EGYPTIAN JOURNAL OF BOTANY (EJBO)

Print ISSN: 0375-9237
Online ISSN: 2357-0350

The significance of Lamiaceae aromatic plants in Saudi Arabia: morphology, phytochemistry, essential oils, and sustainable land management applications

Dalia G. Gabr, Maryam H. AL-Soufi, Ghadah H.S. Al-Hawas, Osama G. Ragab, Doaa M. El Kholy, Zahra J. Almusabih, Renad F. Almutairi, Fatimah E. Alsaihati

PUBLISHED BY
THE EGYPTIAN
BOTANICAL SOCIETY

The significance of Lamiaceae aromatic plants in Saudi Arabia: morphology, phytochemistry, essential oils, and sustainable land management applications

Dalia G. Gabr[1], Maryam H. AL-Soufi[2], Ghadah H.S. Al-Hawas[2], Osama G. Ragab[3], Doaa M. El Kholy[1], Zahra J. Almusabih[2], Renad F. Almutairi[2], Fatimah E. Alsaihati[2]

[1]Botany and Microbiology Department, Faculty of Science (Girls Branch), Al-Azhar University, Cairo, Egypt
[2]Department of Biology, College of Science, Imam Abdulrahman Bin Faisal University, Dammam 31441, Saudi Arabia
[3]Department of Botany and Microbiology, Faculty of Science (Boys Branch), Al-Azhar University, Cairo, Egypt

REVIEW ARTICLE

Aromatic plants are considered as one of the most important species, known for their significant contributions towards the human life since from ancient times to the present day. Their key importance lies in their production of odorous aromatic chemical compounds known as essential oils. These essential oils find extensive use in the food, cosmetic, and pharmaceutical industries. Saudi Arabia is majorly rich towards the diversity of plants which includes aromatic species. The flora of Saudi Arabia consists of a total of 68 species of aromatic plants belonging to five different families, with *Lamiaceae* family being the most dominant, which comprises 42 species. This study aims to provide an overview of 15 endemic medicinal and aromatic plants native to Saudi Arabia, all of which belongs to *Lamiaceae* family. The focus is mainly on their morphology, distribution, phytochemical properties, and the significance of the essential oils extracted from these plants. However, further research and examination are required to fully comprehend the medicinal properties and chemical content of aromatic plants, such as *Ballota undulata, Otostegia fruticosa, Satureja nabateorum*, and *Thymus decussatus*.

Keywords: Morphology, Chemical Properties, Medical Importance, Aromatic Plants, Lamiaceae, ESPE, SDGs

ARTICLE HISTORY
Submitted: January 19, 2025
Accepted: May 30, 2025

CORRESPONDENCE TO
Osama G. Ragab,
Department of Botany and Microbiology,
Faculty of Science (Boys Branch),
Al-Azhar University, Cairo, Egypt
Email: osama_gamal84@azhar.edu.eg
DOI: 10.21608/ejbo.2025.353971.3164

EDITED BY: F. Salama

INTRODUCTION

In ancient times, aromatic plants were known for their benefits in different aspects of life. Plants have been used by our ancestors mainly as source for food and medicine and still been used to this day. The first record of using medicinal plants to make medications dates to roughly 5000 years ago and was discovered on a Sumerian clay slab from Nagpur and thus reveals that our understanding of the connection between diseases and medicinal plant started from old days, and it continues. Consequently, scientists in different fields focus on this type of plants and their extracts to discover new medicine to treat diseases and promote better human health (Perveen & Al-Taweel, 2019).

Botanists define aromatic plants that they are any plants produce aromatic chemical compounds (Gazzani, 2021). Aromatic substances are volatile, odorous, green exudate, oleoresin, and balsam and are known as essential oils (EOs) (Baby P. et al., 2007). These EOs are characterized by their volatile odorous at room temperature, and chemically considered as hydrocarbons, and highly concentrated compounds (Samarth et al., 2017). The main biologically active compounds from aromatic plants are potent for antioxidant, antimicrobial, anticoccidial activities (Christaki et al., 2012). Essential oils are produced from the roots, seeds, stems, fruits, flowers, wood parts, leaves, or barks of plants. Besides, in some cases, the entire plant also produces aromatic compounds. Extracted oils commonly used in cooking, perfumes manufacturing, food and liquor industries, and in pharmaceutical industries (Baby et al., 2007). Aromatic plants have been part of various industries, such as food, cosmetic, pharmaceutical industries (Christaki et al., 2012), and these uses make them one of the most significant plants in human history, providing a huge contribution in economics as well as tourism (Baby et al., 2007). Over 3000 plants were used for their essential oils, of which 300 species are commercially used for flavors and fragrances (Christaki et al., 2012). EOs contain highly concentrated secondary metabolites, in which their chemical composition consists mainly of organic compounds, such as terpenoids, benzenoids, organic sulphur and nitrogenous compounds (Baby et al., 2007). Extraction of EOs uses different physical and chemical methods, commonly the by-steam distillation; however, supercritical carbon dioxide extraction method has become increasingly popular (Christaki et al., 2012).

Aromatic plants are classified based on their origins, and there are three major groups: Tropical Plants which produce aromatic compounds like cinnamon; Subtropical Plants which produce aromatic compounds like mint; and Temperate Plants which produce aromatic compounds like fennel. Asia is well-known for its aromatic plants due to climatic condition that establish a suitable environmental

condition for growth and development of aromatic plants (Chomchalow, 2002). 38,660 species of MAPs (medical and aromatic plants) have been recorded from Asia (Hassanpouraghdam et al., 2022). The majority of aromatic plant families include: Apiaceae, Apocynaceae, Asteraceae, Brassicaceae, Boraginaceae, Cesalpinaceae, Convolvulaceae, Caryophyllaceae, Cucurbitaceae, Fabaceae, Lamiaceae, Malvaceae, Mimosaceae, Oleaceae, Papaveraceae, Phytolaccaceae, Rutaceae, Solanaceae, Scrophulariceae, Verbenaceae of Magnoliopsida, Liliaceae, Poaceae, Orchidaceae, Zingiberaceae, and many more (Alamgir, 2017). Aromatic plants, which are able to produce high content of essential oils, includes Apiaceae, Cupressaceae, Lauraceae, Lamiaceae, Liliaceae, Asteraceae, Myrtaceae and Rutaceae (Bagetta et al., 2015).

Saudi Arabia is characterized by its vastness and diversity of its climate and topography, resulting in the presence of numerous aromatic plants. These plants can be found throughout the country, either growing permanently or as seasonal species, whose presence is associated with specific seasons based on the amount and timing of precipitation. A total of 68 species of aromatic plants with aromatic foliage belong to five families were found in Saudi Arabia (Thomas, 2020), in which Lamiaceae is the most dominant family possessing 42 species, followed by Asteraceae with 14 species. Apiaceae has nine species, Poaceae has two species, Rutaceae has one species (Thomas, 2020).

The Lamiaceae (also known as Mint family) is considered one of the major families of aromatic plants possessing 237 genera and 7756 species, approximately 1056 species are being used to treat diseases (Nazar et al., 2022), while *Salvia* is the largest genus containing about 900 species (Khoury et al., 2016). In Saudi Arabia, Lamiaceae contains 72 species that belong to 25 genera out which 42 species are recorded as foliage aromatic plants (Thomas, 2020). Plants in the Lamiaceae family are typically herbs or shrubs, often possessing aromatic properties and featuring opposite simple leaves. Inflorescences of these plants are frequently arranged in whorls and consist of bisexual, zygomorphic flowers. Flowers of these plants are characterized by a five-lobed (sometimes four-lobed) calyx, a two-lipped corolla, an androecium with 2-4 stamens, and a four-lobed superior ovary. Fruits of these plants consist of nutlets containing 1-4 seeds (Mandaville, 1990). Several studies were done to determine the phytochemistry of Lamiaceae, and the most chemical were recorded, such as alkaloids, tannins, saponins, steroids and phenolic compounds (De Britto et al., 2012). Monoterpenoids, triterpenoids, sesquiterpenoids, phytosterols, flavonoids, organic acids, lignins, glycosides, alcohols, and aldehydes were also identified as components (Bendif et al., 2021). Research on the medicinal properties of plants has yielded numerous important findings for human health. These include anti-inflammatory, antipyretic, antifungal, antispasmodic, antioxidant, antimicrobial, antidiabetic, antiasthmatic, antidiarrheal, antidote, and antiseptic properties. Certain plants also have carminative, anti-inflammatory, antimicrobial, rheumatism, peptic ulcer, blood clotting, anthelmintic, tuberculosis, epilepsy, UTIs, vaginal discharge, insect bites, allergies, diarrhea, and flu-related symptoms (Venkateshappa & Streenath et al., 2013). Thus, present study gives a survey on morphology, phytochemical and medicinal potential of foliage aromatic plants from Lamiaceae which are found in Saudi Arabia, which of some of the plants need further study.

Review Methodology

Data used to compile these survey findings came from an online database (Figure 1). A variety of search

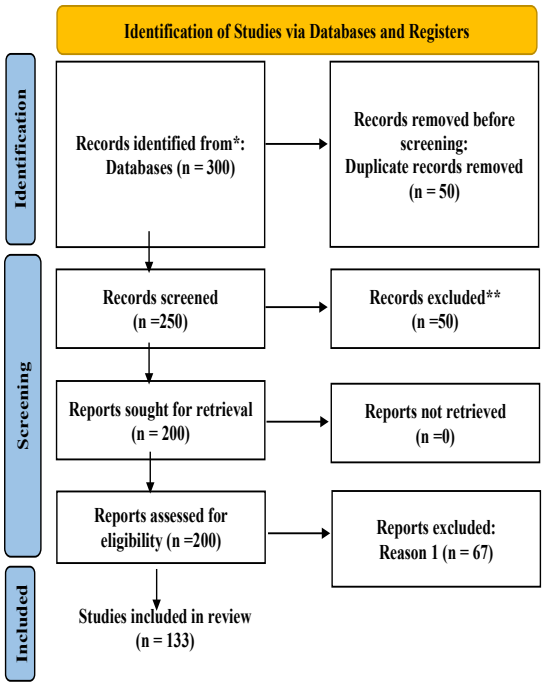


Figure 1. Workflow of this Article Review according to PRISMA Guideline

terms were used, such as morphology, phytochemical, medicinal significance, Lamiaceae, fragrant plants in Saudi Arabia, and species names. Data is gathered from a variety of sources, including books and journal articles borrowed from the university library, and internet resources including Scopus, Google Scholar, PubMed, and Web of Science. Flora of Saudi Arabia websites were combed through for plant morphology (Photo gallery (plantdiversityofsaudiarabia.info), Plants of the World Online (Plants of the World Online | Kew Science), and other sources as (TrekNature | Satureja nabateorum Photo), (File:Plectranthus arabicus 02 ies.jpg - Wikimedia Commons) and (Meriandra benghalensis_Binsar1 | Alka Khare | Flickr).

RESULTS

Ballota undulata (Sieb. ex Fresen.) Benth

Morphological Characteristics: The plant is erect, numerous stemmed, and the below shrub can reach 75cm long, indumentum is of sessile and dense glands, and stellate hair. The plant leaves are petiolate, rugose, which can reach 25x35mm, orbiculate to reniform, and at the base, they could be truncate or cordate, undulate - crenate. Bracts are shorter than verticillasters, numerous and noticeably separated verticillasters. Calyx has campanulate tube to infundibuliform tube, prolonged above into an oblique, veined. Corolla color is white containing crimson spots, with tubes (Chaudhary, 2001).

Distribution: The plant can be found in Eastern Mediterranean and in north of Hijaz, Saudi Arabia (Chaudhary, 2001).

Phytochemical Properties: The essential oil composition is mainly monoterpene hydrocarbons and sesquiterpenes. Monoterpene hydrocarbons were presented in low trace. On the other hand, sesquiterpenes were presented in higher trace both numerically (having 14 derivatives) and quantitatively (58% of the whole essential oil). The main compounds of the *Bellota Undulata* essential oils were sesquiterpenes germacrene and bicyclo-germacrene (Bader et al., 2003).

Biological Importance: *Ballota undulata* was proposed that it has antiallergic, antimicrobial, antispasmodic, and anti-inflammatory properties and can be used as sources for treatment compounds (Alshehri, 2020).

Lavandula dentata L.

Morphological Characteristics: The plant is characterised by silvery tomentose, and branched, thick shrub that can reach 75cm long. Leaves are sessile linear that can reach 20-30 x 2-3mm with robust crenate-dentate. Terminal dense flowers can reach 5cm, apical bract, lilac creating attractive coma at each spike tip. Flora bract color is purple, narrowed, mucronate and cuneate, too. Calyx is generally silvery tomentose, purple, ribbed, tubular, has 8 toothed, 7 are inferior, minor, and triangular, the superior is laterally extended like reniform appendage. Corolla is white tomentose and the external is light blue, the tube is barely excreted, and the limb is practically 5 lobed. Nutlets are mainly brownish (Chaudhary, 2001).

