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Ethnomedicinal, phytochemical and pharmacological properties of *Pogostemon heyneanus* Benth: A review

Himanshi Rathnasekara[1], W.J.A. Banukie Jayasuriya[1]*, L.D.A. Menuka Arawwawala[2] and T. Sugandhika Suresh[3]

[1]Department of Pharmacy and Pharmaceutical Sciences, Faculty of Allied Health Sciences; [3]Department of Biochemistry, Faculty of Medical Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka 10250

[2]Herbal Technology Section, R & D Complex, Industrial Technology Institute, Halbarawa, Thalahena, Malabe, Sri Lanka 10115

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A renewed interest in using nature-originated medicines can be seen throughout the world due to their benefits when compared to synthetic or semi-synthetic drugs in the aspect of increasing the quality of life of human beings. *Pogostemon heyneanus* Benth is a prominent and well-known medicinal plant in Asian countries that is recommended with high value in traditional medicinal practices, Ayurvedic treatments and folkloric use. It is also known as 'Indian patchouli' and 'Java patchouli'. *P. heyneanus* is pharmacologically and economically important due to its essential oil and is used in perfumery industries as well. The consistency of the presence of a wide range of phytochemical constituents such as phenolic compounds, terpenes, steroids, flavonoids, saponins, and tannins enables activities like cytotoxic and anticancer, antimicrobial, antioxidant, gastroprotective, etc. Essential oil of *P. heyneanus* is comprised of α–pinene, β-pinene, limonene, β-pachoulin, seychellene, β-caryophyllene, α–guaiene, nerolidol and patchouli alcohol. Moreover, *P. heyneanus* is a unique cause having acetophenone as its main component which was not reported in the essential oils of other *Pogostemon* species. The scope of the present review was to gather scientific information on *P. heyneanus* in terms of habitat and distribution, traditional uses and ethnopharmacology, phytochemistry, and medicinal activities (cytotoxic and anticancer, antimicrobial, antioxidant and gastroprotective), which were published before 31st July 2022.

Keywords: Bio-activities, Ethnopharmacology, Habitat, Patchouli, Pharmacological, Phytochemicals, *Pogostemon heyneanus*

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Introduction

Plants have been used as sources of condiments, food and aromatics for the well-being of human beings throughout history[1]. Chemical constituents of medicinal plants are one of the richest hot spots for significant new drug discoveries and lead to the pharmacological and physiological efficiency of some treatment regimens[2]. Currently, there is an increasing interest in using medicinal plants, their extracts and essential oils due to the potentially harmful effects exerted by synthetic substances[3]. It is estimated that 80% of the world's population living in developing countries rely on herbal medicines as a primary source of healthcare. The practice of complementary and alternative medicine and traditional medicine is becoming popular[4-6]. The benefits of herbal medicines are considerably higher than that of allopathic medicines. It is predicted that herbal medicines will eventually regain their value and importance in the medical field[7].

*Correspondent author
Email: banukie@sjp.ac.lk

Medicinal plants contain secondary metabolites such as alkaloids, glycosides, polyphenols, flavonols/ flavonoids, terpenoids, or their oxygen-substituted derivatives[8]. Due to the presence of various types of bioactive compounds, the potency of medicinal plants in therapeutic usage is varied *viz* antibacterial, anti-inflammatory, analgesic, anticancer, antioxidant, etc[7]. Biological activities and uses of medicinal plants with special emphasis on the mode of action were reviewed and summarized[3]. Moreover, the synergism of bioactive compounds may enhance their activity.

Essential oils are secondary metabolites synthesised by medicinal plants and are volatile in nature[9]. The oils play an important role in plants by conferring protection. The oils make the plant resist pathogens and herbivores and attract insects to facilitate pollination. Moreover, essential oils play an important role in allelopathic communication between plants[9,10]. The biological activities of essential oils are well documented and possess antimicrobial, antioxidant, anticancer, anti-inflammatory activities, gastroprotection, etc[11,12].

The present review is based on the aromatic plant *Pogostemon heyneanus* Benth which belongs to the family Lamiacea. *Pogostemon* is a genus of about 80 species of herbs or subshrubs with a centre of diversity in tropical and subtropical Asia, with five species endemic to Africa[13,14]. The plant is found in almost all parts of India, China, Thailand, Indonesia, Malaysia, Mauritius, Philippines, West Africa, Vietnam and Sri Lanka except in extremely dry zone[15,16]. The plant is known as Kollan kola or Gankollan kola in Sinhala, Katirpaccai or Kannokkikyacceti in Tamil, Huo Xiang in Chinese, and Pachouli or Java patchouli in English. Other vernacular names which different ethnic groups have used to identify this plant are Sugandhipanadi (Gujarati), Sughandaka (Sanskrit), Xukloti (Assame), Kadirpachai (India), Paat (Konkani), Pach (Marathi)[17.]

P. heyneanus is reported to possess antibacterial, antifungal, cytotoxic and anticancer, antioxidant, gastroprotective, insecticidal, expectorant, diuretic, anti-rheumatic, disinfectant and wound healing activities[17-25]. Almost all plant parts, namely, roots, leaves, shoots, stem, and bark, are used in traditional medicine[17].

It is reported that the essential oil of *P. heyneanus* leaves exhibits various biological activities[26]. The oil is yellowish and warm, with a mildly pungent flavour. The essential oil is mainly composed of α–pinene, β-pinene, limonene, ethanone, 1,3-butanedione, β-pachoulin, seychellene, β caryophyllene, α–guaiene, nerolidol and patchouli alcohol (patchoulol)[26].

The scope of the present review was to gather scientific information on *P. heyneanus* in terms of a) habitat and distribution, b) traditional uses and ethnopharmacology, c) phytochemistry, and d) medicinal activities.

Materials and Methods

A systematic review of published studies on morphological characteristics, ethnobotanical importance, and pharmacological properties of *P. heyneanus* was performed. A comprehensive literature search was conducted using the databases of Google Scholar, Scopus, PubMed, Web of Science and Science Direct for studies published before 31st July 2022. *Pogostemon heyneanus*, phytochemical, pharmacological, ethnopharmacology, and Patchouli were used as the subject headings and keywords and screened, limiting to studies in English.

In the second stage, total results articles from the above databases were pooled together and the duplicate articles were removed. The remaining articles were selected by reading the title and further the abstracts. In proceeding with these stages, articles different from the inclusion criteria were excluded. By reading the full text of the remaining articles, those not meeting the inclusion criteria were excluded. A manual search from the library of the Institute of Indigenous Medicine, University of Colombo, Rajagiriya, Sri Lanka was conducted using books such as Compendium of Medicinal Plants[27,28], Osuthuru Wisithuru[15]and Ayurveda Pharmacopoeia[29] published by the Department of Ayurveda of Sri Lanka in order to obtain additional data. Two reviewers conducted this independent search process, and the final group of articles to be considered was determined after a recursive concurrence procedure.

Results and Discussion

Literature search

The following number of articles could be identified through the literature search using the above search engines; Google Scholar (n= 98), Web of Science (n= 6), PubMed (n= 7), and Science Direct (n= 18). The total numbers of published studies included in the present review were 51 after removing the duplicates. Fig. 1 shows the illustrated diagram of the search strategy.

