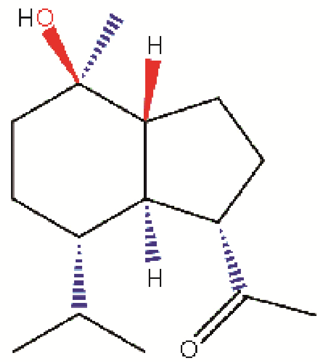



α-Cadinol
**12**

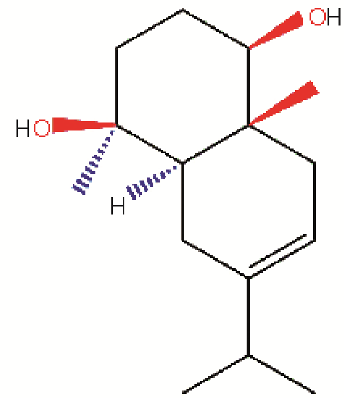
Fig. 1—Chemical structures of different phytochemical constituents in *Homalomena aromatica* Schott.



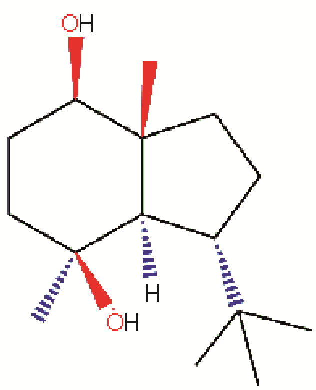
Homalomenol A
**13**



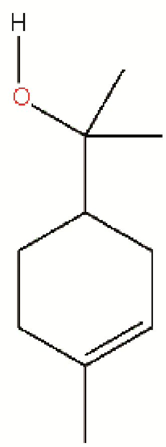
Oplopanone
**14**



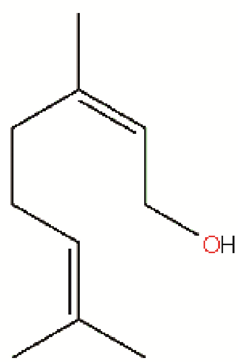
Oplodiol
**15**



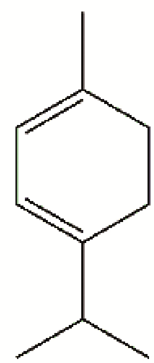
Bullatantriol
**16**



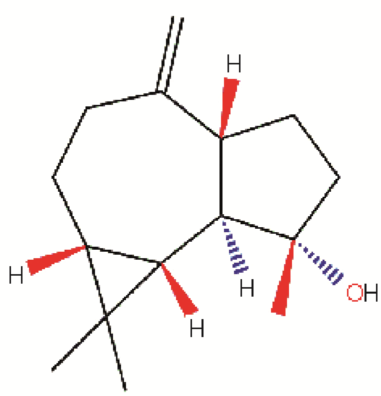
α-Terpineol
**17**



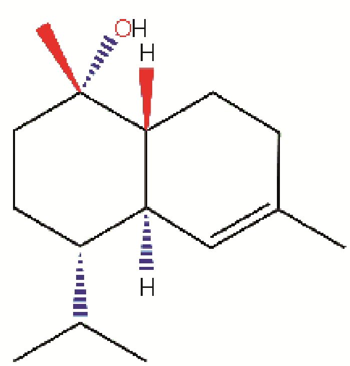
Nerol
**18**



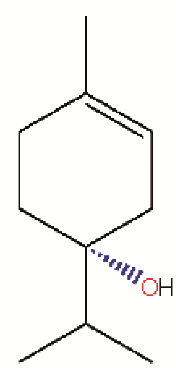
α-Terpinene
**19**



Spathulenol
**20**

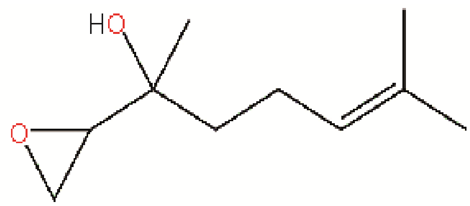


T-cadinol
**21**

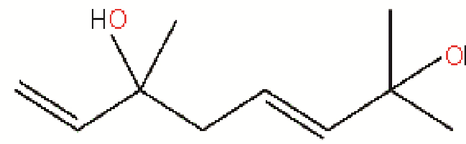


4-terpineol
**22**

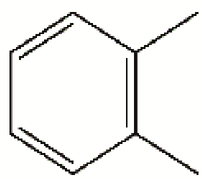
Fig. 1—Chemical structures of different phytochemical constituents in *Homalomena aromatica* Schott. (*Contd*.)