Distribution: Worldwide, it is found in South Europe, North Africa, Ethiopia, and Yemen. In Saudi Arabia, it can be found in Asir (Chaudhary, 2001).

Phytochemical Properties: Majority of *L. dentata* essential oils classes belong to oxygenated monoterpenes (91.18%) while Sesquiterpene hydrocarbons (0.88%) and others by (7.57), the main component of *Lavandula dentata* essential oils are mainly 1,8-cineole, linalool, cis-verbenol, p-Cymen-8-ol, myrtenal, fenchone, pino-carvone, ∝ -terpineol, and ∝-terpinen-7-la. The dominant component is 1,8-cineole (Bousmaha et al., 2006; Dob et al., 2005; Giuliani et al., 2020; Justus et al., 2018; Martins et al., 2019; Vicenço et al., 2022; Wagner et al., 2021).

Essential Oil Importance: *Lavendulan dentata* essential oils used as folk medicine for various reasons in the world (El-Daji, 1996), also, in cases like kidney stones, urine retention, rheumatisms, and in digestive problems. According to (Wagner et al., 2021), this biopesticide could be useful in integrated pest management programs; it exhibited strong insecticide activity against Sitophilus zeamais, Tribolium castaneum, Epicauta atomaria, as well as fungicide activity against Cercospora kikuchii, Cercospora sojina, and Septoria glycines; (Giuliani et al., 2020) confirmed this. It is mostly used in the perfume business and has a wide range of biological activities, including antibacterial, antifungal, anti-inflammatory, antidepressant, sedative, and antioxidant capabilities (El Abdali et al., 2022; Vicenço et al., 2022).

Lavandula pubescens Decne

Morphological Characteristics: The plant is usually much-branches, overspreading- glandular pubescent, oblong-linear lobules, has unbranched or paniculate flowers, made up to 2-flowers verticillasters, has an ovate shape, its calyx is longer than bracts, calyces are longer than acuminate. Also, we notice the flowers become ovoid when it turns to fruits, tall to 5-6 mm traingular-dentate, subequal teeth, the upper part is wider than others, corolla takes a dark blue color, stigmas are nutles, short, deep brown and oblong

(Chaudhary, 2001; Hashem & Hegab, 2018; Nuru et al., 2015; Ya'ni et al., 2018).

Distribution: It is predominant in Egypt, Syria, Palestine, Jordan, Yemen, and Saudi Arabia; especially in the mountain of Asir, Taif, and Albaha (Aprotosoaie et al., 2017; El-Said et al., 2021; Chaudhary, 2001; Hashem & Hegab, 2018; Hosni & Hegazy, 1996; M. N. Khan et al., 2016; Nuru et al., 2015).

Phytochemical Properties: Containing rich in carvacrol and lower concentrations of carvacrol methyl ether caryophyllene oxide and terpinolene (Al-Badani et al., 2017) conferring such a biological property: a volatile fraction that comprises hydrocarbons (terpenes, sesquiterpenes, and diterpenes) and contributes for 90-95% of the total oil (Ali-Shtayeh et al., 2020; Ali et al., 2011; Alorabi et al., 2020; Aprotosoaie et al., 2017; El-Said et al., 2021; Hashem & Hegab, 2018; Park et al., 2019; Rashed et al., 2018; Yani et al., 2021).

Essential Oil Importance: It is extracted using hydro distillation and evaluated using gas chromatography or mass spectrometry (Al-Badani et al., 2017; Ansari et al., 2014), to utility in aromatherapy products medicine, cosmetics and used for removing heavy metal (Ali-Shtayeh et al., 2020; Ali et al., 2011; Alorabi et al., 2020; Aprotosoaie et al., 2017; Baka, 2010; Bordbar & Upson, 2021; El-Said et al., 2021; Hashem & Hegab, 2018; Nuru et al., 2015; Park et al., 2019; Park et al., 2021; Yani et al., 2021).

***Marrubium vulgare* L.**

Morphological Characteristics: The plant is coexisting for longest time ever with many branches' leaves, characterized by white cotton, bracteoles small, subulate, calyx is tubular, 10 toothes equal 10 nerved, upper lip bifid, nutlets ovoid black, its size 2x 1,25mm (Chaudhary, 2001; Masoodi et al., 2008; Ya'ni et al., 2018).

Distribution: It is found in abundance in Pakistan and India; and in Saudi Arabia, we find it; especially in Asir and western highest (Chaudhary, 2001; Hosni & Hegazy, 1996).

Phytochemical Properties: We can define several flavonoids from *M. Vulgare* including apigenin, luteolin, and their derivatives, vitexin as well as several labdane diterpenoids and a little bit of an essential oil (Alkhatib et al., 2010; Boudjelal et al., 2012; De Jesus et al., 2000; Elberry et al., 2015; Herrera-Arellano et al., 2004; Kadri et al., 2011; Lodhi et al., 2017; Masoodi et al., 2008; Meyre-Silva et al., 2005; Nagy & Svajdlenka, 1998; Nawwar et al., 1989; Pukalskas et al., 2012; Rezgui et al., 2020; Sahpaz et al., 2002; Schlemper et al., 1996; Stulzer et al., 2006; Weel et al., 1999; Zarai et al., 2011).

Essential Oil Importance: Until now, scientists discover the unique factor in this plant as hypoglycaemic, hypotensive, antibacterial, and antioxidant. Also, this compound stimulates secretions of the bronchial mucosa, antiarrhythmic effects, analgesic, immunomodulating, vasorelaxant, and gastroprotective (Alkhatib et al., 2010; Boudjelal et al., 2012; De Jesus et al., 2000; De Souza et al., 1998; Elberry et al., 2015; Herrera-Arellano et al., 2004; Kadri et al., 2011; Lodhi et al., 2017; Masoodi et al., 2008; Meyre-Silva et al., 2005; Pukalskas et al., 2012; Rezgui et al., 2020; Sahpaz et al., 2002; Schlemper et al., 1996; Stulzer et al., 2006; Weel et al., 1999; Zarai et al., 2011).

Meriandra benghalensis Benth

Morphological Characteristics: The plant is much-branched, erect, perennial to 1.5 m tall, camphor-smelling; leaves are petiolate and ovate-oblong to elliptic; and the upper surface is rugose, whitish tomentellous beneath, and obtuse. The floral leaves are very small, accrescent to c. 7mm long, slightly bilabiate; the lower surface is two-lobed; and the upper lip is subentire. The corolla is 3-4 mm, two stamina, white to pale lilac slightly excreted; and nutlets are 1.8 mm long, it is wetting not mucilaginous and brown (Chaudhary, 2001; Ya'ni et al., 2018).

Distribution: There are numerous in Saudi Arabia; especially in the Southern Region, Oman, United Arab Emirates, and East Africa (Ali et al., 2012; Chaudhary, 2001).

Phytochemical Properties: There is a sixteen components of essential oils representing 94.5% with β-selinene (4.7%), δ-cadinol (2.1%), arcurcumene (1.7%), 1,8-cineole (10.7%), caryophyllene oxide (5.8%), camphene (5.3%), borneol (3.4%), β-caryophyllene (4.0%), identified twelve contents made up 82% of M. benghalensis and total oil was caryophyllene oxide (5.8%), camphor (43.6%), 1,8-cineole (10.7%), borneol (3.4%) (Ali et al., 2012; Bruno et al., 1985; Lodhi et al., 2017).

Essential Oil Importance: There is some evidence that essential oils may help with gastrointestinal, skin, and respiratory issues; however, further research is needed to confirm this. Furthermore, these plants possess antibacterial properties; operate as astringents, carminatives, and antiseptics; and have the potential to have the greatest impact on human cancer cell lines. MCF7 has many potential uses, including the treatment of diabetes and cancers of the colon and breast. Essential oil, that is both colorless

and aromatic, may be produced by the *M. benghalensis* plant (Ali et al., 2012; Bruno et al., 1985; Demoz et al., 2015; Kaushik et al., 2015; Lodhi et al., 2017; Mothana et al., 2019).

***Mentha longifolia* (Briq.) Briq**

Morphological Characteristics: The plant is rhizomatous variable herb, erect or has ascending branches; leaves are mainly sessile oblong-elliptic to lanceolate, discolors, serrate either obviously or not; the flowers arrangement is terminally and axillary intense spikes; and bracteoles are generally lined setaceous, longer, or same long as flowers. The calyx is hairy, campanulate oil globules could be present or absent; and the corolla is lilac (Chaudhary, 2001).

Distribution: In Europe, Asia, and in Saudi Arabia, it can be found in the Western Mountain (Chaudhary, 2001).

Phytochemical Properties: Chemically, the essential oils of *Mentha longifolia* consist of monoterpenes, commonly oxygenated like menthone, isomenthone, pulegone, 1,8 cineole, piperitenone oxide, borneol (Araghi et al., 2019; Kakhky et al., 2009; Mikaili et al., 2013; Nikšić et al., 2012; Oyedeji & Afolayan, 2006; Singh et al., 2020; Verma et al., 2015). The consumption of the EO consists mainly of pulegone as major component (Mkaddem et al., 2009; Najafian et al., 2020; Patonay et al., 2021).

Essential Oil Importance: The essential oils of the *Mentha longifolia* can be used as treatment for headache, kidney stone, sedative, diuretic, blood purification and antiemetic (Mikaili et al., 2013), anticancer, anti-inflammatory, anti-obesity, anti-diabetic and antioxidant activity, (Abdel-Hameed et al., 2018; Bai et al., 2020; Hajlaoui et al., 2009; Tafrihi et al., 2021). Beyond that, it exhibited antimicrobial properties against a wide range of bacteria and fungi, including *E. coli*, *Salmonella typhimurium*, *Botrytis cinerea*, *Aspergillus flavus*, *Pseudomonas aeruginosa*, *Aspergillus Niger, Trichophyton Longifusus, Microsporm Canis,* and *Mucor ramamnianus* (Mikaili et al., 2013). And according to Gulluce's test, EO reveals a great antimicrobial activity against 30 tested microbes (Gulluce et al., 2007). Multilevel modeling structural equation modeling ML-SEM examination shows that the EO can be a good wood bio-fungicide, and this could lead to possible use as natural wood preservatives (Ali et al., 2021). It also shows an antioxidant activity in medium range versus ABTS and DPPH free radical scavenging, also a high antimicrobial and antimicrobial activity versus yeast and fungi species. These activities could be used in pharmaceutical industry to treat human diseases or in the managing of plant diseases (Mkaddem et al., 2009).

***Ocimum filamentosum* Forssk**

Morphological Characteristics: The plant is characterized by perennial bushy herb, erect, ranging from spicy-sweet to peppery fragrant, and glabrescent or glabrous. The foliage is frequently purple but sometimes green, at least in white-flowered variants, up to 50cm long. Leaves are lanceolate to elliptical, obscurely or entire dentate, acute, 1-1.5 cm wide, 1-4cm long, tapering from the base to a 0.5-1.2cm long petiole. Flowers are verticillate in terminal spikes that are dense at the apex and loose below. Calyx is growing and deflexed in fruit to 6mm long, reticulate-veined, has uneven lobes; the top one is widely oblong, obtuse, and virtually free to the base; however, the others shallowly are separated from each other, acute to briefly acuminate. The corolla is white or pinkish, ranging between 6-12mm long, two lipped with the upper lip four lobed and somewhat spreading and the lower lip is entirely or shortly fimbriate. Nutlets are oblong, ranging between 2-2.5mm long, minutely punctate, and almost black (Chaudhary, 2001).

Distribution: It is found in tropical and warm temperate countries, planted in gardens, and sometimes seen as an apparent escape in certain situations (Chaudhary, 2001).

Phytochemical Properties: A class of naturally occurring chemical compounds mostly composed of terpenoids and hydrocarbons of the terpene alcohol and monoterpene alcohol types; also includes aromatic phenols, bicyclic alcohol, monocyclic ketones, bicyclic monoterpenic ketones, acids, and esters. Essential oil components, that are mono- or sesquiterpenoidal, are produced by condensing isopentenyl pyrophosphate units. Despite their rarity in essential oils, diterpenes may form as a result of other processes (Pandey et al., 2014).

Essential Oil Importance: Essential oils produced by *Ocimum* species had antibacterial, antioxidant, antifungal, and anti-inflammatory properties (Nahak et al., 2011; Qwarse & Sempombe, 2017).