Botanical description

P. heyneanus is a large aromatic herb, straggling under shrub with horizontal branches, and the stem ascends to 1.72 m higher. Fig. 2a shows the whole

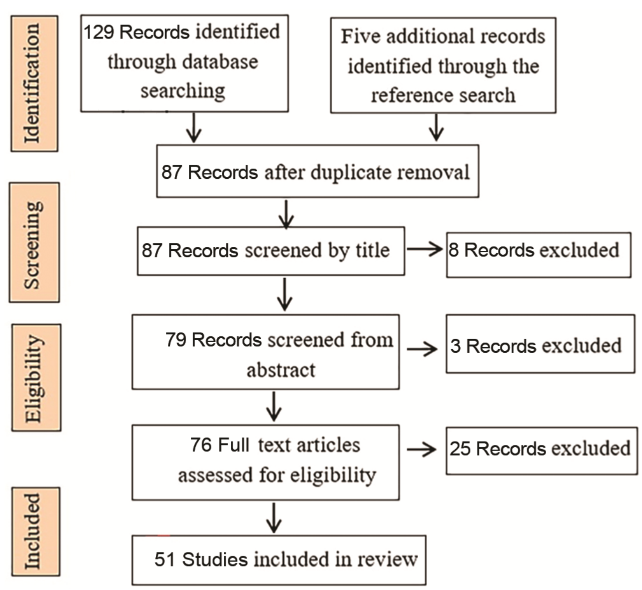

Fig. 1 — Illustrated diagram of the search strategy.

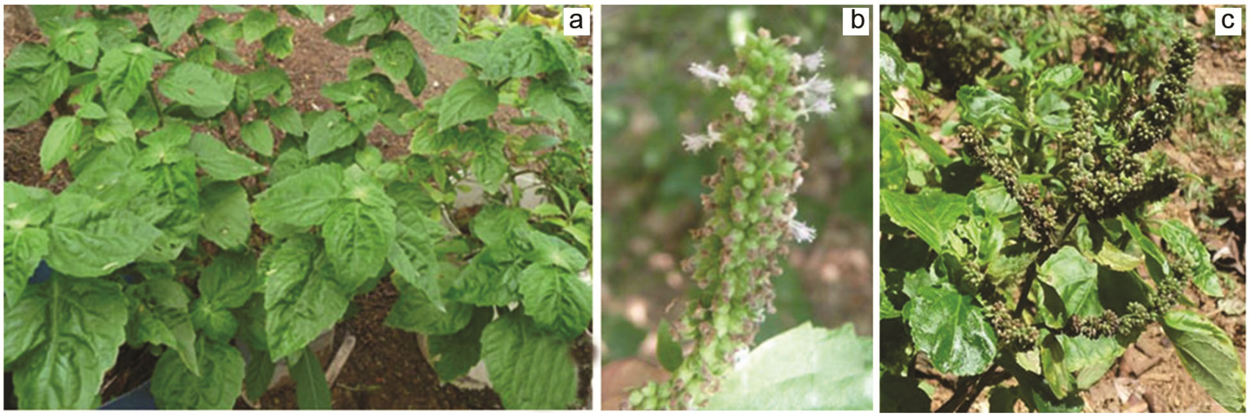

Fig. 2 — *Pogostemon heyneanus*, a) whole plant; b) flower; and c) fruits[30] (Ayurvedic plant database, University of Ruhuna).

plant of *P. heyneanus*. There are 4-angled leaves which are lanceolate and 5-12.5 cm long. These leaves are simple, opposite, without stipules and slightly hairy on both sides. Petioles are 2.5-7.5 cm long. Flowers are irregular, bisexual, numerous, and sessile in small dense fascicles. Furthermore, these are white-tinged with pink colour in pubescent cylindrical spikes. The flower and fruits of *P. heyneanus* are shown in Fig. 2b-c respectively. The calyx is five-toothed. Corolla is normally lilac or white and blipped into 4-lobed. The tube is approximately 5 mm, and the bracts are foliaceous with four stamens. Panicles are 14 cm long and vertically globose and dense. Nutlets are 1 mm in diameter and pale brown. The flowering and fruiting period of *P. heyneanus* is from April to May[17,30,31].

Taxonomy[32]

Taxonomy of *P. heyneanus* is as follows, Domain: Eukaryota, Kingdom: Plantae, Subkingdom: Tracheobionta, Superdivision: Spermatophyta, Division: Magnoliophyta, Class: Magnoliopsida, Subclass: Asteridae, Order: Lamiales, Family: Lamiaceae, Genus: *Pogostemon*, Species: *heyneanus*

Habitat and distribution

P. heyneanus is a prominent plant in Sri Lanka which grows throughout the country except for the extremely dry zones and is especially found towards the hill country[15,17]. The plant is native to tropical regions of Asia and is now extensively cultivated in China, India, Thailand, Indonesia, Malaysia, Mauritius, Philippines, West Africa and Vietnam[16]. The habitat of *P. heyneanus* is described as it grows wild in moist, partially shady places in semi-evergreen and evergreen forests[33]. It is considered a lucrative commercial crop in countries like Indonesia[34]. When considering the South American region, it is grown in Paraguay and Brazil[35].

Uses in traditional medicine

P. heyneanus is used in the Ayurveda system of medicine in Sri Lanka, which has Tikta, Katu and Madura Rasa (bitter, pungent, and sweet taste, respectively), Laghu and Theekshna Guna (properties related to lightness and piercing action), UshnaVeerya (hot in potency), and KatuVipaka (pungent taste after digestion). It also possesses Kapha-Vatahara action (pacify Kapha and VataDosha in the body)[27]. The plant is used as prayoga in peenasa (rhinitis), Suthikaawastha (after parturition), and makkallashoolaya (pain due to infection in the uterus after childbirth)[29].

P. heyneanus is used as a gargle for weak and spongy gums, pyorrhoea and halitosis. It acts internally as an aromatic, stomachic, diuretic and carminative with astringent properties. Furthermore, the plant is used in anorexia, chronic dyspepsia and flatulence and is considered as expectorant, diuretic and stimulating disinfectant. It is used as a disinfectant for the genitourinary mucous membrane. Moreover, it is used in chronic bronchitis, gangrene of the lungs and phthisis, cardiac dropsy and gonorrhoea. Powdered leaves are used as sternutatory[17,36]. In addition to that, a decoction of the leaves is given for cough and asthma, and poultices are applied for boils, headaches, jaundice and bilious fever. The decoction of the root is specifically used for dropsy and rheumatism[20,26].

SushrutaSamhitha has described "Sheetada" as one of the tooth-based illnesses. *P. heyneanus* is used by traditional physicians for the treatment of "Sheetada"[24]. *P. heyneanus* is considered an ingredient of a traditional medicinal formula that can be used to manage haemorrhoids. Other formulation ingredients were *Myristica fragrans* Houtt, *Syzygium aromaticum* (L.) Merr., *Piper longum* L., *Nigella sativa* L., *Cuminum cyminum* L., *Foeniculum vulgare* Mill., *Coriandrum sativum* L., *Glycyrrhiza glabra* L., *Allium cepa* L., *Sesamum indicum* L., *Caryotaurens* L.[37] whereas kollanaadichuurnaya is used as a combination remedy with many other medicinal plant parts[15,29].

Thaalankai oil is a traditional Siddha polyherbal formulation which is used in Sri Lanka for the treatment of joint diseases (Vata diseases). The formulation includes 27 plant ingredients, including *P. heyneanus*[38].

Chandraprabhavati is a polyherbal preparation used as a remedy for inflammation, joint and bone diseases and kidney diseases. The formulation of Chandraprabhavati is mentioned in the Ayurvedic text book known as Sharanghadara Samhita. Tejapatra (*Cinnamomum tamala* L.), which is used in Ayurveda medicine, is defined as Patraka in the English translation of Sharanghadara Samhita, whereas Tejapatra is defined as *P. heyneanus* in the Sinhala translation of Sharanghadara Samhita[39]. However, *C. tamala* is not grown in Sri Lanka. Notably, *Cinnamomum tamala* is substituted by *P. heyneanus* (Kollankola).