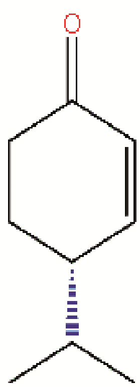
α-methyl-α-(4-methyl-3-pentenyl) - oriranemethanol
**23**



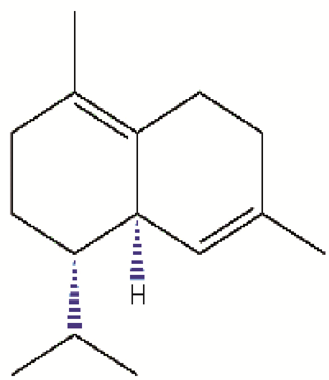
2, 6-Dimethylocta-3, 7-diene-2, 6-diol
**24**



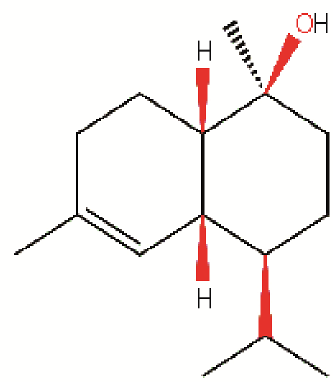
1, 2-dimethylbenzene
**25**



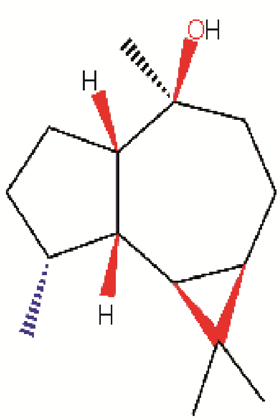
Cryptone
**26**



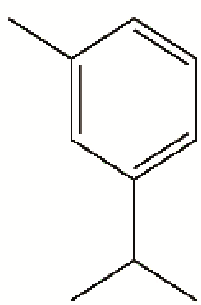
δ-cadinene
**27**



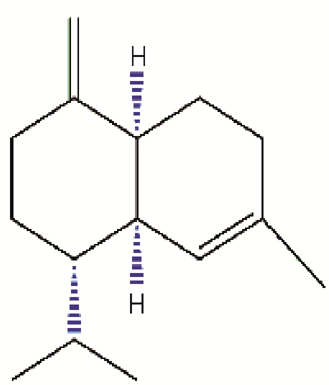
T-muurolol
**28**



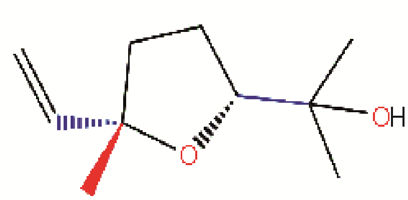
Viridiflorol
**29**



M-Cymene
**30**

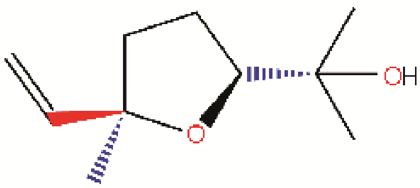


γ-Muurolene
**31**

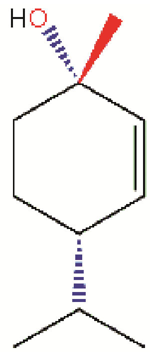


*cis*-Linalool oxide
**32**

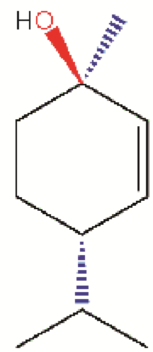
Fig. 1—Chemical structures of different phytochemical constituents in *Homalomena aromatica* Schott. (*Contd*.)