***Origanum syriacum* L**

Morphological Characteristics: The plant is glandular subshrub with woolly canescent. The stem is branched and erect and can reach 60cm long. Leaves are sessile, short, and petiolate with dense canescent woolen ovate. Verticillasters are inflorescent and at the end of each branch of the terminal panicles a cluster of dense spikes is found. Bracts are long like calyces. The calyx is shell shaped and edenate 2.5mm

long. The corolla color is white and 4mm long with excreted tube. Nutlets color is dark brown also subspherical (Chaudhary, 2001).

Distribution: It is endemic to (Al Hafi et al., 2016), found in E. Mediterranean; and in Saudi Arabia, it can be found in north al Hejaz (Chaudhary, 2001).

Phytochemical Properties: The EO of *Origanum syriacum* is rich in carvacrol; moreover, it contains preponderance of p-cymene, thymol, y-terpinene, in addition to phenolic derivative (Al Hafi et al., 2016; Alwafa et al., 2021; Başer et al., 2003; El Gendy et al., 2015; Figuérédo et al., 2005; Ibrahim et al., 2012; Zgheib et al., 2016).

Essential Oil Importance: Traditionally, it represents a fundamental condiment in the Middle East. The EO is also used as inactive against Salmonella enteritidis, Candida albicans, and Pseudomonas aeruginosa. Additionally, it is a great inhibition for some microorganisms, such as E. coli, Enterococcus faecalis, Bacillus spizizenii, and Staphylococcus aureus (Al Hafi et al., 2016). It has antimicrobial activities against several species (Ibrahim et al., 2012). The EO helps combat the candida bacteria that causes denture stomatitis (Shamseddine & Chidiac, 2021). Also, (Alwafa et al., 2021) reported that the essential oils have antimicrobial and antioxidant activities.

***Otostegia fruticosa* (Benth.) Sebald**

Morphological Characteristics: The plant is much-branched subshrub with small hairs, with undivided petiolate leaves, entire to dentate; at the upper leaves, we found the axile on these verticillasters several- flowered. Also, it is characterized by a short tube under the spreading limb with enlarging limb and horizontally spreading and the corolla is bilabiate, five toothed and ten nerved (Ahmed et al., 2022; Chaudhary, 2001; Ya'ni et al., 2018).

Distribution: In the continent of Africa, we find it in Egypt and Africa; while in the continent of Asia, it is in Saudi Arabia, especially in the southwestern region (Ahmed et al., 2022; Al-Namazi et al., 2022; Chaudhary, 2001; Hosni & Hegazy, 1996).

Phytochemical Properties: The leaf oil includes many unique components, including β-caryophyllene (8.8%), myrtenyl formate (3.9%), τ-cadinol (9.3%), bornyl formate (5.2%), and two diterpenoids that are not recognized; i.e., 12.7% and 9.4%, respectively (Ahmed et al., 2022; Al-Jumayi, 2020; Al-Madhagy et al., 2022; Ali et al., 2017; Ansari et al., 2021).

Essential Oil Importance: By using hydrodistillation and gas chromatography, the essential oils of Otostegia fruticosa were extracted and studied. The oil has many uses, including treating tonsillitis, sunstroke, eye problems, paralysis, and mosquito repellant. It exhibited strong cytotoxicity against the cell lines MCF-7 (IC_{50} = 55.1 µg/mL) and MDA-MB231 (IC_{50} = 70.3 µg/mL) (Ahmed et al., 2022; Al-Jumayi, 2020; Ali et al., 2017; Ansari et al., 2020; Ansari et al., 2021).

***Plectranthus arabicus* E.A. Bruce**

Morphological Characteristics: It is a little annual plant that grows to be around 15cm long, watery-succulent, and has a pungent scent. Leaves are sessile, oblanceolate, widely dentate, with four teeth on each side, gradually narrowing to the cuneate base, brittle-suculent, and up to 2 cm long. Verticillasters are several-flowered, distant racemoses with green leafy-bracted terminal and axillary inflorescences. Flowers are beautiful deep blue, long-pedicellate, with capillary pedicels up to 4mm long and spreading. Calyx is small, about 2mm long, and grows to be about 4mm long. In fruit, top lip is orbicular, about 1.5 mm broad, and reticutale. The corolla is 3-6 mm length, with an upper lip that is white or pale blue and a lower lip that is deep blue, and boat shaped. Nutlets are small, red, and lenticular-keeled, measuring less than 1×1mm (Chaudhary, 2001).

Distribution: It is widespread in South of Arabian Peninsula, which is distributed through the high mountains like Asir, and in Yemen, too (Chaudhary, 2001).

Phytochemical Properties: The oil has a high concentration of hary anch diterpenoids, triterpenoids, phenolics, flavonoids and fatty acids. P. arabicus oil included 132 identified components, or 95.2% and 98.4% of the total oil compositions, respectively. (M. Khan et al., 2016) stated that 1,8-cineole (50.5 ± 1.37%), β-pinene (7.0 ± 0.08%), camphor (6.3 ± 0.19%), and β-myrcene (4.1 ± 0.10%) were the main components of *P. arabicus* oil. The following categories were identified by phytochemical screening: carbs and glycosides, sterols, alkaloids, tannins, protein and amino acids, and oxidase enzyme. Saponin and cardenolides were not found. Various environmental factors are believed to contribute to changes in the plant's phytochemical makeup (Al-Saleem et al., 2018).

Essential Oil Importance: The oil has antibacterial, antifungal, insecticidal, antitumoral effects and antiplasmodial (M. Khan et al., 2016). A number of diseases and conditions, including cancer, diabetes, Alzheimer's, stroke, and atherosclerosis, are treated using pharmaceutical formulations that include natural antioxidants (Shaheen et al., 2017).

Rosmarinus officinalis

Morphological Characteristics: All throughout the globe, people have turned to the ancient medicinal plant *Rosmarinus officinalis* to alleviate inflammatory disorders (Borges et al., 2019). It grows to about 2 meters, with erect and brown branches. Leaves are opposite, rough, deeply curled, fringed, and have a noticeable midrib. The length of the leaf is 1.0–2.5 cm and its breadth are 4 cm. Due to the abundance of trichomes, the underside of the leaf has a rather woolly gray color, while the top side is green. With an obtuse apex, tapering, and nonpetiolate base, the margins are whole and firmly revolute (Begum et al., 2013; European Pharmacopoeia, 2007).

Distribution: Although rosemary is native to the Asia and South European regions, it is also grown in the Mediterranean region and India (Kokate et al., 2010; Who, 2007). There are numerous of rosemary in Saudi Arabia; especially in Riyadh region (Elansary et al., 2020), Jizan region (Kokate et al., 2010; El-shabasy, 2016).

Phytochemical Properties: Through the study of **(**Elansary et al., 2020) on the polyphenolic compounds of *R. officinalis* plant growing in the north of Riyadh in the Kingdom of Saudi Arabia, several polyphenols, including rosmarinic acid and gentisic acid, were validated by the HPLC-DAD studies. According to (Borges et al., 2019), the essential oil samples of *R. officinalis* included 150 different chemical components. According to (Aouadi et al., 2021; Rašković et al., 2014; and Takayama et al., 2016), the primary components of the essential oil of R. officinalis were 18-cineole, α-pinene, and camphor. In addition to the three chemicals already mentioned, *Verbenone, Limonene, B-pinene, α-terpineol*, and *γ-pinene* are also found in the subtropical parts of north India, according to (Verma et al., 2020). Monthly samples of R. officinalis essential oil gathered in Sardinia for a whole year were analyzed chemically, and the results showed that 27 chemicals from 6 different categories were present (Melito et al., 2019).

Essential Oil Importance: The high concentration of rosmarinic acid in *R. officinalis's* leaf extracts is responsible for the plant's antioxidant properties. Moreover, the extracts exhibited antiproliferative and cytotoxic effects, as well as antibacterial and antifungal actions. (Aouadi et al., 2021) estimated the anticoccidial activity of *R. officinalis* essential oils. Rosemary oil has a role in removing free radicals and protective effects for the liver (Rašković et al., 2014). It also has an effect in lowering blood pressure and improving patients live (Fernández et al., 2014).

***Salvia lanigera* Poir**

Morphological Characteristics: It is a dwarf shrublet with branches ascending-erect from the base, and its height ranges from 10 to 30cm. Leaves and stems are pubescent with rather tall wavy white hairs. Flowering portions are slightly fragrant and have a strong odor. Leaves are oblong-lanceolate in outline, pinnatisect with linear, crenulate, 1-2 mm-wide, obtuse lobes, revolute-margined, 2-8 cm long, 0.5-2 cm wide, smaller above, petiolate or sub-sessile. Flowers are verticillate, sub-sessile, with a calyx that is 5-6mm long and firmly 2-labiate, with an inconspicuous upper lip with teeth that is mostly purple, thickly hirsute with spreading straight whitish glandular hairs. The corolla is blue violet to quite dark purple, 2-2.5 times the length of the calyx, with the upper lip surpassing the lower. Nutlets are ovoid, 2-2.5mm long, smoothish, and almost black in color (Mandaville, 1990).

Distribution: It is found in shallow silts inland, typically near the stony borders of tiny ravines and wadis. It is locally common (Chaudhary, 2001).

Phytochemical Properties: The main class of the essential oil of *S. lanigera* is Monoterpenes then sesquiterpenes and phenylpropanoids. Thymol was primarily responsible for the high percentage of monoterpenes. Cedrol, methyl chavicol, and spathulenol were other prominent components. According to (Flamini et al., (2007), most of the essential oil consisted of oxygenated derivatives, such as phenols, ketones, aldehydes, and alcohols. Hexadecanoic acid, α-thujonec, carvacrol, and thymol were determined to be the main components among 67 identified chemicals that made up 93.6% of the oil (Tenore et al., 2011). Four diterpene-quinones of the royleanone class are present in the plants (Ibrahim et al., 2013).

Essential Oil Importance: It is grown for culinary, medicinal, and decorative uses, and hence has ethnopharmacological and economic significance, particularly for small farmers. They're widely utilized in traditional medicine, and numerous pharmacological investigations have tried to figure out what chemicals are responsible for their therapeutic benefits (Mossi et al., 2011). *S. lanigera* is a tea condiment that includes thymol, a component with a strong odor that imparts a distinct flavor to meals and beverages. Aside from thymol, additional compounds with pleasant odors include cedrol, methyl chavicol, linal-ool, and myrtenol (Flamini et al., 2007). Particularly beneficial as natural preservation components, they offer a lot of promise in the food and cosmetic industries, especially in antioxidant

systems. In fact, several species are commonly utilized as antibacterial and antioxidant agents to stabilize fat and fat-containing diets (Tenore et al., 2011).

***Satureja nabateorum* Danin & Hedge**

Morphological Characteristics: It is an under-shrub with a woody base, several stems, and a powerful perfume, densely retrorse hairy and covered with reddish sessile glands on all parts. Summer flowering shoots bear inflorescence and short axillary branches with small, crowded leaves; sessile winter leaves, up to 12x12mm, obtuse, flat, oblong, obtuse, thick, deciduous from lower part of stems; sessile summer leaves, up to 12x12mm, thick, oblong, flat, obtuse, deciduous from lower part of stems; and six to ten verticillasters blossomed, forming thick spicate inflorescences. Bracteoles are tiny, about the same length as the calyx, which is tubular, 5-nerved, thickly white-haired, and speckled with sessile glands, 2.5 mm long, equally 5-toothed, triangular teeth 1 mm long. The corolla is 6-8 mm long, white pubescent on the exterior; the tube is excreted; and the top lip is obtuse, with lilac anthers on the stamens (Chaudhary, 2001).

Distribution: It is localized only in the mountain ranges immediately around the Dead Sea, including the Jordanian Edom and the Palestinian Tubas (Al-Maharik & Jaradat, 2022).

Phytochemical Properties: The examined EOs of *S. nabateorum* included 42 compounds, accounting for almost 99% of peak area, including thymol (46.07±1.1 and 40.64±1.21%), p-cymene (15.02±1.02% and 11.51±0.97 %), and -terpinene (21.15±1.05% and 20.65±1.12 %). Carvacrol (27.24-88.71%) was found to be the most prevalent component in the EOs of most Sat-ureja species, followed by -terpinene (3.18-23.20%) and p-cymene (2.77-13.34%). Sesquiterpenes were relatively low in *S. nabateorum* EOs, but phenolic monoterpenes and monoterpenes were present in considerable concentrations (about 95%) (Al-Maharik & Jaradat, 2022; Azaz et al., 2005).

Essential Oil Importance: *Satureja* EO can be used in several biological and commercial applications antimicrobials, sedatives, food preservatives, digestive properties, food additives, and carminative. EOs have high antifungal effectiveness (Al-Maharik & Jaradat, 2022; Azaz et al., 2005).