A survey conducted among traditional practitioners in Western and Sabaragamuwa provinces in Sri Lanka revealed *P. heyneanus* as a treatment for snake bites in Sri Lanka[40]. Further the external application of *P. heyneanus* has been used as an antidote for snake bites[41].

A survey conducted in the Eastern province of Trincomalee district, Muthunagar Grama Niladhari division in Sri Lanka, has predominantly focused on medicinal plants which are used in the traditional medicinal system in Sri Lanka. The study was conducted from January 2014 to January 2015 and identified 176 species of medicinal plants belonging to 59 families in the interested area. Among the identified plants, *P. heyneanus* was also identified as a medicinal plant in this area. Pachchilai is the vernacular name for *P. heyneanus*. It is a shrub and a locally distributed medicinal plant[42].

The plant is ethnobotanically important for Kuruma tribe of Wayanad district of Kerala for treating cuts and wounds. Kadirpacha is the vernacular name of *P. heyneanus,* and the whole plant is made into ash and mixed with mustard oil and then applied on wounds[25]. Leaves, flowers, fruits, and roots are utilised in traditional medicine in the Malay peninsula, the Philippines, and Indo-China[43].

Phytochemistry

The presence of important phytochemicals makes the plant useful for treating a range of diseases and has the potential to provide valuable drugs for human usage[26]. According to the literature, Sri Lankan *P. heyneanus* leaves contain saponins, alkaloids, tannins and flavonoids[26]. In addition, the introduced variety *P. heyneanus* had shown high total phenolic content (by a spectrophotometric method using Folin-Ciocalteu reagent than that of Sri Lankan (0.83±0.01 mg Gallic acid equivalents per gram of sample) grown *P. heyneanus*[26,44]. Higher amounts of total phenolic and total flavonoid contents were observed in leaf extracts when compared to stem and root extracts in a study conducted in Sri Lanka[21]. Patchouli alcohol was presented in all the plant components, leaf, stem and root in higher percentages as 44.56±1.2, 20.72±1.23, and 5.76±1.00 respectively[21].

The presence of phenolics, flavonoids, tannins, alkaloids, saponins, terpenoids and cardiac glycosides in the aqueous extract of *P. heyneanus* leaves is reported. Further, total polyphenols (0.45±0.01 mg Gallic acid equivalents per g of sample) and flavonoids (1.34±0.01 mg Quercetin equivalents per g of sample) are present in the aqueous extract[22].

Qualitative analysis of *P. heyneanus* leaves' chloroform extract showed steroids and flavonoids. The quantitative analysis was carried out by gravimetric methods and revealed that high amounts of steroids, flavonoids, tannins and total phenols at 73.40±0.29, 3.20±0.02,1.17±0.02 and 0.66% w/w respectively. The leaf powder of *P. heyneanus* had high concentrations of saponins[20].

The essential oil with a distinctive, persistent and camphoraceous scent has been extracted from steam distillation of shade-dried leaves of *P. heyneanus*[35]. Therefore, this plant is highly valuable in the perfumery industry due to its strong fixative properties[26].

In this review, an attempt has been made to present the chemical composition of essential oil extracted from *P. heyneanus* grown in Sri Lanka and other countries. Table 1 summarises the extraction and the analytical techniques used to isolate and identify the phytochemicals from *P. heyneanus*. According to the studies in Table 1, major constituents found in the essential oil are patchouli alcohol, β-pinene, acetophenone and caryophyllene.

It is said that the essential oil of *P. heyneanus* has lower industrial interest, due to the lower patchoulol content[46]. However, patchoulol is considered important for the duration of the odour of the essential oil. Therefore, patchoulol is frequently used as an

Table 1 — Phytoconstituents isolated from *Pogostemon heyneanus* essential oil in different extraction conditions

Part of the plant	Extraction method	Analytical method	Constituents of essential oil	Country	References
Leaves	Not mentioned	GC-MS	Patchouli alcohol, α-pinene, β-pinene, nerolidol, β-patchouline, α- patchouline, β – caryophyllene, α-guaiene, delta-guaiene, seychellene, α- gurjunene	India	47
Leaves	Hydrodistillation using a Clevenger-type apparatus, dried in the presence of anhydrous sodium sulfate	GC-MS	Patchoulyl alcohol, α-guaiene, aromadendrene and δ-guaiene.	Amazon	45
Leaves and twigs	Oil was extracted using an extractor coupled to a heat exchanger. The extraction period lasted 6 hours, never surpassing the 0.2 kgf/cm2 pressure throughout the entire extraction process	GC-MS	Patchouli alcohol, α-bulnesene, α-guaiene, seychelene, α-patchoulene, δ-elemene, β-patchoulene, β-elemene, cyclohexene, β-caryophyllene, aciphyllene, 7-epi-α-selinene, *nor*-Spathulenol, caryophyllene oxide and pogostol.	Belém, Pará, Brazil	35
Leaves	Hydrodistilled in a Clevenger type apparatus for 8 hours. The oil was dried over anhydrous sodium sulfate	GC-MS	Acetophenone, β-pinene, (*E*)-nerolidol, patchouli alcohol, monoterpenes, oxygenated monoterpenes, sesquiterpenes, oxygenated sesquiterpenes, benzenoid compounds and aliphatic compounds including α-pinene, 3-octanone, limonene, terpinolene, linalool, α-terpineol, benzoyl acetone, (E)-caryophyllene, α-guaiene, seychellene, α-humulene, α-patchoulene, aciphyllene, α-bulnesene, 7-epi-α-selinene, α-bulnesene epoxide, caryophyllene oxide and pogostol.	Courtallum hills of the southern Western Ghats in Tamil Nadu, India	33
Leaves	Distilled for 160 min using a Clevenger-type system	GC-MS	β-pinene. α-pinene, acetophenone, limonene, β-patchoulene, β-caryophyllene, α-guaiene, seychellene, α-humulene, α-patchoulene, α-bulnesene, (E)nerolidol, caryophyllene oxide, patchoulol and pogostol.	Federal University of Sergipe, SãoCristóvão-SE, Brazil.	46
Leaves	Hydro-distillation for 4 h at 60° C using a Clevenger apparatus. The essential oil was extracted with diethyl ether and dried over anhy drous sodium sulphate	GC-MS	The oil represented mainly a mixture of monoterpenes and sesquiterpenes. Trans-nerolidol, patchouli alcohol and caryophyllene were the major sesquiterpenes, whereas β-pinene was the major monoterpene. Other constituents were acetophenone and dimethyl-4-(1-methylethylidene)-, (8S-cis)-5(1H)-azulenone	Wayanad, Kannur and Kozhikode districts of Kerala, India.	23
Leaves	Hydro-distilled in a Clevenger-type distillation apparatus for 8 h. The oil was collected and dried over anhydrous sodium sulfate	GC-MS	β-pinene, ethenone, nerolidol, α–pinene, limonene, 1,3-butanedione, β-caryophyllene, α –guaiene, and patchouli alcohol.	Sri Lanka	26
Leaves, stems and roots	Hydro distilled in a Clevenger-type apparatus for 5 h	GC-MS	In roots, kaempferol was identified as the main component.	Sri Lanka	21
Leaves			Patchoulene, patchouli alcohol, eugenol, and patchoulipyridine, epiguapyridine, helwangin, and sesquiterpene vochellene.		36

(*Contd.*)

Table 1 — Phytoconstituents isolated from *Pogostemon heyneanus* essential oil in different extraction conditions — *(Contd.)*

Part of the plant	Extraction method	Analytical method	Constituents of essential oil	Country	References
Leaves	Samples were hydro-distilled in a Clevenger apparatus for about 8 h	GC–MS and GC- flame ionization detector (FID)	Acetophenone, β-pinene, (E)-caryophyllene, α-pinene, patchouli alcohol, α-guaiene, α-thujene, benzaldehyde, myrcene, limonene, terpinolene, linalool, terpinene-4-ol, α-terpineol, myrtenol, seychellene, α-humulene, allo-aromadendrene, viridiflorene, α-bulnesene, germacrene B, (E)-Nerolidol, caryophyllene oxide, curzerenone, humulene epoxide II, selina-3,11-dien-6-α-ol, pogostol, pogostone and (2E,6E)-Farnesol	Kerala, India.	18

indicator of essential oil quality[48]. The structures of some of the volatile chemical constituents found in *P. heyneanus* are presented in Fig. 3.