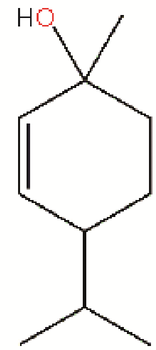

*trans*-Linalool oxide
**33**



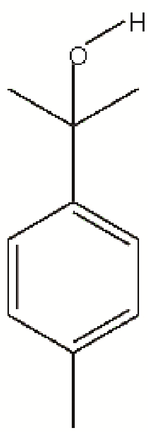

*cis*-p-menth-2-en-1-ol
**34**



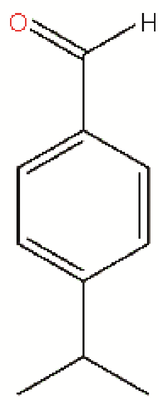

*Trans*-p-menth-2-en-1-ol
**35**



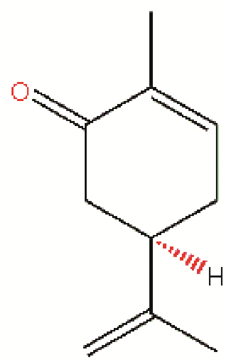

p-menth-2-en-1-ol
**36**



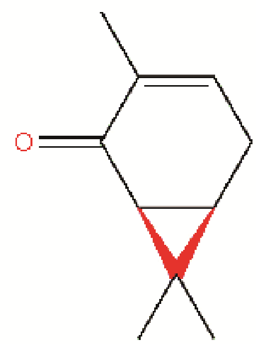

p-cymen-8-ol
**37**



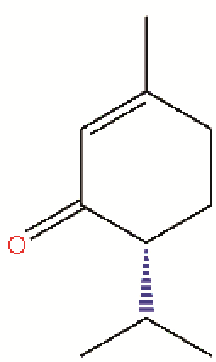

Cuminaldehyde
**38**



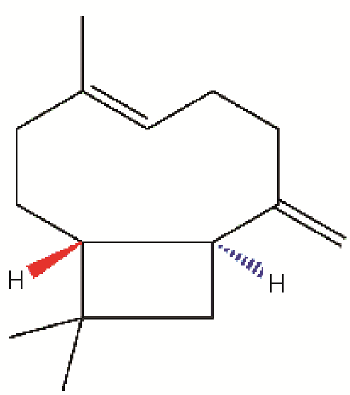

Carvone
**39**



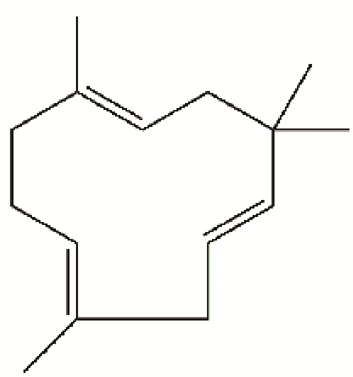

Car-3-en-2-one
**40**



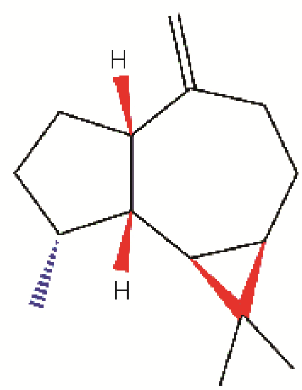

Piperitone
**41**




β-caryophyllene
**42**

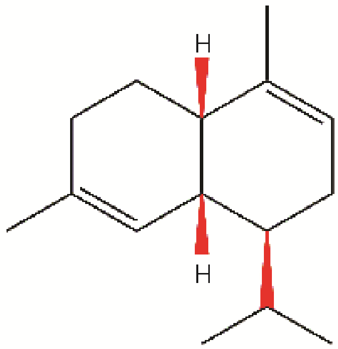


α-humulene
**43**

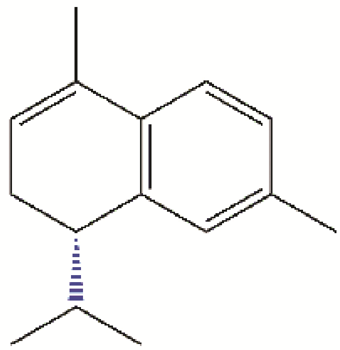



allo-aromadendrene
**44**

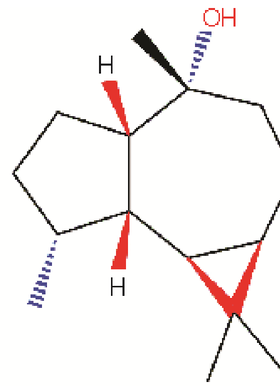