***Teucrium polium* L.**

Morphological Characteristics: It is a dwarf shrublet white woolly-canescent appearance, a low, extremely aromatic, numerous erect, branched from the base, spreading or ascending stems 10-40 cm long. Leaves are oblong, sessile, obtuse, crenulate at least in upper half, strongly revolute, 8-20 mm long, 3-6 mm broad, smaller above. Inflorescence is corymbose and terminal, or subterminal and axillary; flowers are mildly fragrant, sessile in dense ovoid to subglobose heads 12-15 mm in diameter on peduncles mostly equaling or exceeding the subtending leaves. The calyx is tomentose woolly, 3-5 mm long with triangular teeth immersed in hairs. The corolla is 7-8 mm long, white or to very pale pink, yellowish in throat, exceeding the calyx with one lip prominent, pubescent at back and in lower parts (Chaudhary, 2001).

Distribution: It is found around limestone hills or ravines, rocky hills. It is infrequent (Chaudhary, 2001).

Phytochemical Properties: The following were the principal components: β-pinene, germacrene, α-pinene, myrcene, limonene, bicyclogermacrene, trans-β-guaiene, spathulenol, and β-bourbonene. It contains many chemical compounds, the most important of which are: alkaloids known as stacadrine, sisterone, volatile oil (contains caddisin compounds in its composition), carbohydrates (glucose, fructose, sucrose, rhamnose, raffinose), unsaturated sterols, triterpenes, bitter and tannins, flavones and glucosides, flavonoids (Asgharipour & Shabankare, 2017) and polyphenols (Nacéra et al., 2013). The main constituents identified were -caryophyllene, 8-cedren-13-ol, sabinene, and germacrene D (Aburjai et al., 2006).

Essential Oil Importance: For almost 2000 years, it has been used in traditional medicine as a diaphoretic, diuretic, tonic, antipyretic, cholagogic herb, and antispasmodic (Ljubuncic et al., 2006). Antinociceptive, antioxidant capabilities and highlight their potential as natural preservatives or medicinal ingredients.

***Thymus decussatus* Benth**

Morphological Characteristics: The plant is a small shrub, having complex branches can reach 100cm long. Leaves are generally elliptic lanceolate, and narrow can reach 10x2mm, has oil globules over the leaf superficial, plus there are extended setose cilia toward the base, with flowers. The calyx is pilose covered with oil globules. The corolla is pilose from outside, plus a few oil globules (Chaudhary, 2001).

Distribution: Worldwide, it is found in Egypt, and in Saudi Arabia, it can be found in north Hijaz (Chaudhary, 2001).

Phytochemical Properties: *T. decussatus* chemistry EO is made up of oxygenated monoterpenes, the primary component of which is carvacrol, and

monoterpene hydrocarbons, the main component of which is p-cymene (Saleh et al., 2020). (El-Hela, 2007) found that the main component of the essential oil for the *T. decussatus* was thymol.

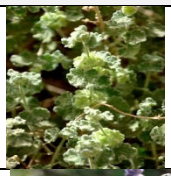
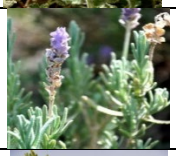
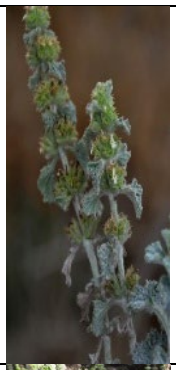
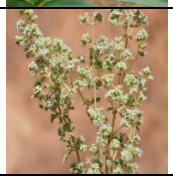
Essential Oil Importance: Thymus decussatus essential oil (EO) has antibacterial action against Ehrlich ascites carcinoma cell (EAC) as well as two human cancer cell lines (El-Hela, 2007). It also has a strong inhibitory effect on Staphylococcus aureus, Escherichia coli, and *Aspergillus niger*. Furthermore, it is famous as treatment to nausea (Saleh et al., 2020). Table 1 provides a synopsis of the medicinal applications and essential oil compounds of fifteen species of fragrant Lamiaceae plants native to Saudi Arabia. Figure 3 shows a comparison of the species' essential oils and phytochemical relevance based on varying numbers of references.

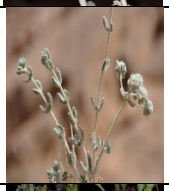
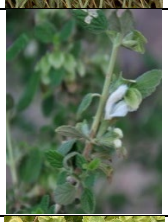
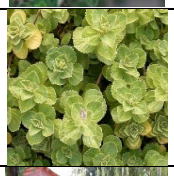
The Adoption for Aromatic Plants for Sustainable land Management to Combat Desertification

Desertification is a major global problem and a great environmental challenge that is a threat to human existence and affects the lives of 250 million people (Patel, 2021). It has a devastating impact on the four components of sustainability (environmental, social, politics, economical (ESPE) (Ghrefat, 2011; Gupta et al., 2021). Desertification has an extreme impact on economic, and it results on the world loss of about US$42 billion annually (Ghrefat, 2011). Desertification has decreased agricultural productivity by affecting the ability of the degraded land to produce crops which exacerbate a world's food shortage and threats global food security (You et al., 2021). Desertification is caused by several factors, mainly: climatic variations and human activities (i.e., deforestation, overgrazing, unsustainable water management, intensive use of agricultural lands, urbanization, unsustainable agriculture techniques, and unsustainable land management practices) (Patel, 2021). Desertification is a major challenge afflicting Saudi Arabia, in addition to its arid environment, other factors that led to desertification are the fundamental characteristics of arid region soil (i.e., low soil moisture and organic matter content) which represents 45% of total soils in Saudi Arabia (Khalifa & Yousef, 2015; Najmadeen, 2010; Waqas et al., 2018). The desertification is expected to increase globally and in the affected area in the KSA. Therefore, a quick remedial action needs to be taken to combat and prevent desertification and restore degraded land caused by desertification (Kim & van der Beek, 2018). Restoration of degraded land is known as a crucial component of the United Nations Sustainable Development Goals (SDGs) which makes balance between the four sustainable components (ESPE) and can be achieved by the implementation of several methods (Gupta et al., 2021). These methods can be done either through unsustainable physical, chemical, and biological methods requiring suitable and costly applied technologies or through sustainable methods (Ghrefat, 2011; Gupta et al., 2021). Saudi Arabia uses various adaptations and mitigation measures to minimize desertification, such as controlling the shifting sand dunes and diminishing the danger of wind erosion (Kim & van der Beek, 2018). Adoption of sustainable approaches to prevent soil erosion and tackle desertification is more recommended to meet Saudi Vision 2030 aim. Sustainable methods can be implemented using different strategies, such as afforestation, use of sustainable agricultural practices, use of sustainable land management (Ghrefat, 2011; Gupta et al., 2021). Sustainable land management becomes necessary to prevent land degradation towards water and food security (Gupta et al., 2021). Adoption of aromatic plants cultivation on degraded lands, as a source of sustainable land management, is an excellent option due to the following reasons (Gupta et al., 2021):

- The worldwide surge in demand for high-value essential oils was derived from aromatic plants, such as *chrysopogon zizanioides* and *cymbopogon martini*, which are utilized in cosmetics, flavouring & fragrance, spices, insecticides, food processing, and herbal drinks. The high resistance of aromatic gases for numerous biotic and abiotic stress, such as degraded and polluted land with low input, was amended with organic materials and microbial enzymatic.
- Their permanent nature, multiple cropping, and low maintenance cost.
- The high adaptation on degraded land for some aromatic plants, such as *ocimum basilicum, lavandula vera*, and *matricaria chamomilla*.
- Promotion of aromatic plants cultivation assists declining dependency on productive agricultural lands and obtaining the followings benefits: a) effective contribution in the restoration of degraded land, b) desertification combat, c) alleviation of the harshness of climate change, d) mitigation of soil carbon sequestration, e) improvement of soil quality, f) management of soil resources, g) lessening of competition between cultivation of food and aromatic crops on arable lands, h) remediation of contaminated sites, i) assisting achieving SDGs.

Table 1. Summary of the Essential Oil Compound and Medical Uses for 15 Species of Lamiaceae Aromatic Plants in Saudi Arabia

Plant Species		Essential Oil Main Compounds	Medical Uses for Essential Oil	Phytochemical Properties References	Essential Oil Importance References	Saudi Arabia References
Ballota undulata		Monoterpene hydrocarbons and sesquiterpenes	Antiallergic, antimicrobial, antispasmodi, and anti-inflammatory	Bader et al. (2003)	Alshehri (2020)	Alshehri (2020)
Lavandula dentata		Oxygenated monoterpenes and Sesquiterpene hydrocarbons, the dominant component is 1,8-cineole	Folk medicine, treatment for kidney stones, urine retention, rheumatisms and in digestive proplemsm, insecticide and fungicide activity	Vicenço et al. (2022) Wagner et al. (2021) Giuliani et al. (2020) Martins et al. (2019) Justus et al. (2018) Bousmaha et al. (2006) Dob et al. (2005)	El Abdali et al. (2022) Vicenço et al. (2022) Wagner et al. (2021) Giuliani et al. (2020)	
Lavandula pubescens		Rich in carvacrol and lower concentrations of carvacrol methyl ether caryophyllene oxide and terpinolene	Utility in aromatherapy products medicine, cosmetics and used for removing heavy metal	El-Said et al. (2021) Yani et al. (2021) Ali-Shtayeh et al. (2020) Alorabi et al. (2020) Park et al. (2019) Hashem and Hegab (2018) Rashed et al. (2018) Al-Badani et al. (2017) Aprotosoaie et al. (2017) Ali et al. (2011)	Bordbar and Upson (2021) El-Said et al. (2021) Yani et al. (2021) Ali-Shtayeh et al. (2020) Alorabi et al. (2020) Park et al. (2019) Hashem and Hegab (2018) Al-Badani et al. (2017) Aprotosoaie et al. (2017) Nuru et al. (2015) Ansari et al. (2014) Ali et al. (2011) Baka (2010)	Bordbar and Upson (2021) Alorabi et al. (2020) Aprotosoaie et al. (2017) Nuru et al. (2015) Ansari et al. (2014) Baka (2010)
Marrubium vulgare		Flavonoids, several labdane diterpenoids and a little bit of an essential oil	Hypoglycaemic, hypotensive, antibacterial, and antioxidant, stimulates secretions of the bronchial mucosa, antiarrhythmic effects, analgesic, immunomodulating, vasorelaxant, and gastroprotective	Rezgui et al. (2020) Lodhi et al. (2017) Elberry et al. (2015) Boudjelal et al. (2012) Pukalskas et al. (2012) Kadri et al. (2011) Zarai et al. (2011) Alkhatib et al. (2010) Masoodi et al. (2008) Stulzer et al. (2006) Meyre-Silva et al. (2005) Herrera-Arellano et al. (2004) Sahpaz et al. (2002) De Jesus et al. (2000) Weel et al. (1999) Nagy and Svajdlenka (1998) Schlemper et al. (1996) Nawwar et al. (1989)	Rezgui et al. (2020) Lodhi et al. (2017) Elberry et al. (2015) Pukalskas et al. (2012) Boudjelal et al. (2012) Kadri et al. (2011) Zarai et al. (2011) Alkhatib et al. (2010) Masoodi et al. (2008) Stulzer et al. (2006) Meyre-Silva et al. (2005) Herrera-Arellano et al. (2004) Sahpaz et al. (2002) De Jesus et al. (2000) Weel et al. (1999) Nagy and Svajdlenka (1998) Schlemper et al. (1996)	Lodhi et al. (2017) Elberry et al. (2015)
Meriandra Benghalensis		M. benghalensis (82%), β-selinene, 1,8-cineole arcurcumene, camphene, borneol	Treatment of respiratory, skin, and digestive diseases, antirheumatic, astringent, carminative, against the Human cancer cell lines MCF7	Lodhi et al. (2017) Ali et al. (2012) Bruno et al. (1985)	Lodhi et al. (2017) Mothana et al. (2019) Demoz et al. (2015) Kaushik et al. (2015) Ali et al. (2012) Bruno et al. (1985)	Mothana et al. (2019)
Mentha longifolia		Monoterpenes, commonly oxygenated like menthone, isomenthone, pulegone, 1,8 cineole, piperitenone oxide, borneol	Treatment for headache, kidney stone, sedative, diuretic, blood purification and antiemetic, antimicrobial activity against 30 tested microbes	Patonay et al. (2021) Najafian et al. (2020) Singh et al. (2020) Araghi et al. (2019) Verma et al. (2015) Mikaili et al. (2013) Nikšić et al. (2012) Kakhky et al. (2009) Oyedeji and Afolayan (2006)	Ali et al. (2021) Tafrihi et al. (2021) Bai et al. (2020) Abdel-Hameed et al. (2018) Mikaili et al. (2013) Mkaddem et al. (2009) Hajlaoui et al. (2009) Gulluce et al. (2007)	
Ocimum filamentosum		Natural organic substances mostly consisting of terpenic hydrocarbons and terpenoids	Had antibacterial, antioxidant, antifungal, and anti-inflammatory properties	Pandey et al. (2014)	Qwarse and Sempombe (2017) Nahak et al. (2011)	
Origanum syriacum		Carvacrol, preponderance of p-cymene, thymol, γ-terpinene, phenolic derivative	Inactive against *Salmonella enteritidis*, *Candida albicans*, *Pseudomonas,* antimicrobial activates against several species	Al Hafi et al. (2016) Zgheib et al. (2016) El Gendy et al. (2015) Ibrahim et al. (2012) Figuérédo et al. (2005) Başer et al. (2003)	Shamseddine and Chidiac (2021) Al Hafi et al. (2016) Ibrahim et al. (2012)	