The effect of different drying temperatures on the yield of the essential oil of *P. heyneanus* was determined[49]. Freshly harvested leaves were dried at 40, 45, 50, 55, and 60°C in an oven and at room temperature (32±2°C). The total antioxidant capacity (by Ferric reducing antioxidant power), total phenolic contents (by Folin-Ciocalteu reagent), and total flavonoid contents (by Aluminium chloride method) of leaves were determined. The highest oil recovery was observed at 55°C, while a considerable loss in bioactive compounds and antioxidant activity was observed at the same temperature[49]. The yield of oil at different drying temperatures was recorded[50]. Like Amadoru *et al.*[50], the highest oil content was observed at 55°C.

Pharmacological activities

Cytotoxic and anticancer activity

Anticancer activities of methanol, ethanol and chloroform extracts of leaves of *P. heyneanus* on MCF 7 (human breast cancer cell line - non-metastatic) were evaluated by 3-(4, 5-dimethythiazol-2-yl)-2, 5-diphenyl tetrazolium bromide (MTT) assay. The methanol, ethanol and chloroform extracts gave IC_{50} values of 102.33 µg/mL, 262.33 µg/mL and 56.66 µg/mL respectively. Chloroform extract has exhibited effective cytotoxicity (P <0.001) and was further evaluated on MDA MB 231 (human breast cancer cell line). Cytotoxic activity of chloroform extract against MDA-MB-231 cell line gave an IC_{50} value of 152±0.75 µg/mL. However, there was a significant difference (P <0.01) in the cytotoxic effect on the two cell lines tested[20].

The cytotoxic and antimitotic potential of *P. heyneanus* were evaluated using *Allium cepa* L. root tip assay[51]. Dried and powdered leaves of *P. heyneanus* were boiled with distilled water, and the extract was prepared. Roots of *A. cepa* were immersed in four different concentrations of the aqueous leaf extract (0.5, 0.1, 0.05 and 0.01%) for three different durations (2,1 and 0.5 h). The root tip slides were scanned, and the number of cells was recorded. Mitotic Index was calculated while the percentage of aberrant cells demarked the degree of chromosomal aberration. The extract was found to be cytotoxic at all tested concentrations when compared to the negative control. Hence, the aqueous extract of *P. heyneanus* has demonstrated dose-dependent inhibitory action on the cell division of *A. cepa.* It is envisaged that the low mitotic index is due to the direct genotoxic effect of *P. heyneanus*[51].

Antimicrobial activity

The antimicrobial activity of nanoemulsions prepared using the essential oil of *P. heyneanus* was evaluated against *Shigella flexneri* (Gram-negative), *Staphylococcus aureus* (clinical isolate), *Streptococcus mutans* (Gram-positive) and *Candida albicans* (pathogenic fungi). The nanoemulsion of *P. heyneanus* essential oil was effective against the tested microbes as per the minimum inhibitory concentrations (MIC) obtained. The oil was very effective at concentrations of 3.12, 12.5, and 6.25 mg/mL against *S. flexneri*, *S. aureus* and *S. mutans*, respectively. Furthermore, the oil has exhibited anti-candida activity at 25 mg/mL. The antimicrobial effect of the essential oil might be due to the presence of acetophenone[18]. Furthermore, nanoemulsion of *P. heyneanus* essential oil has exhibited biofilm eradication against *S. mutans* (50%),

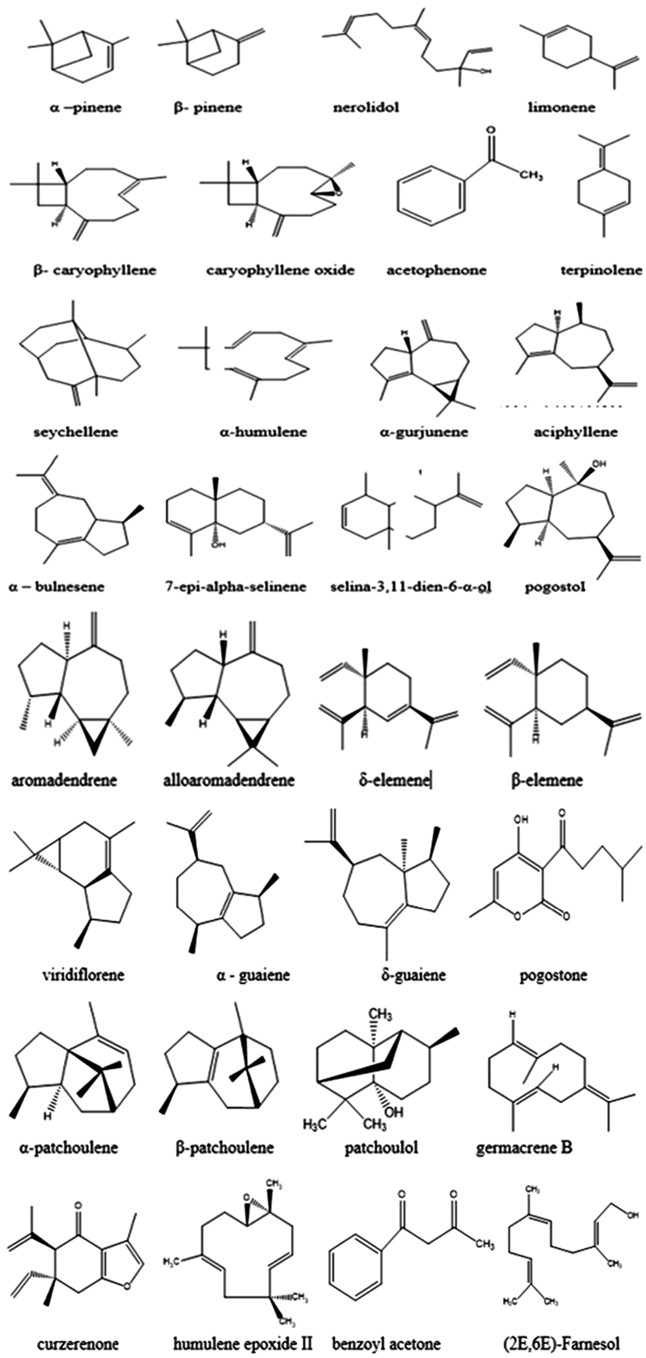

Fig. 3 — The structures of some volatile chemical constituents found in *Pogostemon heyneanus*[63,64].

S. aureus (25%), *S. flexneri* (31%) at 6.25 mg/mL. However, the effect of eradicating biofilms was less efficient than antibacterial and anti-candida activities[18].