Fig. 1—Chemical structures of different phytochemical constituents in *Homalomena aromatica* Schott. (*Contd*.)



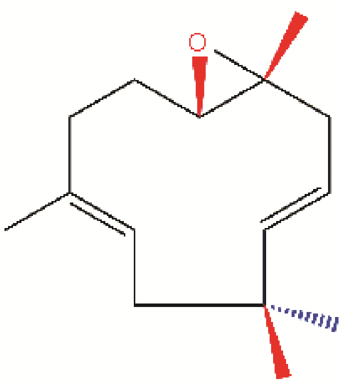

α-muurolene
**45**



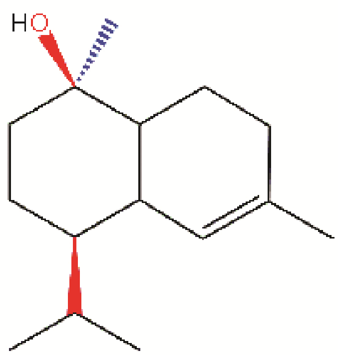
α-calacorene
**46**



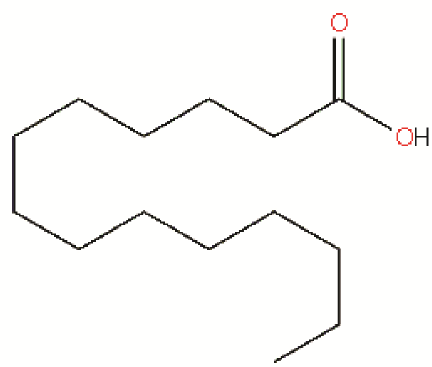

Ledol
**47**



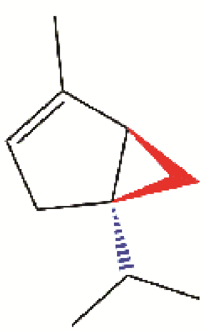

Humulene epoxide II
**48**



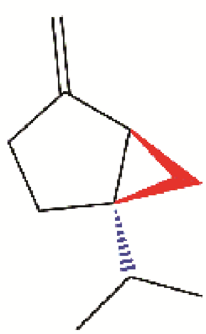

*Epi*-α-cadinol
**49**



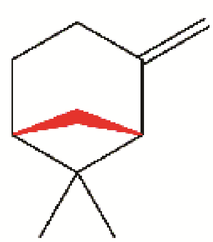

Hexadecanoic acid
**50**



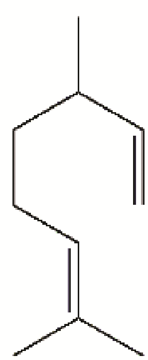
α-Thujene
**51**



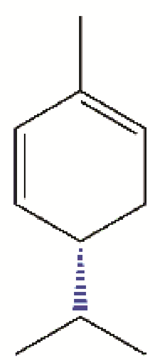
Sabinene
**52**



β-Pinene
**53**

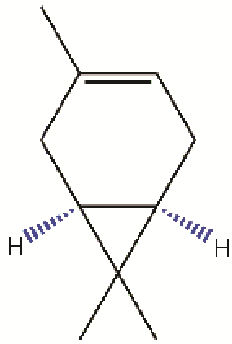


Myrcene
**54**

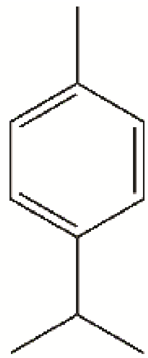


α-Phellandrene
**55**

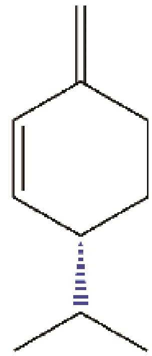
Fig. 1—Chemical structures of different phytochemical constituents in *Homalomena aromatica* Schott. (*Contd.*)