Satureja nabateorum		Thymol, p-cymene, γ-terpinene, Carvacrol	Used as antimicrobials, sedatives, food preservatives, food additives, and carminative.	Al-Maharik and Jaradat (2022)	Al-Maharik and Jaradat (2022)	
Teucrium polium		β-pinene, germacrene, α-pinene, myrcene, limonene, bicyclogermacrene, trans-β-guaiene, spathulenol and β-bourbonene	Used as traditional medicine as diaphoretic, diuretic, tonic, antipyretic, cholagogic herb, and antispasmodic antinociceptive, antioxidant capabilities	Asgharipour and Shabankare (2017) Nacéra et al. (2013) Aburjai et al. (2006)	Nacéra et al. (2013) Ljubuncic et al. (2006)	
Thymus decussatus		Oxygenated monoterpenes (mainly carvacrol), monoterpene hydrocarbon (mainly p-cymene), and thmol.	Antimicrobial activity against cancer cell – lines, inhibitory influence against Staphylococcus aureus, Escherichia coli, and *Aspergillus nige, used to* treat nausea	Saleh et al. (2020) El-Hela (2007)	Saleh et al. (2020) El-Hela (2007)	
Otostegia fruticosa		β-caryophyllene, diterpenoids	Very good cytotoxicity against cancer cell lines, used to treat tonsillitis, sunstroke, eye diseases, paralysis and mosquito repellent	Ahmed et al. (2022) Al-Madhagy et al. (2022) Ansari et al. (2021) Al-Jumayi (2020) Ali et al. (2017)	Ahmed et al. (2022) Ansari et al. (2021) Al-Jumayi (2020) Ansari et al. (2020) Ali et al. (2017)	Ahmed et al. (2022) Ansari et al. (2021) Al-Jumayi (2020) Ansari et al. (2020)
Plectranthus arabicus		High concentration of hary anch diterpenoids. triterpenoids, phenolics, flavonoids, fatty acids,	Antibacterial, antifungal, insecticidal, antitumoral effects and antiplasmodial	Al-Saleem et al. (2018) M. Khan et al. (2016)	Shaheen et al. (2017)	Al-Saleem et al. (2018) Shaheen et al. (2017) M. Khan et al. (2016)
Rosmarinus officinalis		Polyphenols, including rosmarinic acid, gentisic acid, ,8-cineole, α-pinene and camphor	Antioxidant, antiproliferative, cytotoxic, antibacterial and antifungal activities, protective effects for the liver, lowering blood pressure	Elansary et al. (2020) Borges et al. (2019) Rašković et al. (2014) Takayama et al. (2016) Aouadi et al. (2021) Verma et al. (2020)	Elansary et al. (2020) Borges et al. (2019) Aouadi et al. (2021) Fernández et al. (2014) Rašković et al. (2014)	Elansary et al. (2020)
Salvia lanigera		Monoterpenes then sesquiterpenes and phenylpropanoids.	Utilized in traditional medicine, has antibacterial and antioxidant activities, used in fat-containing diets	Ibrahim et al. (2013) Tenore et al. (2011) Flamini et al. (2007)	Mossi et al. (2011) Tenore et al. (2011) Flamini et al. (2007)	

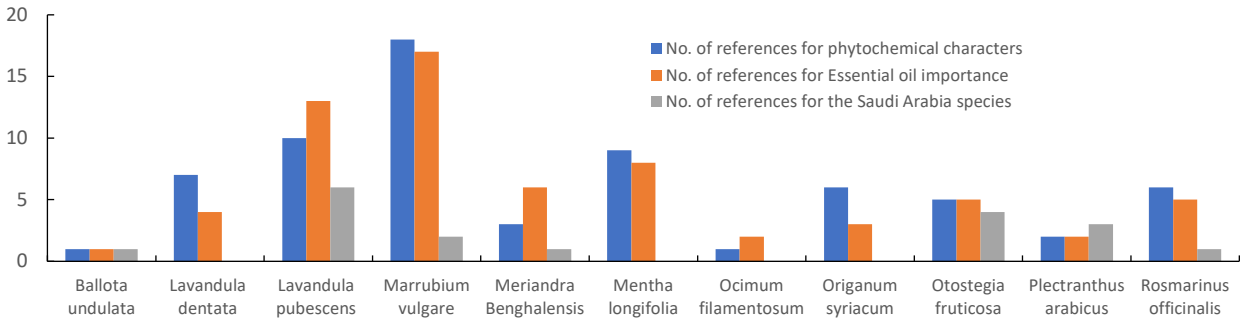


Figure 2. The analysis of 15 species of fragrant Lamiaceae plants grown in Saudi Arabia, comparing their phytochemical and essential oil relevance based on varying numbers of references

CONCLUSION AND FUTURE RECOMMENDATION

The morphological characteristics, phytochemical properties, and the importance of essential oils in certain aromatic plants belonging to the Lamiaceae family in the Kingdom of Saudi Arabia have been adequately described. Aromatic plants contain volatile aromatic substances, odorous compounds, green exudates, oleoresins, and balsams. Some of these plants have demonstrated key activities, such as antioxidant, antimicrobial, and anticoccidial properties. They are integral to various aspects of our lives, and comprehending and appreciating their significance and applicability can lead to significant advancements in various fields, including the cosmetic and pharmaceutical industries. These uses make them one of the most significant plant groups in human history, contributing significantly to both the economy and tourism. Furthermore, certain species, such as *Ballota undulata*, *Otostegia fruticosa*, *Satureja nabateorum*, and *Thymus decussatus*, require further research and examination to identify their important chemical constituents and medical significance. Among the species found in Saudi Arabia, even the most extensively studied ones require further investigation. Aromatic crops have the potentiality to play a vital role in land rehabilitation and serve as a sustainable land management strategy to combat desertification. However, improvements are needed in terms of adopting enhanced cultivation practices, implementing integrated farming techniques, and utilizing byproducts generated from the cultivation of aromatic plants.

AUTHOR CONTRIBUTION

Conceptualization; D.G.G, M.H.A, G.H.A, R.F.A, F.E.A and Z.J.A., Methodology; M.H.A, D.M.E, O.G.R, and E.A. Data Analysis; M H.S, A.Y.M, D.M.E, O.G.R and F.E.A. Figures and tables preparation; R.F.A, F.E.A, G.H.A, D.G.G, O.G.R, Z.J.A and M.H.S. Writing original draft preparation; D.M.E, G.H.A, F.E.A and Z.J.A. Writing review and editing R.F.A, M.H.A, D.G.G, O.G.R. All authors have read and agreed to the published version of the manuscript.

FUNDING

This research has not got external funding.

DATA AVAILABILITY

This investigation offers all data collected or estimated throughout this effort.

ETHICAL APPROVAL

There are no experiments on people or animals in this study.

CONFLICT OF INTEREST

The authors declare no competing interests.

REFERENCES

Abdel-Hameed, E.-S. S., Salman, M. S., Fadl, M. A., Elkhateeb, A., & Hassan, M. M. (2018). Chemical Composition and Biological Activity of *Mentha longifolia* L. Essential Oil Growing in Taif, KSA Extracted by Hydrodistillation, Solvent Free Microwave and Microwave Hydrodistillation *Journal of Essential Oil Bearing Plants*, *21*(1), 1-14.

Aburjai, T., Hudaib, M., & Cavrini, V. (2006). Composition of the Essential Oil from J*ordanian Germander* (Teucrium polium L.) *Journal of Essential Oil Research*, *18*(1), 97-99.

Ahmed, S. M., Dessoky, E. S., & Abdel-Hamid, A. M. E. (2022). Comparison Among Six Dna Barcodes For Molecular Authentication Of *Otostegia fruticosa Pak. J. Bot*, *54*(3), 897-902.

Al-Badani, R. N., da Silva, J. K. R., Mansi, I., Muharam, B. A., Setzer, W. N., & Awadh Ali, N. A. (2017). Chemical Composition and Biological Activity of *Lavandula pubescens* Essential Oil from Yemen *Journal of Essential Oil Bearing Plants*, *20*(2), 509-515.

Al-Madhagy, S. A., Gad, S. S., Mostafa, E. S., Angeloni, S., Saad, M. A., Sabry, O. M., Caprioli, G., & El-Hawary, S. S. (2022). A new arsenal of polyphenols to make Parkinson's disease extinct: HPLC-MS/MS profiling, very interesting MAO-B inhibitory activity and antioxidant activity of *Otostegia fruticosa Natural Product Research*, 1-6.

Al-Namazi, A. A., Algarni, S. M., Wan, J. S. H., Al Mosallam, M. S., & Alotaibi, F. (2022). Floristic composition of Jandaf Mountain as biodiversity hotspot area in southwestern Saudi Arabia *Saudi Journal of Biological Sciences*, *29*(5), 3654-3660.

Al-Saleem, M. S., Awaad, A. S., Alothman, M. R., & Alqasoumi, S. I. (2018). Phytochemical standardization and biological activities of certain desert plants growing in Saudi Arabia *Saudi Pharmaceutical Journal*, *26*(2), 198-204.

Alamgir, A. N. M. (2017). *Therapeutic use of medicinal plants and their extracts: volume 1*. Springer.

Ali-Shtayeh, M. S., Abu-Zaitoun, S. Y., Dudai, N., & Jamous, R. M. (2020). Downy Lavender Oil: A Promising Source of Antimicrobial, Antiobesity, and Anti-Alzheimer's Disease Agents *Evidence-Based Complementary and Alternative Medicine*, *2020*, 5679408.

Ali, H. M., Elgat, W. A. A. A., El-Hefny, M., Salem, M. Z. M., Taha, A. S., Al Farraj, D. A., Elshikh, M. S., Hatamleh, A. A., & Abdel-Salam, E. M. (2021). New Approach for Using of *Mentha longifolia* L. and Citrus reticulata L. Essential Oils as Wood-Biofungicides: GC-MS, SEM,

and MNDO Quantum Chemical Studies. *Materials*, *14*(6).

Ali, N. A., Wurster, M., Alkaf, A. G., Fadail, I., Sharaf, I., & Lindequist, U. (2011). Lavandula pubescens Decine-A potential source of carvacrol-rich essential oil in Yemen *The University of Aden Journal of Natural and Applied Sciences*.

Ali, N. A. A., Wurster, M., Denkert, A., Arnold, N., Fadail, I., Al-Didamony, G., Lindequist, U., Wessjohann, L., & Setzer, W. N. (2012). Chemical Composition, Antimicrobial, Antioxidant and Cytotoxic Activity of Essential Oils of Plectranthus cylindraceus and Meriandra benghalensis from Yemen *Natural Product Communications*, *7*(8), 1934578X1200700834.

Alkhatib, R., Joha, S., Cheok, M., Roumy, V., Idziorek, T., Preudhomme, C., Quesnel, B., Sahpaz, S., Bailleul, F., & Hennebelle, T. (2010). Activity of ladanein on leukemia cell lines and its occurrence in *Marrubium vulgare Planta medica*, *76*(01), 86-87.

Alorabi, A. Q., Alharthi, F. A., Azizi, M., Al-Zaqri, N., El-Marghany, A., & Abdelshafeek, K. A. (2020). Removal of Lead(II) from Synthetic Wastewater by *Lavandula pubescens* Decne Biosorbent: Insight into Composition–Adsorption Relationship. *Applied Sciences*, *10*(21).

Alshehri, K. M. (2020). Phytochemical analysis, anticancer screening and antimicrobial activity of Ballota undulata Fresen (Benth.) from Al- Baha region Saudi Arabia. *International Journal of Research in Pharmaceutical Sciences*. 11(4):7863-7877.

Alwafa, R. A., Mudalal, S., & Mauriello, G. (2021). *Origanum syriacum* L. (Za'atar), from Raw to Go: A Review. *Plants*, *10*(5).

Ansari, A. A., Abbas, Z. K., Saggu, S., Rehman, H., & Moawed, M. M. (2014). Growth responses of *Lavandula pubescens* to temperature regimes of Tabuk, Saudi Arabia *Journal of Medicinal Plants*, *2*(6), 38-41.