A review by Trifan and coworkers focused on essential oils extracted from plant materials which were combated against multidrug resistance microbial strains. They have suggested that these findings would be significant in reducing the usage of antibiotics. *Enterococcus* spp*, Staphylococcus aureus, Klebsiella* spp, *Acinetobacter baumannii, Pseudomonas aeruginosa,* and *Enterobacter* spp were the focused multidrug-resistant organisms, and the antimicrobial activity of essential oils was reviewed considering the stability, bio efficiency, and design of the nanostructured delivery systems. They have explored in the review that essential oil-loaded nanoemulsion particles (approximately 45 nm) of *P. heyneanus* were known to be highly effective against methicillin-resistant *S. aureus* (MRSA) and biofilm eradication. Acetophenone is the main constituent in the essential oil of *P. heyneanus,* and reviewed that it has an inhibitory effect against multidrug-resistant (MDR) *S. aureus.* In addition to that, the nanometric size and the lipophilic nature of the essential oil facilitate the interaction with the hydrophobic cell surface of the MRSA strains. At the same time, the usage of Tween 80 as the surfactant provides higher stability of the nanoemulsion by decreasing the size of the essential oil droplet considerably[52].

Antibiofilm and antivirulence efficacy of the essential oil of *P. heyneanus* against the biofilms of *Candida albicans*, *C. glabrata* and *C. tropicalis* were explored[53]. The oil showed a significant reduction in the biofilms of *C. albicans* (61%), *C. glabrata* (56%) and *C. tropicalis* (54%). The oil has disrupted the mature biofilms of all three *Candida* strains at biofilm inhibitory concentration and significantly reduced the preformed biofilms with an inhibition range of 55–67%. Furthermore, the oil at its biofilm inhibitory concentration reduced the metabolic activity of cells of *Candida* spp. in the preformed biofilms. Minimal appearance of microcolonies and reduction in the thickness of biofilm was observed. Moreover, the antivirulence efficacy of the essential oil at its biofilm inhibitory concentration has been observed by inhibiting *C. albicans*, the transition from yeast cells towards the hyphal formation. According to the confocal microscopy performed to analyse the efficacy of the oil at its biofilm inhibitory concentration on the architecture of preformed biofilms of *C. albicans*, there was a dispersion of the biofilms formed on the substratum[53]. According to the scanning electron microscopy analysis performed for the essential oil against *C. albicans*, there was a complete reduction in the thick aggregation of yeast cells. As evident by the estimation of the exopolysaccharide assay, there was a considerable reduction of sugars present in the exopolysaccharide layer[53].

The essential oil obtained from *P. heyneanus* has suppressed the formation of biofilms (up to 60–80%) of *S. pyogenes* (Group A *Streptococcus*), causing pharyngitis[54]. The oil inhibited the biofilms dose-dependently, and the anti-biofilm activity was varied with different M serotypes of *S. pyogenes*. Researchers have envisaged that sesquiterpenes might play a role in the fatty acid membrane disruption of *S. pyogenes* and thereby inhibiting biofilm formation[54].

Both stem and leaves of *P. heyneanus* were extracted using hexane, ethyl acetate and methanol separately. Three extracts were tested for antimicrobial susceptibility testing. Cut well diffusion method was used on *E. coli*, whereas the agar disk diffusion method was used on *E. coli*, *S. aureus*, methicillin-resistant *S. aureus* (MRSA) and *C. albicans*. Hexane and ethyl acetate extract of *P. heyneanus* exhibited antibacterial activity against Gram-negative *E. coli* strains in cut-well agar diffusion and agar disk diffusion methods. Both extracts were active against Gram-positive *S. aureus*. All three extracts have demonstrated antifungal activity on *C. albicans* and had moderate toxicity to the brine shrimp assay. However, hexane and ethyl acetate extracts have shown the highest maximal efficacy at 100% mortality[50].

Antibiofilm and antivirulence potential of essential oil obtained by hydro-distillation of shade-dried leaves of *P. heyneanus* and nerolidol, which is one of the major components of *P. heyneanus* were explored against methicillin-resistant *S. aureus* (MRSA) and clinically isolated (GSA-140, GSA-44, GSA-395, and GSA-410) strains isolated from throat swabs of patients with pharyngitis[55]. Observed MIC was at a range of (2-6 % v/v) for the oil, whereas nerolidol showed MIC at the range of 0.025% v/v against all tested strains. Furthermore, the percentage inhibition in biofilm formation was 60-80% at a concentration ranging from 3-0.5% v/v against all MRSA strains, whereas nerolidol showed a percentage inhibition of 88% against the GSA-44 strain. The essential oil has demonstrated a significant reduction in preformed biofilms with a percentage inhibition of 80 % against the clinical isolate GSA-395, whereas the percentage inhibition showed by nerolidol was 85 % against GSA-44. Moreover, it is envisaged that the synergistic effect of the essential oil and DNase (commercially available DNase and marine bacterial DNase) has enhanced biofilm (preformed) disruption ability against GSA-44[55]. Reduction in biofilms by the oil was evident by light microscopy analysis on the tested strains. Disruption of preformed biofilms of GSA-44 by nerolidol was visualised using confocal laser scanning microscopy and light microscopy. Scanning electron microscope analysis has revealed the inhibition of preformed biofilm formation of GSA-44 by essential oil from *P. heyneanus* and nerolidol by reducing the exopolymeric substances[55].

Aqueous and ethanolic leaf extracts of *P. heyneanus* were investigated for their antifungal activity against *C. albicans*, *C. parapsilosis*, *C. krusii*, *C. tropicalis* and *C. glabrata*. The ethanolic extract has demonstrated significant activity against *C. glabrata*. However, the aqueous extract of leaves showed no anti-*candida* activity against any tested spp[56].

Antifungal activity of microencapsulated *P. heyneanus* essential oil on *Aspergillus flavus* (in terms of kinetic activity and its order) was determined[57]. Inhibition zones of antifungal in *P. heyneanus* essential oil and its microencapsulation result toward *A. flavus* are categorised into insensitive excluding patchouli oil 100%, which the inhibition zones included into a sensitive category[57].

Antioxidant activity

Total antioxidant capacity of the leaves, stems, and roots of *P. heyneanus* was evaluated using a Ferric reducing antioxidant power assay[21]. Higher amounts of total antioxidant capacity were observed in leaf extracts when compared to stem and root extracts.

Local and introduced varieties of *P. heyneanus* were investigated for total phenolic content and total antioxidant capacity. The higher amount of total phenolic content (6.41 mg Gallic acid equivalent per g of sample) and total antioxidant capacity (108.53 mg Trolox equivalent per g of extract) were reported in the leaf extracts of the introduced variety[26].

Antioxidant activities of methanol, ethanol, and chloroform extracts of leaves of *P. heyneanus* were evaluated by 2,2, diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay and H_2O_2 scavenging assay. A percentage of 50 % DPPH free radicals was scavenged at 25±1.2 µg/mL (IC_{50} value) by the positive control (Ascorbic acid). The IC_{50} values of methanol, ethanol and chloroform extracts were 85±2.35, 96.4±1.6 and 99.2±0.6 µg/mL respectively. The IC_{50} values of methanol, ethanol and chloroform extracts in H_2O_2 scavenging assay were 284.9±1.5, 462.3±0.7 and 238.6±0.4 µg/mL, respectively, whereas the positive control (Ascorbic acid) exhibited 155±2.3 µg/mL of IC_{50} value[20].

Gastroprotective activity

The potent antacid effect of aqueous extract and its fractions of *P. heyneanus* leaves has been observed *in vitro*[22]. Neutralising capacity was determined using the titration method of Fordtran, and Vatier's artificial stomach model determined the duration of consistent neutralisation of artificial gastric acid. Different concentrations of the aqueous extract (18.6 and 37.2 mg/mL) and the residual of the aqueous fraction (21.5 and 43.0 mg/mL) demonstrated a significant neutralising effect. The residual of the aqueous fraction (43.0 mg/mL) has exhibited the highest neutralising capacity and higher duration of consistent neutralisation among the tested fractions[22].