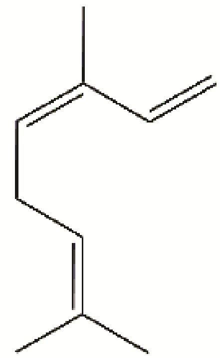
δ-3-Carene
**56**



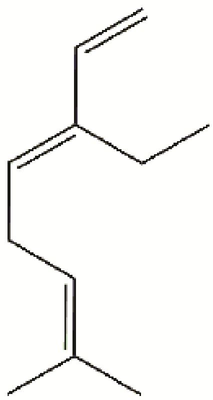
p-Cymene
**57**



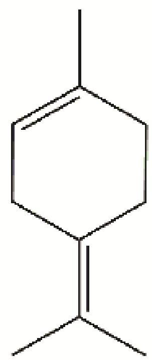
β-Phellandrene
**58**



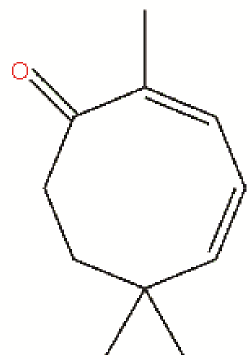
(Z)-β-Ocimene
**59**



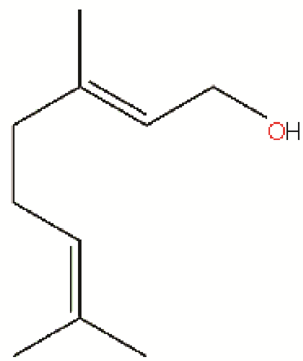
(*E*)-β-Ocimene
**60**



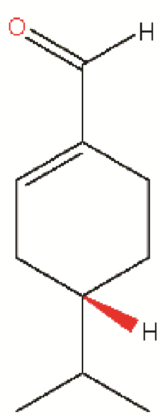
Terpinolene
**61**



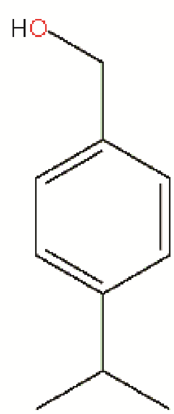
Eucarvone
**62**



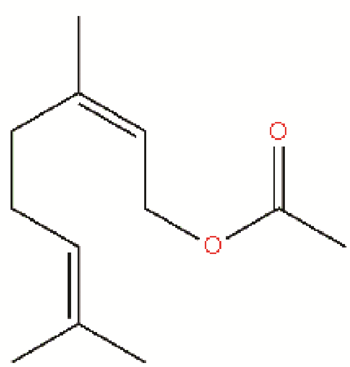
Geraniol
**63**



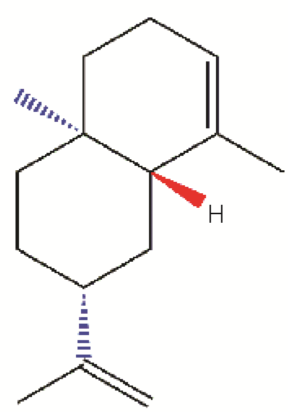
Phellandral
**64**



Cuminol
**65**



Neryl acetate
**66**



α-Selinene
**67**

Fig. 1—Chemical structures of different phytochemical constituents in *Homalomena aromatica* Schott. (*Contd*.)