Ansari, M. N., Rehman, N. U., Karim, A., Bahta, T., Abujheisha, K. Y., Ahamad, S. R., & Imam, F. (2020). Evaluation of bronchodialatory and antimicrobial activities of *Otostegia fruticosa*: a multi-mechanistic approach *Saudi Pharmaceutical Journal*, *28*(3), 281-289.

Ansari, M. N., Rehman, N. U., Karim, A., Soliman, G. A., Ganaie, M. A., Raish, M., & Hamad, A. M. (2021). Role of Oxidative Stress and Inflammatory Cytokines (TNF-α and IL-6) in Acetic Acid-Induced Ulcerative Colitis in Rats: Ameliorated by *Otostegia fruticosa*. *Life*, *11*(3).

Aprotosoaie, A. C., Gille, E., Trifan, A., Luca, V. S., & Miron, A. (2017). Essential oils of *Lavandula* genus: a systematic review of their chemistry *Phytochemistry Reviews*, *16*(4), 761-799.

Ahmed, S. M., Dessoky, E. S., & Abdel-Hamid, A. M. E. (2022). Comparison Among Six Dna Barcodes For Molecular Authentication Of *Otostegia fruticosa Pak. J. Bot*, *54*(3), 897-902.

Al-Badani, R. N., da Silva, J. K. R., Mansi, I., Muharam, B. A., Setzer, W. N., & Awadh Ali, N. A. (2017). Chemical Composition and Biological Activity of *Lavandula pubescens* Essential Oil from Yemen *Journal of Essential Oil Bearing Plants*, *20*(2), 509-515.

Al-Jumayi, H. (2020). Amelioration of gentamicin-induced nephrotoxicity using essential oil extract from *Otostegia fruticosa* leaves in albino rats *Plant Cell Biotechnol. Mol. Biol*, *21*, 90-106.

Al-Madhagy, S. A., Gad, S. S., Mostafa, E. S., Angeloni, S., Saad, M. A., Sabry, O. M., Caprioli, G., & El-Hawary, S. S. (2022). A new arsenal of polyphenols to make Parkinson's disease extinct: HPLC-MS/MS profiling, very interesting MAO-B inhibitory activity and antioxidant activity of *Otostegia fruticosa Natural Product Research*, 1-6.

Al-Maharik, N., & Jaradat, N. (2022). Phytochemical Profile, Antimicrobial, Cytotoxic, and Antioxidant Activities of Fresh and Air-Dried *Satureja nabateorum* Essential Oils. *Molecules*, *27*(1).

Al-Saleem, M. S., Awaad, A. S., Alothman, M. R., & Alqasoumi, S. I. (2018). Phytochemical standardization and biological activities of certain desert plants growing in Saudi Arabia *Saudi Pharmaceutical Journal*, *26*(2), 198-204.

Al Hafi, M., El Beyrouthy, M., Ouaini, N., Stien, D., Rutledge, D., & Chaillou, S. (2016). Chemical Composition and Antimicrobial Activity of *Origanum libanoticum*, *Origanum ehrenbergii*, and *Origanum syriacum* Growing Wild in Lebanon *Chemistry & Biodiversity*, *13*(5), 555-560.

Ali-Shtayeh, M. S., Abu-Zaitoun, S. Y., Dudai, N., & Jamous, R. M. (2020). Downy Lavender Oil: A Promising Source of Antimicrobial, Antiobesity, and Anti-Alzheimer's Disease Agents *Evidence-Based Complementary and Alternative Medicine*, *2020*, 5679408.

Ali, H. M., Elgat, W. A. A. A., El-Hefny, M., Salem, M. Z. M., Taha, A. S., Al Farraj, D. A., Elshikh, M. S., Hatamleh, A. A., & Abdel-Salam, E. M. (2021). New Approach for Using of *Mentha longifolia* L. and Citrus reticulata L. Essential Oils as Wood-Biofungicides: GC-MS, SEM, and MNDO Quantum Chemical Studies. *Materials*, *14*(6).

Ali, N. A., Wurster, M., Alkaf, A. G., Fadail, I., Sharaf, I., & Lindequist, U. (2011). Lavandula pubescens Decine-A potential source of carvacrol-rich essential oil in Yemen *The University of Aden Journal of Natural and Applied Sciences*.

Ali, N. A. A., Alhamzy, E. H., Chhetri, B. K., Dosoky, N. S., & Setzer, W. N. (2017). Chemical Composition, Antimicrobial, and Cytotoxic Activities of the Essential Oil of Otostegia fruticosa subsp. schimperi from Yemen *Natural Product Communications*, *12*(6), 1934578X1701200634.

Ali, N. A. A., Wurster, M., Denkert, A., Arnold, N., Fadail, I., Al-Didamony, G., Lindequist, U., Wessjohann, L., & Setzer, W. N. (2012). Chemical Composition, Antimicrobial, Antioxidant and Cytotoxic Activity of Essential Oils of Plectranthus cylindraceus and

Meriandra benghalensis from Yemen *Natural Product Communications*, *7*(8), 1934578X1200700834.

Alorabi, A. Q., Alharthi, F. A., Azizi, M., Al-Zaqri, N., El-Marghany, A., & Abdelshafeek, K. A. (2020). Removal of Lead(II) from Synthetic Wastewater by *Lavandula pubescens* Decne Biosorbent: Insight into Composition–Adsorption Relationship. *Applied Sciences*, *10*(21).

Alwafa, R. A., Mudalal, S., & Mauriello, G. (2021). *Origanum syriacum* L. (Za'atar), from Raw to Go: A Review. *Plants*, *10*(5).

Ansari, A. A., Abbas, Z. K., Saggu, S., Rehman, H., & Moawed, M. M. (2014). Growth responses of *Lavandula pubescens* to temperature regimes of Tabuk, Saudi Arabia *Journal of Medicinal Plants*, *2*(6), 38-41.

Ansari, M. N., Rehman, N. U., Karim, A., Bahta, T., Abujheisha, K. Y., Ahamad, S. R., & Imam, F. (2020). Evaluation of bronchodialatory and antimicrobial activities of *Otostegia fruticosa*: a multi-mechanistic approach *Saudi Pharmaceutical Journal*, *28*(3), 281-289.

Ansari, M. N., Rehman, N. U., Karim, A., Soliman, G. A., Ganaie, M. A., Raish, M., & Hamad, A. M. (2021). Role of Oxidative Stress and Inflammatory Cytokines (TNF-α and IL-6) in Acetic Acid-Induced Ulcerative Colitis in Rats: Ameliorated by *Otostegia fruticosa*. *Life*, *11*(3).

Aouadi, M., Sebai, E., Saratsis, A., Kantzoura, V., Saratsi, K., Msaada, K., Sotiraki, S., & Akkari, H. (2021). Essential oil of *Rosmarinus officinalis* induces in vitro anthelmintic and anticoccidial effects against *Haemonchus contortus* and *Eimeria* spp. in small ruminants *Veterinární medicína*, *66*(4), 146-155.

Aprotosoaie, A. C., Gille, E., Trifan, A., Luca, V. S., & Miron, A. (2017). Essential oils of *Lavandula* genus: a systematic review of their chemistry *Phytochemistry Reviews*, *16*(4), 761-799.

Araghi, A. M., Nemati, H., Azizi, M., Moshtaghi, N., Shoor, M., & Hadian, J. (2019). Assessment of phytochemical and agro-morphological variability among different wild accessions of *Mentha longifolia* L. cultivated in field condition *Industrial Crops and Products*, *140*, 111698.

Asgharipour, M. R., & Shabankare, H. G. (2017). Comparison of chemical composition of *Teucrium polium* L. essential oil affected by phenological stages *Bangladesh Journal of Botany*, *46*(2), 583-588.

Azaz, A. D., Kürkcüoglu, M., Satil, F., Can Baser, K. H., & Tümen, G. (2005). In vitro antimicrobial activity and chemical composition of some *Satureja* essential oils *Flavour and Fragrance Journal*, *20*(6), 587-591.

Baby, P. S., Joy, P.P., Mathew, S., Mathew, G. and Joseph, A. (2007). Aromatic Plants. Horticultural sciences. New India Publishing, Volume 7. 223pp.

Bader, A., Caponi, C., Cioni, P. L., Flamini, G., & Ivano, M. (2003). Composition of the essential oil of *Ballota undulata*, *B. nigra* ssp. foetida and *B. saxatilis Flavour and Fragrance Journal*, *18*(6), 502-504.

Bagetta, G., Cosentino, M., & Sakurada, T. (2015). *Aromatherapy: Basic Mechanisms and Evidence Based Clinical Use* (Vol. 2). CRC Press.

Bai, X., Aimila, A., Aidarhan, N., Duan, X., & Maiwulanjiang, M. (2020). Chemical constituents and biological activities of essential oil from *Mentha longifolia*: effects of different extraction methods *International Journal of Food Properties*, *23*(1), 1951-1960.

Baka, Z. A. M. (2010). Antifungal activity of six Saudi medicinal plant extracts against five phyopathogenic fungi *Archives of Phytopathology and Plant Protection*, *43*(8), 736-743.

Başer, K. H. C., Kürkçüoğlu, M., Demirci, B., & Özek, T. (2003). The essential oil of *Origanum syriacum* L. var. *sinaicum* (Boiss.) letswaart *Flavour and Fragrance Journal*, *18*(2), 98-99.

Begum, A., Sandhya, S., Vinod, K. R., Reddy, S., & Banji, D. (2013). An in-depth review on the medicinal flora Rosmarinus officinalis (Lamiaceae) *Acta scientiarum polonorum Technologia alimentaria*, *12*(1), 61-74.

Bendif, H., Ben Miri, Y., Souilah, N., Benabdallah, A. and Miara, M. D. (2021). Phytochemical constituents of Lamiaceae family. *Rhazes: Green and Applied Chemistry*. 11 (2): 71-88.

Bordbar, F., & Upson, T. M. (2021). Taxonomic review and phylogenetic investigations of Lavandula from Iran and Oman *Edinburgh Journal of Botany*, *78*.

Borges, R. S., Ortiz, B. L. S., Pereira, A. C. M., Keita, H., & Carvalho, J. C. T. (2019). Rosmarinus officinalis essential oil: A review of its phytochemistry, anti-inflammatory activity, and mechanisms of action involved *Journal of ethnopharmacology*, *229*, 29-45.

Boudjelal, A., Henchiri, C., Siracusa, L., Sari, M., & Ruberto, G. (2012). Compositional analysis and in vivo anti-diabetic activity of wild Algerian *Marrubium vulgare* L. infusion *Fitoterapia*, *83*(2), 286-292.

Bousmaha, L., Boti, J. B., Bekkara, F. A., Castola, V., & Casanova, J. (2006). Infraspecific chemical variability of the essential oil of *Lavandula dentata* L. from Algeria *Flavour and Fragrance Journal*, *21*(2), 368-372.

Bruno, M., Mellerio, G., Piozzi, F., & Vita-Finzi, P. (1985). GC-MS analysis of the essential oil of Meriandra benghalensis. In *Essential oils and aromatic plants* (pp. 151-154). Springer.

Chaudhary, S. A. (2001). *Flora of the Kingdom of Saudi Arabia* (Vol. 2), Part 2. Ministry of Agriculture and Water, Riyadh.*Vol. 2* (2), 309-418.

Chomchalow, N. (2002). Production of Aromatic Plants in Asia - An Overview. *Assumption University Journal of Technology*. 6(2): 95-108.

Christaki, E., Bonos, E., Giannenas, I. and Florou-Paneri, P. (2012). Aromatic Plants as a Source of Bioactive Compounds. *Agriculture. 2:* 228-243. https://doi.org/10.3390/agriculture2030228.

De Britto, A. J, Sebastian, S. R., Mary Sujin, R. (2012). Antibacterial activity of selected species of Lamiaceae against human pathogens. *Indian Journal of Natural Products and Resources*. 3(3):334-342.

De Jesus, R. A. P., Cechinel-Filho, V., Oliveira, A. E., & Schlemper, V. (2000). Analysis of the antinociceptive properties of marrubiin isolated from Marrubium vulgare *Phytomedicine*, *7*(2), 111-115.

De Souza, M. M., De Jesus, R. A. P., Cechinel-Filho, V., & Schlemper, V. (1998). Analgesic profile of hydroalcoholic extract obtained from Marrubium vulgare *Phytomedicine*, *5*(2), 103-107.

Demoz, M. S., Gachoki, K. P., Mungai, K. J., & Negusse, B. G. (2015). Evaluation of the anti-diabetic potential of the methanol extracts of aloe camperi, meriandra dianthera and a polyherb *Journal of Diabetes Mellitus*, *5*(04), 267.

Dob, T., Dahmane, D., Tayeb, B., & Chelghoum, C. (2005). Chemical composition of the essential oil of *Lavandula dentata* L. from Algeria *International Journal of Aromatherapy*, *15*(2), 110-114.