Insecticidal activity

The essential oil of shade-dried leaves of *P. heyneanus* was extracted. A mosquito larvicidal assay was conducted using the fourth instar larvae of the mosquito *Aedes albopictus* L. Seven different concentrations (5, 10, 20, 25, 50, 100, and 200 ppm) of essential oil were evaluated, and 100% mortality was observed at concentrations of 200 and 100 ppm. Furthermore, mortality rates were dose-dependent. Higher mortality rates were observed at lower concentrations with a lethal concentration (LC_{50}) of 7.53 ppm and (LC_{90}) of 23.92 ppm. Therefore, it is evident that the plant may be considered a safe alternative source for mosquito larval control agents in integrated management programs[23].

Mosquito-repellent efficacy of *Curcuma longa*, *P. heyneanus* and *Zanthoxylum limonella* (Dennst.) Alston essential oils have been investigated separately and in combination under laboratory and field conditions[58]. The laboratory trials of the repellent efficacy of the individual essential oils indicated that the essential oil from *P. heyneanus* provided complete protection times of 23.2, 49.2, 123.4, and 125.2 min at concentrations of 5, 10, 20, and 30%, respectively. Combinations of *Curcuma longa* L. and *P. heyneanus* (1:2) have shown complete protection times of 48.4, 133.4, 244.6 and 246.6 min at tested concentrations. Combination of *Z. limonella* and *P. heyneanus* (1:2) has shown complete protection times of 46.6,120.2, 228.4, and 243.4 min at the same concentrations. However, the mixture of essential oils of *C. longa*, *Z. limonella* and *P. heyneanus* in a ratio of 1:1:2 has demonstrated the longest duration of protection. Furthermore, the mixture was found to produce a better complete protection time in field conditions than in laboratory conditions. As evident by this study, the essential oils' protection duration can be increased via synergistic repellent action of combined essential oils[58].

Allelopathic activity of the essential oil of *P. heyneanus* was analysed compared to *Piper hispidinervum* L.as germination of the seeds is mainly affected by the oils, and it was tested through the concentration series using ether methanol as the eluent. Furthermore, they have depicted that the intensity of inhibition relates to the concentration. They have explored that *P. hispidinervium* shows higher allelopathic activity than *P. heyneanus*[59].

Furthermore, in a study conducted using the extracts of *N. sativa* and *P. heyneanus* were tested as contact insecticides against the stored-product pests *Sitophilus oryzae* L., *Stegobium paniceum* L., *Tribolium castaneum* (Hbst.) and *Callosobruchus chinensis* L. Both extracts were toxic to the tested pests, as evident by the study[60].

Essential oil of *P. heyneanus* leaves was mixed with two other essential oils obtained from *C. longa* rhizomes and *Z. limonella* fruits at a ratio of 1:1:2. Repellent activities of three different concentrations (5, 10, and 20% (v/v)) of the mixture was tested against blackflies three times in three different locations in northeastern India. Each concentration was tested using six volunteers (between 21 to 45 years), each on three different days. Percentage repellency and repellency index were found to be higher in 20% concentration[61].

Repellent activity of five essential oils extracted from *Homalomena aromatica* (Spreng.) Schott, *Citrus aurantifolia* (Christm) Swingle, *Vitex negundo* L., *Ageratum conyzoides* L. including *P. heyneanus* have been evaluated on the human volunteers against *Simulium* (blackflies) in three locations of Arunachal Pradesh, India. Among the tested concentrations (5, 7.5, and 10%), the average protection time achieved with a 10% concentration of each essential oil was significantly higher than the other two concentrations. The study concludes the possibility of tested essential oils formulating into new repellents against blackflies[62].

Use in oral hygiene

Due to the suitability for oral administration of *P. heyneanus*, the plant was studied for its effects on Sheetada. It was revealed that the leaves of *P. heyneanus* could be effectively used for the treatment of sheetada, which is one of the tooth-based illnesses. Furthermore, the extract was especially effective against gum bleeding of the patients[24].

Conclusion

The present review summarises scientific information on *P. heyneanus* in terms of its habitat and distribution, traditional uses and ethnopharmacology, phytochemistry, and medicinal activities. There are traditional claims for the usefulness of the plant's fresh leaves and essential oil for a range of ailments. Therefore, gathered information may help bridge the gap between traditional claims and modern scientific studies on *P. heyneanus*. We admit several limitations to the extent to which conclusions can be drawn from the present review. There were minimal studies evaluating the effects of *P. heyneanus* in humans, and the majority of the studies were *in vitro* or *in vivo*. To claim therapeutic effects, clinical trials should be carried out depending on the prominent *in vivo* studies and or traditional claims. Further randomised double-blinded placebo-controlled clinical trials are required to establish the therapeutic safety and efficacy of *P. heyneanus* as a promising non-toxic pharmaceutical agent.

Conflict of interest

The authors report no conflict of interest.

References

1 Astutik S, Pretzsch J and Kimengsi J N, Asian medicinal plants' production and utilisation potentials: A review, *Sustainability*, 2019, **11**(19), 5483. doi: org/ 10.3390/su11195483.

2 Ahmed N, Mahmood A, Mahmood A, Sadeghi Z and Farman M, Ethnopharmacological importance of medicinal flora from the district of Vehari, Punjab province, Pakistan, *J Ethnopharmacol*, 2015, **168**, 66-78. doi: org/10.1016/j.jep. 2015.02.048.

3 Christaki E, Bonos E, Giannenas I and Flrou-Paneri P, Aromatic plants as a source of bioactive compounds, *Agriculture*, 2012, **2**(3), 228-243. doi.org/10.3390/ agriculture2030228.

4 Hassan B A R, Medicinal plants (importance and uses), *Pharm Anal Acta*, 2012, **3**(10), 2153-2435. doi: org/10.4172/2153-2435.1000e139.

5 Karunamoorthi K, Jegajeevanram K, Vijayalakshmi J and Mengistie E, Traditional medicinal plants: A source of phytotherapeutic modality in resource-constrained health care settings, *J Evid-Based Complement Altern Med*,2013, **18**(1), 67-74. doi: org/10.1177/2156587212460241.

6 Jeelani S M, Rather G A, Sharma A and Lattoo S K, In perspective: Potential medicinal plant resources of Kashmir Himalayas, their domestication and cultivation for commercial exploitation, *J Appl Res Med Aromat Plants*, 2017, **8**, 10-25. doi: org/10.1016/j.jarmap.2017.11.001.

7 Raina H, Soni G, Jauhari N, Sharma N and Bharadvaja N, Phytochemical importance of medicinal plants as potential sources of anticancer agents, *Turk J Bot*, 2014, **38**(6), 1027–1035. doi: org/10.3906/bot-1405-93.

8 Jain C, Khatana S and Vijayvergia R, Bioactivity of secondary metabolites of various plants: A review, *Int J Pharm Sci Res*, 2019, **10**(2), 494-504. doi: org/10.13040/IJPSR.0975-8232.10(2).494-04. http://dx. doi.org/10.13040/IJPSR.0975-8232.10(2).494-04

9 Rozza A L and Pellizzon C H, Essential oils from medicinal and aromatic plants: A review of the gastroprotective and ulcer-healing activities, *Fundam Clin Pharmacol*, 2013, **27**, 51–63. doi: org/10.1111/j.1472-8206.2012.01067.x.