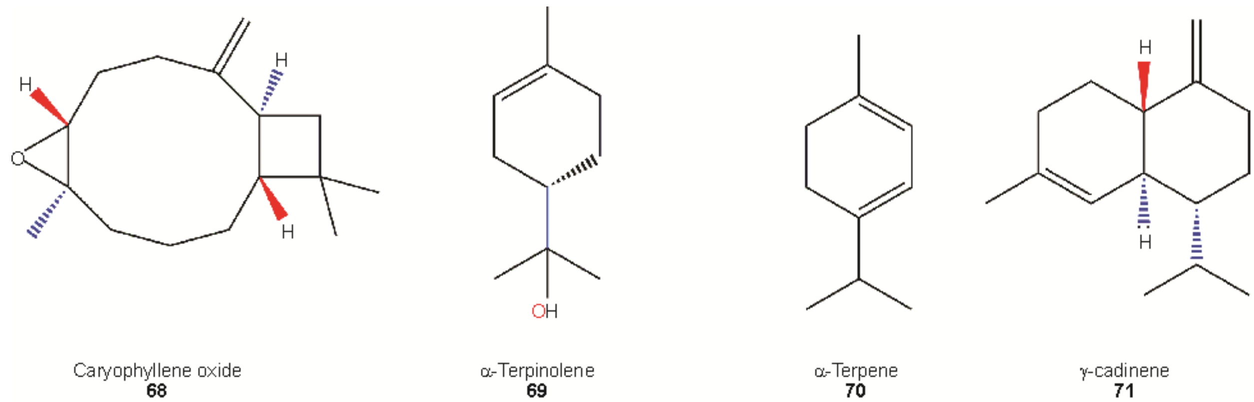



Fig. 1—Chemical structures of different phytochemical constituents in *Homalomena aromatica* Schott. (*Contd*.)

the first time. Other major components were identified as linalool (62.5 %), terpene-4-ol (7.08 %), δ -cadinene (5.57 %), α -cadinol (3.71 %), and spatulenol (1.81 %)[6]. In the last few decades, as many as 71 compounds have been identified in Rhizome oil of *H. aromatic* with varying content of major components, however, linalool remain as the most abundant constituent (50-70 %) in *H. aromatica* essential oil. Future research should be directed towards isolation and purification of these compounds coupled with *in vitro* bioactivity assay for possible application.

## Conclusion and perspective

Northeast India is home to *H. aromatica,* a potent medicinal and aromatic herb. However, despite its importance, conservation of this herb is one of the major challenges confronting the region. The herb is being overexploited as a forest product without conservation and/or cultivation measures, and therefore, as a result *H. aromatica* has already become endangered[14]. Despite its immense commercial interest, limited studies including traditional knowledge, essential oil composition, and bioactivity studies have been carried out till date[6-9,11-18,20-26,29,30]. The agro-climatic condition of Northeast India is highly suitable for the growth and development of this medicinal aromatic herb[8]. Large scale scientific cultivation will reduce collection pressure in the wild habitat and create new windows for entrepreneurial opportunity. Regardless of its endangered status invoking immediate scientific intervention for its conservation and utilization, development of strategies for its conservation and economic utilization remain a challenge till today. More investigations are needed to fully employ and unearth the potential of this herb. Research priority should be directed towards identification of superior genotype and mass multiplication for large scale cultivation, in-depth research should also focus on phytochemical profiling, pharmacological investigations, molecular profiling so as to excavate novel bioactive compounds/activities, identify superior genotype and production of quality planting material for large scale cultivation. Highly efficient *in vitro* propagation protocol should be developed to utilize biotechnological tools for conservation and utilization of this endangered herb. The use of scientific cultivation practices, value addition to the products, storage infrastructure, and creation of adequate marketing opportunities can improve the economy of this region, particularly the tribal population. Identification, collection, and maintenance of genetically diverse wild germplasm from Northeast India would be of great importance in the formulation of conservation strategies. Genetic diversity analysis would also provide foundation data for managing *H. aromatica* germplasm resources, including the construction of a core collection and regional variety distribution and subrogation. It will also help in evaluation of genetic relationships and characterization of other *Homalomena* spp. Medicinal plants are under the threat of overexploitation and biodiversity depletion. There is an urgent need for their *ex situ* conservation. Germplasm collection and *in vitro* conservation of *H. aromatica* will opens fresh avenues towards conservation, management and sustainable utilization of this overexploited herb for human and livestock health care and to promote conservation and sustainable uses of medicinal plants in and around site of global significance.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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