El-Hela, A. A. (2007). Chemical composition and biological studies of the essential oil of Thymus decussatus benth growing in Egypt *Egyptian Journal of Biomedical Sciences*, *23*, 146-153.

El-Said, H., Ashgar, S. S., Bader, A., AlQathama, A., Halwani, M., Ascrizzi, R., & Flamini, G. (2021). Essential Oil Analysis and Antimicrobial Evaluation of Three Aromatic Plant Species Growing in Saudi Arabia. *Molecules*, *26*(4).

El-Shabasy A., (2016). Survey on medicinal plants in the flora of Jizan Region, Saudi Arabia. International Journal of Botany Stusdies.

El Abdali, Y., Agour, A., Allali, A., Bourhia, M., El Moussaoui, A., Eloutassi, N., Salamatullah, A. M., Alzahrani, A., Ouahmane, L., Aboul-Soud, M. A. M., Giesy, J. P., & Bouia, A. (2022). *Lavandula dentata* L.: Phytochemical Analysis, Antioxidant, Antifungal and Insecticidal Activities of Its Essential Oil. *Plants*, *11*(3).

El Gendy, A. N., Leonardi, M., Mugnaini, L., Bertelloni, F., Ebani, V. V., Nardoni, S., Mancianti, F., Hendawy, S., Omer, E., & Pistelli, L. (2015). Chemical composition and antimicrobial activity of essential oil of wild and cultivated Origanum syriacum plants grown in Sinai, Egypt *Industrial Crops and Products*, *67*, 201-207.

Elansary, H. O., Szopa, A., Kubica, P., Ekiert, H., El-Ansary, D. O., Al-Mana, F. A., & Mahmoud, E. A. (2020). Saudi *Rosmarinus officinalis* and *Ocimum basilicum* L. Polyphenols and Biological Activities. *Processes*, *8*(4).

Elberry, A. A., Harraz, F. M., Ghareib, S. A., Gabr, S. A., Nagy, A. A., & Abdel-Sattar, E. (2015). Methanolic extract of *Marrubium vulgare* ameliorates hyperglycemia and dyslipidemia in streptozotocin-induced diabetic rats *International journal of diabetes mellitus*, *3*(1), 37-44.

El-Daji, A. (1996). Encyclopédie des plantes médicinales et aromatiques European Pharmacopoeia, 2007. Direct. Qual. Med. Counc. Eur. (EDQM), Strasbourg.

Fernández, L. F., Palomino, O. M., & Frutos, G. (2014). Effectiveness of *Rosmarinus officinalis* essential oil as antihypotensive agent in primary hypotensive patients and its influence on health-related quality of life *Journal of ethnopharmacology*, *151*(1), 509-516.

Figuérédo, G., Cabassu, P., Chalchat, J.-C., & Pasquier, B. (2005). Studies of Mediterranean oregano populations—V. Chemical composition of essential oils of oregano: *Origanum syriacum* L. var. *bevanii* (Holmes) Ietswaart, *O. syriacum* L. var. sinaicum (Boiss.) Ietswaart, and O. syriacum L. var. syriacum from Lebanon and Israel *Flavour and Fragrance Journal*, *20*(2), 164-168.

Flamini, G., Cioni, P. L., Morelli, I., & Bader, A. (2007). Essential oils of the aerial parts of three Salvia species from Jordan: *Salvia lanigera*, *S. spinosa* and *S. syriaca Food chemistry*, *100*(2), 732-735.

Gazzani M (2021). Antioxidant and antimicrobial activities of aromatic plants. *Medicinal & Aromatic Plants journal*. 10(422):1-2.

Ghrefat, (2011). Causes, impacts, extent, and control of desertification. Chapter 5. King Saud University, Department of Geology and Geophysics, Saudi Arabia, *Nova Science Publishers, Inc.*

Giuliani, C., Bottoni, M., Ascrizzi, R., Milani, F., Papini, A., Flamini, G., & Fico, G. (2020). Lavandula dentata from Italy: Analysis of Trichomes and Volatiles *Chemistry & Biodiversity*, *17*(11), e2000532.

Gulluce, M., Sahin, F., Sokmen, M., Ozer, H., Daferera, D., Sokmen, A., Polissiou, M., Adiguzel, A., & Ozkan, H. (2007). Antimicrobial and antioxidant properties of the essential oils and methanol extract from *Mentha longifolia* L. ssp. longifolia *Food chemistry*, *103*(4), 1449-1456.

Gupta, A. K., Tomar, J. M. S., Kaushal, R., Kadam, D. M., Rathore, A. C., Mehta, H., & Ojasvi, P. R. (2021). Aromatic plants based environmental sustainability with special reference to degraded land management *Journal of Applied Research on Medicinal and Aromatic Plants*, *22*, 100298.

Hajlaoui, H., Trabelsi, N., Noumi, E., Snoussi, M., Fallah, H., Ksouri, R., & Bakhrouf, A. (2009). Biological activities of the essential oils and methanol extract of tow cultivated mint species (*Mentha longifolia* and *Mentha pulegium*) used in the Tunisian folkloric medicine *World Journal of Microbiology and Biotechnology*, *25*(12), 2227-2238.

Hashem, H. A. E. A., & Hegab, R. H. (2018). Effect of magnetic water and ascorbic acid on the productivity of *Lavandula pubescens* Decne and nutrients availability in soil under Siwa Oasis conditions *Middle East Journal of Agriculture Research*, *7*(3), 1072-1089.

Hassanpouraghdam, M. B., Ghorbani, H., Esmaeilpour, M., Alford, M. H., Strzemski, M., & Dresler, S. (2022). Diversity and Distribution Patterns of Endemic Medicinal and Aromatic Plants of Iran: Implications for Conservation and Habitat Management. *International Journal of Environmental Research and Public Health*, *19*(3).

Herrera-Arellano, A., Aguilar-Santamaria, L., Garcia-Hernandez, B., Nicasio-Torres, P., & Tortoriello, J. (2004). Clinical trial of *Cecropia obtusifolia* and *Marrubium vulgare* leaf extracts on blood glucose and

serum lipids in type 2 diabetics *Phytomedicine*, *11*(7-8), 561-566.

Hosni, H. A., & Hegazy, A. K. (1996). Contribution to the flora of Asir, Saudi Arabia *Candollea*, *51*, 169-202.

Ibrahim, L., Karaky, M., Ayoub, P., El Ajouz, N., & Ibrahim, S. (2012). Chemical composition and antimicrobial activities of essential oil and its components from Lebanese *Origanum syriacum* L *Journal of Essential Oil Research*, *24*(4), 339-345.

Ibrahim, M. E., El-Sawi, S. A., Aziz, E. E., & Ibrahim, F. M. (2013). Chemical Composition and Antimicrobial Activity of the Essential Oil of S*alvia langiera* Poir. Herbs Growing Wild in Egypt *World Applied Sciences Journal*, *26*(4), 427-432.

Justus, B., Almeida, V. P. d., Gonçalves, M. M., Assunção, D. P. d. S. F. d., Borsato, D. M., Arana, A. F. M., Maia, B. H. L. N. S., Paula, J. d. F. P. d., Budel, J. M., & Farago, P. V. (2018). Chemical composition and biological activities of the essential oil and anatomical markers of *Lavandula dentata* L. cultivated in Brazil *Brazilian Archives of Biology and Technology*, *61*.

Kadri, A., Zarai, Z., Békir, A., Gharsallah, N., Damak, M., & Gdoura, R. (2011). Chemical composition and antioxidant activity of *Marrubium vulgare* L. essential oil from Tunisia *African journal of Biotechnology*, *10*(19), 3908-3914.

Kakhky, A. M., Rustaiyan, A., Masoudi, S., Tabatabaei-Anaraki, M., & Salehi, H.-R. (2009). Composition of the Essential oil of *Perovskia abrotanoides* Karel. and *Mentha longifolia* L. from Iran *Journal of Essential Oil Bearing Plants*, *12*(2), 205-212.

Kaushik, A., Aron, A., Mihreteab, S., Mohamedkassm, N., & Kidane, E. M. (2015). Phytochemical screening and antimicrobial activity of medicinal plants used by Eritrean traditional healers *World Journal of Pharmaceutical Research*, *4*(4), 501-509.

Khalifa, N., & Yousef, L. F. (2015). A short report on changes of quality indicators for a sandy textured soil after treatment with biochar produced from fronds of date palm *Energy Procedia*, *74*, 960-965.

Khan, M., Al-Saleem, M. S. M., & Alkhathlan, H. Z. (2016). A detailed study on chemical characterization of essential oil components of two *Plectranthus* species grown in Saudi Arabia *Journal of Saudi Chemical Society*, *20*(6), 711-721.

Khan, M. N., Mobin, M., Abbas, Z. K., & Almutairi, K. A. (2016). Impact of varying elevations on growth and activities of antioxidant enzymes of some medicinal plants of Saudi Arabia *Acta Ecologica Sinica*, *36*(3), 141-148.

Khoury, M., Stien, D., Eparvier, V., Ouaini, N., & El Beyrouthy, M. (2016). Report on the Medicinal Use of Eleven *Lamiaceae* Species in Lebanon and Rationalization of Their Antimicrobial Potential by Examination of the Chemical Composition and Antimicrobial Activity of Their Essential Oils *Evidence-Based Complementary and Alternative Medicine*, *2016*, 2547169.

Kim, A., & van der Beek, H. (2018). A holistic assessment of the water-for-agriculture dilemma in the Kingdom of Saudi Arabia *CIRS Occasional Papers*(19).

Kokate, C. K., Purohit, A. P., & Gokhale, S. B. (2010). Pharmacognosy Vol. I & II *Nirali Prakashan, Pune, Appendix A1-A6*.

Ljubuncic, P., Dakwar, S., Portnaya, I., Cogan, U., Azaizeh, H., & Bomzon, A. (2006). Aqueous Extracts of Teucrium polium Possess Remarkable Antioxidant Activity In Vitro *Evidence-Based Complementary and Alternative Medicine*, *3*, 436479.

Lodhi, S., Vadnere, G. P., Sharma, V. K., & Usman, M. R. (2017). Marrubium vulgare L.: A review on phytochemical and pharmacological aspects *J. Intercult. Ethnopharmacol*, *6*(4), 429-452.

Mandaville J. P. (1990). Flora of Eastern Saudi Arabia. London and New York.

Martins, R. d. P., Gomes, R. A. d. S., Malpass, A. C. G., & Okura, M. H. (2019). Chemical characterization of *Lavandula dentata* L. essential oils grown in Uberaba-MG *Ciência Rural*, *49*.

Masoodi, M. H., Ahmed, B., Zargar, I. M., Khan, S. A., Khan, S., & Singh, P. (2008). Antibacterial activity of whole plant extract of *Marrubium vulgare African journal of Biotechnology*, *7*(2).

Melito, S., Petretto, G. L., Chahine, S., Pintore, G., & Chessa, M. (2019). Seasonal Variation of Essential Oil in *Rosmarinus officinalis* Leaves in Sardinia *Natural Product Communications*, *14*(7), 1934578X19864005.

Meyre-Silva, C., Yunes, R. A., Schlemper, V., Campos-Buzzi, F., & Cechinel-Filho, V. (2005). Analgesic potential of marrubiin derivatives, a bioactive diterpene present in *Marrubium vulgare (Lamiaceae) Il Farmaco, 60(4), 321-326.*

Mikaili, P., Mojaverrostami, S., Moloudizargari, M., & Aghajanshakeri, S. (2013). Pharmacological and therapeutic effects of *Mentha Longifolia* L. and its main constituent, menthol *Ancient science of life*, *33*(2), 131.

Mkaddem, M., Bouajila, J., Ennajar, M., Lebrihi, A., Mathieu, F., & Romdhane, M. (2009). Chemical Composition and Antimicrobial and Antioxidant Activities of *Mentha* (*longifolia* L. and *viridis*) Essential Oils *Journal of Food Science*, *74*(7), M358-M363.

Mossi, A. J., Cansian, R. L., Paroul, N., Toniazzo, G., Oliveira, J. V., Pierozan, M. K., Pauletti, G., Rota, L., Santos, A. C. A., & Serafini, L. A. (2011). Morphological characterisation and agronomical parameters of different species of *Salvia* sp.(Lamiaceae) *Brazilian Journal of Biology*, *71*, 121-129.

Mothana, R. A., Nasr, F. A., Khaled, J. M., Al-Zharani, M., Noman, O. M., Abutaha, N., Al-Rehaily, A. J., Almarfadi, O. M., Kumar, A., & Kurkcuoglu, M. (2019). Analysis of Chemical Composition and Assessment of Cytotoxic, Antimicrobial, and Antioxidant Activities of the Essential Oil of *Meriandra dianthera* Growing in Saudi Arabia. *Molecules*, *24*(14).