10 Oliveira M S de, Almeida M M, Salazar M de LAR, Pires F C S, Bezerra F W F, *et al.*, Potential of medicinal use of essential oils from aromatic plants, In: *Potential of Essential Oils*, edited by H E Shemy (IntechOpen, London, UK), 2018, 1–20. doi: 10.5772/intechopen.78002.

11 Properzi A, Angelini P, Bertuzz G and Venanzoni R, Some biological activities of essential oils, *Med Aromat Plants*, 2013, **2**(5), 136. doi: org/10.4172/2167-0412.1000136.

12 Mancianti F and Ebani V V, Biological activity of essential oils, *Molecules*, 2020, **25**(3), 678. doi: org/10.3390/ molecules25030678.

13 Yao G, Deng Y and Ge X, A taxonomic revision of *Pogostemon* (Lamiaceae) form China, *Phytotaxa*, 2015, **200**(1), 001-067. doi: org/10.11646/phytotaxa.200.1.1.

14 Bongcheewin B, Pramali K, Traiperm P, Chantaranothai P and Paton A, *Pogostemon nudus* sp. nov. (Lamiaceae) from Thailand, *Nord J Bot*, 2017, **35**(3), 289–299. doi: org/10.1111/njb.01439.

15 Wimalasekara S, Osuthuru Visithuru, vol 1, Part 3, (Department of Ayurveda, Colombo, Sri Lanka), 1994,

16 Chakrapani P, Venkatesh K, Singh B C S, Jyothi B A, Kumar P, *et al.*, Phytochemical, pharmacological importance of Patchouli (*Pogostemoncablin* (Blanco) Benth) an aromatic medicinal plant, *Int J Pharm Sci Rev Res*, 2013, **21**(2), 7-15.

17 Jayaweera D M A, Medicinal Plants (Indigenous and Exotic) Used in Ceylon, Part III (National Science Council of Sri Lanka, Sri Lanka) 1981.

18 Adhavan P, Kaur G, Princy A and Murugan R, Essential oil nano emulsions of wild patchouli attenuate multidrug resistant gram-positive, gram-negative and *Candida albicans*, *Ind Crops Prod*, 2017, **100**, 106-116. doi: org/10.1016/j.indcrop.2017.02.015.

19 Karpiński T M, Essential oils of Lamiaceae family plants as antifungals, *Biomolecules*, 2020, **10**(1), 103. doi: 10.3390/biom10010103.

20 Rai V, Pai V and Kedilaya P, A preliminary evaluation of anticancer and antioxidant potential of two traditional medicinal plants from Lamiaceae-*Pogostemon heyneanus* and *Plectranthus amboinicus*, *J Appl Pharm*, 2016, **6**(8), 73-78. doi: 10.7324/JAPS.2016.60811.

21 Dharmadasa R M, Abeysinghe D C and Rathnayake R M D H, Constituents of essential oil, antioxidant activity, phenolic and flavonoid contents in different parts of *Pogostemon heyneanus* Benth. (Lamiaceae), 71st Annual Sessions Sri Lanka Association for the Advancement of Science, held on 2015 (Colombo, Sri Lanka) 2015, 19.

22 Rathnasekara H L, Jayasuriya W J A B N Arawwawala L D A M and Suresh T S, Evaluation of *in vitro* neutralizing effects of aqueous extract of pogostemon heyneanus leaves and its frations, *J Nat Health Prod Res*, 2021, **3**(1), 31. doi: org/10.33211/jnphr.20.

23 Anjana S and Thoppil J E, Chemical composition of the essential oils of four *Pogostemon* spp. and their larvicidal activity against *Aedes albopictus* Skuse (Diptera : Culicidae), *Int J Environ Biol*, 2013, **3**(1), 26–31.

24 Wickramasinghe M S K, Dissanayake K G C and Serasignhe K, Effect of the leaves of *Pogostemon heyneanus* for Sheetada, World Ayurveda Congress, held on 2002 (Kerala, India) 2002, 130.

25 Thomas B, Arumugam R, Veerasamy A and Ramamoorthy S, Ethnomedicinal plants used for the treatment of cuts and wounds by Kuruma tribes, Wayanadu districts of Kerala, India, *Asian Pac J Trop Biomed*, 2014, **4**(1), S488–S491. doi: 10.12980/APJTB.4.2014B571.

26 Dharmadasa R M, Rathnayake R M D H, Abeysinghe D C, Rashani S A N, Samarasinghe K, *et al*., Screening of local and introduced varieties of *Pogostemon heyneanus* Benth. (Lamiaceae), for superior quality physical, chemical and biological parameters, *World J Agric Res*, 2014, **2**(6), 261-266. doi: 10.12691/wjar-2-6-2.

27 Anonymous**,** Compendium of medicinal plants, a Sri Lankan study, vol II, (Department of Ayurveda, Maharagama, Sri Lanka), 2002.

28 Anonymous**,** Compendium of medicinal plants, a Sri Lankan study, vol. IV, Department of Ayurveda, Maharagama, Sri Lanka, 2004.

29 Anonymous, Ayurveda Pharmacopoeia. vol 1, Part II, Department of Ayurveda, Maharagama, Sri Lanka, 1979.

30 Ayurvedic Medicinal Plants of Sri Lanka Compendium, Barberyn Ayurveda Resorts and the University of Ruhuna, available at: http://www.instituteofayurveda.org/plants/.

31 Pandey A K and Tripathi N N, Diversity and distribution of aromatic plants in forests of Gorakhpur division, U.P., India, *Biol Forum*, 2010, **2**(2), 25-33.

32 Das K, Patchouli (*Pogostemon cablin* Benth) oils, In *Essential Oils in Food Preservation*, *Flavor and Safety*, edited by V R Preedy, (Academic Press, London, UK), 2916, 633-639.

33 Murugan R, Mallavarapu G R, Padmashree K V, Rao R R and Livingstone C, Volatile oil composition of *Pogostemon heyneanus* and comparison of its composition with patchouli oil, *Nat Prod Commun*, 2010, **5**(12), 1961-1964. doi: org/10.1177/1934578X100050122.

34 Ritawati S, Utama P and Pancaningsih E, Evaluation of land suitability for cultivation of java patchouli (*Pogostemon heyneanus* Benth) in the dry land of northern Serang, Banten province, IOP Conference Series: Earth and Environmental Science, The 1st International Conference on Agriculture and Rural Development, (Banten, Indonesia), 2019, **383**(1), 012045.

35 Souza Filho A P, Cunha R L, Vasconcelos M A M and Zoghbi M, Essential oil components of *Pogostemon heyneanus* Benth, *Piper hispidinervum* C. DC. and *Ocimum americanum* L. obtained in the Amazon, *J Essent Oil-Bear Plants*, 2010, **13**(3), 347–352. doi: 10.1080/0972060X.2010.10643833.

36 Rama R V, Shiddamallayya N, Kavya N, Kavya B and Venkateshwarlu G, Diversity and therapeutic potentiality of the family Lamiaceae in Karnataka State, India: An overview, *Species*, 2015, **13**(37), 6-14.

37 Ekanayake E M A H K, Evaluation of the effects and efficacy of herbal formulation derived from Sri Lankan ola leaves manuscript in the management of haemorrhoids, Postgraduate Diploma in Pancakarma, Gampaha Wickramarachchi Ayurveda Institute, University of Kelaniya, Sri Lanka, 2019.

38 Rajeev S R P, Comparative drug review on siddha drug “thaazhankaaiennai” for vaathanoi (Rheumatism), *SSR Inst Int J Life Sci*, 2021, **7**(1), 2734-2741.

39 Weerasekera K R, Wijayasiriwardhena C, Dhammarathana I, Tissera M H A and Ariyawansha H A S, Pharmacognostical review on substitutes for Tejapatra in Sri Lankan herbal medicine, *Ayur Pharm Int J Ayurveda Allied Sci*, 2014, **3**(12), 376-380.