Nacéra, B., Nassima, B., Chahrazed, B., & Xavier, F. (2013). Chemical analysis and antimicrobial activity of *Teucrium polium* L. essential oil from Western Algeria *Journal of Medicinal Plants Research*, *7*(14), 897-902.

Nagy, M., & Svajdlenka, E. (1998). Comparison of Essential Oils from *Marrubium vulgare* L. and *M. peregrinum* L *Journal of Essential Oil Research*, *10*(5), 585-587.

Nahak, G., Mishra, R. C., & Sahu, R. K. (2011). Taxonomic distribution, medicinal properties and drug development potentiality of *Ocimum* (Tulsi) *Drug Invention Today*, *3*(6).

Najafian, S., Rowshan, V., & Fathi, S. (2020). Comparison of Chemical Constituents of Essential Oil from Aerial Constituent of *Mentha longifolia* and *Salvia multicaulis* Obtained by Hydro distillation and Headspace Analysis *Journal of Essential Oil Bearing Plants*, *23*(4), 719-727.

Najmadeen, H. H. M. A. O. M.-A. H. H. (2010). Effects Of Soil Texture On Chemical Compositions, Microbial Populations And Carbon Mineralization In Soil *Egypt. J. Exp. Biol. (Bot.)*, *6*(1), 59.

Nawwar, M. A. M., El-Mousallamy, A. M. D., Barakat, H. H., Buddrus, J., & Linscheid, M. (1989). Flavonoid lactates from leaves of *Marrubium* vulgare *Phytochemistry*, *28*(11), 3201-3206.

Nazar, N., Howard, C., Slater, A., & Sgamma, T. (2022). Challenges in Medicinal and Aromatic Plants DNA Barcoding—Lessons from the Lamiaceae. *Plants*, *11*(1).

Nikšić, H., Kovač Bešović, E., Makarević, E., & Durić, K. (2012). Chemical composition, antimicrobial and antioxidant properties of Mentha longifolia (L.) Huds. essential oil *Journal of Health Sciences*, *2*(3), 192-200.

Nuru, A., Al-Ghamdi, A. A., Tena, Y. T., Shenkut, A. G., Ansari, M. J., & Al-Maktary, A. (2015). Floral phenology, nectar secretion dynamics, and honey production potential, of two lavender species (Lavandula Dentata, and L. Pubescens) in southwestern Saudi Arabia *Journal of Apicultural Science*, *59*(2), 135-144.

Oyedeji, A. O., & Afolayan, A. J. (2006). Chemical Composition and Antibacterial Activity of the Essential Oil Isolated from South African Mentha longifolia (L.) L. subsp. capensis (Thunb.) Briq *Journal of Essential Oil Research*, *18*(sup1), 57-59.

Pandey, A. K., Singh, P., & Tripathi, N. N. (2014). Chemistry and bioactivities of essential oils of some Ocimum species: an overview *Asian Pacific Journal of Tropical Biomedicine*, *4*(9), 682-694.

Park, C. H., Park, Y. E., Yeo, H. J., Chun, S. W., Baskar, T. B., Lim, S. S., & Park, S. U. (2019). Chemical Compositions of the Volatile Oils and Antibacterial Screening of Solvent Extract from Downy Lavender. *Foods*, *8*(4).

Park, C. H., Yeo, H. J., Park, Y. E., Kim, Y. J., Park, C., Kim, J. K., & Park, S. U. (2021). Integrated Analysis of Transcriptome and Metabolome and Evaluation of Antioxidant Activities in Lavandula pubescens. *Antioxidants*, *10*(7).

Patel, R. (2021). Desertification: Description, Causes and Impacts. Quest *Journals Journal of Research in Humanities and Social Science. 9(7),*

Patonay, K., Szalontai, H., Radácsi, P., & Zámboriné-Németh, É. (2021). Chemotypes and Their Stability in Mentha longifolia (L.) L.—A Comprehensive Study of Five Accessions. *Plants*, *10*(11).

Perveen, S., & Al-Taweel, A. (2019). *Pharmacognosy: Medicinal Plants*. BoD–Books on Demand.

Pukalskas, A., Venskutonis, P. R., Salido, S., de Waard, P., & van Beek, T. A. (2012). Isolation, identification and activity of natural antioxidants from horehound (Marrubium vulgare L.) cultivated in Lithuania *Food chemistry*, *130*(3), 695-701.

Qwarse, M., & Sempombe, J. (2017). Cytotoxicity, Antibacterial and Antifungal Activities of Five Plant Species used by Agro-Pastoral Communities in Mbulu District, Tanzania *International Journal of Research in Pharmacy and Chemistry*, *7*(1), 1-14.

Rashed, M. M. A., Ghaleb, A. D. S., Li, J., Nagi, A., Hua-wei, Y., Wen-you, Z., & Tong, Q. (2018). Enhancement of Mass Transfer Intensification for Essential Oil Release from Lavandula pubescence Using Integrated Ultrasonic-Microwave Technique and Enzymatic Pretreatment *ACS Sustainable Chemistry & Engineering*, *6*(2), 1639-1649.

Rašković, A., Milanović, I., Pavlović, N., Ćebović, T., Vukmirović, S., & Mikov, M. (2014). Antioxidant activity of rosemary (Rosmarinus officinalis L.) essential oil and its hepatoprotective potential *BMC Complementary and Alternative Medicine*, *14*(1), 225.

Rezgui, M., Majdoub, N., Mabrouk, B., Baldisserotto, A., Bino, A., Kaab, L. B. B., & Manfredini, S. (2020). Antioxidant and antifungal activities of marrubiin, extracts and essential oil from Marrubium vulgare L. against pathogenic dermatophyte strains *Journal de Mycologie Médicale*, *30*(1), 100927.

Sahpaz, S., Garbacki, N., Tits, M., & Bailleul, F. (2002). Isolation and pharmacological activity of phenylpropanoid esters from Marrubium vulgare *Journal of ethnopharmacology*, *79*(3), 389-392.

Saleh, I., Abd-ElGawad, A., El Gendy, A. E.-N., Abd El Aty, A., Mohamed, T., Kassem, H., Aldosri, F., Elshamy, A., & Hegazy, M.-E. F. (2020). Phytotoxic and antimicrobial activities of Teucrium polium and Thymus decussatus essential oils extracted using hydrodistillation and microwave-assisted techniques *Plants*, *9*(6), 716.

Samarth, R. M., Samarth, M., & Matsumoto, Y. (2017). Medicinally important aromatic plants with radioprotective activity *Future Science OA*, *3*(4), FSO247.

Schlemper, V., Ribas, A., Nicolau, M., & Cechinel Filho, V. (1996). Antispasmodic effects of hydroalcoholic extract of Marrubium vulgare on isolated tissues *Phytomedicine*, *3*(2), 211-216.

Shaheen, U., Khalik, K. A., Abdelhady, M. I. S., Howladar, S., Alarjah, M., & Abourehab, M. A. S. (2017). HPLC profile of phenolic constituents, essential oil analysis and antioxidant activity of six Plectranthus species growing

in Saudi Arabia *Journal of Chemical and Pharmaceutical Research*, *9*(4), 345-354.

Shamseddine, L., & Chidiac, J. J. (2021). Composition's effect of Origanum Syriacum essential oils in the antimicrobial activities for the treatment of denture stomatitis *Odontology*, *109*(2), 327-335.

Singh, N., Singh, H. P., Batish, D. R., Kohli, R. K., & Yadav, S. S. (2020). Chemical characterization, phytotoxic, and cytotoxic activities of essential oil of Mentha longifolia *Environmental Science and Pollution Research*, *27*(12), 13512-13523.

Stulzer, H. K., Tagliari, M. P., Zampirolo, J. A., Cechinel-Filho, V., & Schlemper, V. (2006). Antioedematogenic effect of marrubiin obtained from Marrubium vulgare *Journal of ethnopharmacology*, *108*(3), 379-384.

Tafrihi, M., Imran, M., Tufail, T., Gondal, T. A., Caruso, G., Sharma, S., Sharma, R., Atanassova, M., Atanassov, L., Valere Tsouh Fokou, P., & Pezzani, R. (2021). The Wonderful Activities of the Genus Mentha: Not Only Antioxidant Properties. *Molecules*, *26*(4).

Takayama, C., de-Faria, F. M., de Almeida, A. C. A., Dunder, R. J., Manzo, L. P., Socca, E. A. R., Batista, L. M., Salvador, M. J., Souza-Brito, A. R. M., & Luiz-Ferreira, A. (2016). Chemical composition of Rosmarinus officinalis essential oil and antioxidant action against gastric damage induced by absolute ethanol in the rat *Asian Pacific Journal of Tropical Biomedicine*, *6*(8), 677-681.

Tenore, G. C., Ciampaglia, R., Arnold, N. A., Piozzi, F., Napolitano, F., Rigano, D., & Senatore, F. (2011). Antimicrobial and antioxidant properties of the essential oil of Salvia lanigera from Cyprus *Food and Chemical Toxicology*, *49*(1), 238-243.

Thomas, J. (2020). Onward (continuously updated). Plant diversity of Saudi Arabia, King Saud University. Website: (http://plantdiversityofsaudiarabia.info/Biodiversity-Saudi-Arabia/Flora/Checklist/Cheklist.htm).

Venkateshappa, S. M. and Streenath, K. P. (2013). Potential medicinal plants of Lamiaceae. American International Journal of Research in Formular. 3(1): 82-87.

Verma, R. S., Padalia, R. C., Chauhan, A., Upadhyay, R. K., & Singh, V. R. (2020). Productivity and essential oil composition of rosemary (Rosmarinus officinalis L.) harvested at different growth stages under the subtropical region of north India *Journal of Essential Oil Research*, *32*(2), 144-149.

Verma, R. S., Pandey, V., Chauhan, A., & Tiwari, R. (2015). Essential Oil Composition of Mentha longifolia (L.) L. Collected from Garhwal Region of Western-Himalaya *Journal of Essential Oil Bearing Plants*, *18*(4), 957-966.

Vicenço, C. B., Silvestre, W. P., Menegol, I. V., Carraro, M. C., & Pauletti, G. F. (2022). Insecticidal Activity of Lavandula dentata L. Essential Oil on Anticarsia gemmatalis (Hübner, 1818) *Brazilian Archives of Biology and Technology*, *64*.

Wagner, L. S., Sequin, C. J., Foti, N., & Campos-Soldini, M. P. (2021). Insecticidal, fungicidal, phytotoxic activity and chemical composition of Lavandula dentata essential oil *Biocatalysis and Agricultural Biotechnology*, *35*, 102092.

Waqas, M., Nizami, A. S., Aburiazaiza, A. S., Barakat, M. A., Rashid, M. I., & Ismail, I. M. I. (2018). Optimizing the process of food waste compost and valorizing its applications: A case study of Saudi Arabia *Journal of Cleaner Production*, *176*, 426-438.

Weel, K. G. C., Venskutonis, P. R., Pukalskas, A., Gruzdiene, D., & Linssen, J. P. H. (1999). Antioxidant activity of horehound (Marrubium vulgare L.) grown in Lithuania *Lipid / Fett*, *101*(10), 395-400.

Who, G. (2007). WHO guidelines for assessing quality of herbal medicines with reference to contaminants and residues.

Ya'ni, A., Hassan, S., Elwan, Z., Ibrahim, H., & Eldahshan, O. (2018). Morphological and anatomical studies on selected Lamiaceae medicinal plants in Bani Matar District, Sana'a (Yemen) *Taeckholmia*, *38*(1), 17-39.

Yani, A. A., Eldahshan, O. A., Hassan, S. A., Elwan, Z. A., & Ibrahim, H. M. (2021). Essential Oil Composition and Antimicrobial Activities of Lavandula pubescens *Acta Scientific Pharmaceutical Sciences (ISSN: 2581-5423)*, *5*(10).

You, Y., Zhou, N., & Wang, Y. (2021). Comparative study of desertification control policies and regulations in representative countries of the Belt and Road Initiative *Global Ecology and Conservation*, *27*, e01577.

Zarai, Z., Kadri, A., Ben Chobba, I., Ben Mansour, R., Bekir, A., Mejdoub, H., & Gharsallah, N. (2011). The in-vitro evaluation of antibacterial, antifungal and cytotoxic properties of Marrubium vulgare L. essential oil grown in Tunisia *Lipids in Health and Disease*, *10*(1), 161.

Zgheib, R., Chaillou, S., Ouaini, N., Kassouf, A., Rutledge, D., El Azzi, D., & El Beyrouthy, M. (2016). Chemometric Tools to Highlight the Variability of the Chemical Composition and Yield of Lebanese Origanum syriacum L. Essential Oil *Chemistry & Biodiversity*, *13*(10), 1326-1347.