40 Dharmadasa R M, Akalanka G C, Muthukumarana P R M and Wijesekara R G S, Ethnopharmacological survey on medicinal plants used in snakebite treatments in Western and Sabaragamuwa provinces in Sri Lanka, *J Ethnopharmacol*, 2016, **179**, 110-127. doi: 10.1016/j.jep.2015.12.041.

41 Félix-Silva J, Silva-Junior A A, Zucolotto S M and Fernandes-Pedrosa M D F, Medicinal plants for the treatment of local tissue damage induced by snake venoms: An overview from traditional use to pharmacological evidence, *J Evid-Based Complementary Altern Med*, 2017, **2017**, 52. doi: 10.1155/2017/5748256.

42 Vidyadharshini K, Dharshikah S, Gunadasa H L T and Mohanalohini N, Survey on commonly using medicinal plants in Muthunagar grama niladhari division, Trincomalee District, Sri Lanka, 2nd International Conference on Agriculture and Forestry, (Colombo, Sri Lanka) 2015, 1–12.

43 Golob P, Moss C, Dales M, Fidgen A, Evans J, *et al*., The use of spices and medicinals as bioactive protectants for grains, in, Food and Agriculture Organization Agricultural Services Bulletin (Food and Agriculture Organization of the United Nations, Rome, Italy), 1999.

44 Rathnayake R M D H, Dharmadasa R M and Abeysinghe D C, Effect of different spacing and fertiliser levels on physical and chemical yield of different parts of *Pogostemon heyneanus* Benth. (Lamiaceae), *World J Agric Res*, 2019, **7**(2), 49-55. doi: 10.12691/wjar-7-2-2.

45 Maia J G S and Andrade E H A, Database of the Amazon aromatic plants and their essential oils, *Quim Novax*, 2009, **32**(3), 595-622. doi: 10.1590/S0100-40422009000300006.

46 Blank A F, Sant’ana T C P, Santos P S, Arrigoni-Blank M F, Prata A P N, *et al*., Chemical characterisation of the essential oil from patchouli accessions harvested over four seasons, *Ind Crops Prod*, 2011, **34**(1), 831–837. doi: org/10.1016/j.indcrop.2011.01.021.

47 Anonymous, Aushadiya Shaka Sangrahaya – Sri Lanka Adhyayanayak, vol. II, 1st edn, (Department of Ayurveda, Navinna), 2002, 51.

48 Anonis D P and Perfumer C, Woody notes in perfumery, patchouly oil, absolute and aroma chemicals, Part I, *Perfum Flavor Mag*, 2006, **31**(11), 36–39.

49 Amadoru I J, Abeysinghe D C, Gunathilaka H A W S, Kulathilaka S H C and Dharmadasa R M, Effect of different drying temperatures on oil yield, antioxidant capacity and bioactive compounds of *Pogostemon heyneanus* Benth. (Lamiaceae), 15th Agricultural Research Symposium of Wayamba University Research Congress 2017, (Makandura, Sri Lanka), 2017*,* 470-474.

50 Karunathilaka B S B, Priyadarshana A, Rajapakse S, Jayasinghe L and Wickramasinghe A, Antimicrobial activity

and brine shrimp lethality of some selected medicinal plants, RSU International Research Conference, (Pathum Thani, Thailand), 2016, 7-14.

51 Sheela A and Thoppil J E, Evaluation of cytotoxicity of the aqueous leaf extract of *Pogostemon heyneanus* Benth. (Java Patchouli), *Biotropia*, 2017, **24**(1), 28-34. doi: org/10.11598/btb.2017.24.1.507.

52 Trifan A, Luca S V, Greige-Gerges H, Miron A, Gille E, *et al.*, Recent advances in tackling microbial multidrug resistance with essential oils: Combinatorial and nano-based strategies, *Crit Rev Microbiol*, 2020, **46**(3), 338-357. doi: 10.1080/1040841X.2020.1782339.

53 Banu S F, Rubini D, Shanmugavelan P, Murugan R, Gowrishankar S, *et al.*, Effects of patchouli and cinnamon essential oils on biofilm and hyphae formation by *Candida* species, *J Mycol Med*, 2018, **28**(2), 332-339. doi: 10.1016/j.mycmed.2018.02.012.

54 Nithyanand P, Shafreen R M B, Muthamil S, Murugan R and Pandian S K, Essential oils from commercial and wild Patchouli modulate Group A Streptococcal biofilm, *Ind Crops Prod*, 2015, **69**, 180-186. doi: org/10.1016/ j.indcrop.2015.02.022.

55 Rubini D, Banu S F, Nisha P, Murugan R, Thamotharan S, *et al*., Essential oils from unexplored aromatic plants quench biofilm formation and virulence of Methicillin-resistant *Staphylococcus aureus*, *Microb Pathog*, 2018, **122**, 162-173. doi: 10.1016/j.micpath.2018.06.028.

56 Rathnayake R M T P K and Panagoda G J, Anti-candidal activity of *Acronychia pedunculata* (L.) MIQ, and *Pogostemon heyneanus* Benth, evaluation of minimum inhibitory concentration (MIC) of *A. pedunculata* (l.) MIQ and its effect on relative cell surface hydrophobicity, Peradeniya University Research Sessions PURSE – 2012, (Peradeniya, Sri Lanka), 2012, 107.

57 Musta R, Nurliana L, Risnawati, Damhuri and Prasetya N B A, Antifungal kinetics activity of Patchouli oil *Pogostemon heyneanus* and its microencapsulation on *Aspergillus flavus*, *Rasayan J Chem*, 2021, **14**(1), 351–358. doi: 10.31788/RJC.2021.1415928.

58 Das N G, Dhiman S, Talukdar P K, Rabha B, Goswami D, *et al.*, Synergistic mosquito-repellent activity of *Curcuma longa, Pogostemon heyneanus* and *Zanthoxylum limonella* essential oils, *J Infect Public Health*, 2015, **8**(4), 323-328. doi: 10.1016/j.jiph.2015.02.005.

59 Souza Filho A P, Vasconcelos M A M, Zoghbi M and Cunha R L, Potentially allelopathic effects of the essential oils of *Piper hispidinervium* C. DC. and *Pogostemon heyneanus* (Benth) on weeds, *Acta Amaz*, 2009, **39**(2), 389–395.

60 Deshpande R S, Adhikary P R and Tipnis H P, Stored grain pest control agents from *Nigella sativa* and *Pogostemon heyneanus*, *Bulletin Grain Technol*, 1974, **12**, 232–234.

61 Sunil D, Bipul R, Pronobesh C, Das N G, Hazarika S, *et al.*, Field evaluation of repellency of a polyherbal essential oil against blackflies and its dermal toxicity using rat model, *Trop Biomed*, 2012, **29**(3), 391–397.

62 Hazarika S, Dhiman S, Rabha B, Bhola R K and Singh L, Repellent activity of some essential oils against *Simulium* species in India, *J Insect Sci*, 2012, **12**(5), 1-9. doi: 10.1673/031.012.0501.

63 Dahiya S, Batish D R and Singh H P, Ethnobotanical, phytochemical and pharmacological aspects of Bengal pogostemon (*Pogostemon benghalensis*), *J Herb Med Pharmacol*, 2020, **9**(4), 318-327. doi: 10.34172/jhp.2020.40.

64 Ashwini S, Amol K, Basawaraj H and Shrishail C, A comprehensive review on *Pogostemon benghalensis* (Burm.F.) O. Kuntze, *J Pharmacogn Phytochem*, 2013, **1**(1), 10-15.