Biological Fertilization and its Effect on Selected Aromatic Plants

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1. Introduction

Aromatic crops play a pivotal role in mankind daily life as important flavoring agents in foods, beverages (Sarim, 2016) and pharmaceuticals (Bano et al., 2017) and also as ingredients in perfumes and cosmetics (Talal and Feda, 2003). Herbal medicines are currently in demand and their popularity is increasing day by day (Manish et al., 2010).

In general, aromatic crops is showing different promising biological activities. These activities can include protection from and/or alleviation of some ailment, which is supported with different proposed mechanisms of action (Marek et al., 2020). Therefore, quality is one of the most important and critical factors in aromatic crops. In order to reach this high quality, Promotion ecologically sound plant protection measures is highly suggested such as bio-management (Peter, 2006).

Global concerns about degradation of land resources and maintaining natural ecosystems, beside particular attention to the soils which are the bases of agricultural systems, these were clearly expressed in the World Conservation Strategy (IUCN, 1980). Moreover, the most important constraint limiting crop yield in developing nations worldwide, and especially among resource-poor farmers, is soil infertility. Therefore, maintaining soil quality can reduce this problems , utilization of bio-fertilizers is considered as a promising alternative, particularly for these developing countries (Khalid , 2012).

A biological fertilizer (also bio-fertilizer) is a substance which contains living microorganisms, when applied to seed, plant surfaces, or soil colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant (Vessey , 2003).

Soil microorganisms represent important component in the evaluation of soil quality used as biological indicator or as sustainability index for production systems. Therefore, emphasis is now laid on the use of bio fertilizers in the crop production like biological nitrogen fixers (*Azotobacter/ Azospirillum /Rhizobium*) and phosphate solubilizing bacteria (PSB). These bio fertilizers improve crop production by supplying nutrients, producing vitamins such as thiamine and riboflavin and plant hormones viz., indole acetic acid (IAA) and gibberellins (GA) (Bao et al., 2015).

However, the current use of microorganisms in agriculture remains at a low level despite the significant investment in scientific work to understand and use natural microbial resources to improve plant growth and quality. Keeping above facts in view, this chapter will demonstrate the biological potential of selected aromatic plants, discussing the effect of bio-fertilizers on growth, yield and quality of essential oil of these selected plants trying to address its effective implementation on these aspects.

2. Biological Activity of Aromatic Plants

Nowadays because of the emergence of drug resistant strains of pathogens from one side and increasing the prices of medicine due to war and sanctions, people have motivated to use the complementary and alternative therapies, and a strong trend has emerged to study natural sources for biologically active extracts that can be integrated with synthetic drugs in the production of more effective and safer medication, the following will focus on biological activities of some selected aromatic plants for potential use as possible means to treat different disease.

2.1. Davana (Artemisia pallens Wall.)

Davana (*Artemisia pallens* Wall.) is a small herbaceous aromatic plant belonging to *Asteraceae* family, it is native to the southern part of India, Its leaves and flowers are utilized in traditional Ayurveda medicinal preparation (Prasannakumar et al., 2011). The essential oil of davana is obtained by hydro-distillation from newly blossoming flowers (Mallavarapu et al., 1999), and its major constituents are davanone, linalool (Z)- and (E)-methyl cinnamate, (E)-ethyl cinnamate, bicyclogermacrene, davana ether, 2-hydroxyisodavanone, and farnesol (Gopal et al., 1999). Artemisinin is largely obtained from *A. annua* plant, and its main antimalarial compound (Aidah et al., 2018).

Artemisia species are used for the treatment of diseases such as malaria, hepatitis, cancer (Luigi et al., 2015) and its essential oils have been largely employed for their antiseptic properties.

- Antimicrobial Activities

An essential oil sample of davana (*Artemisia pallens* Wall. ex DC.) were investigated by (Stefanie et al., 2008) and it showed antimicrobial activities against *Staphylococcus aureus*, *Pseudomonas aeruginosa, Salmonella enterica* subsp. *enterica* and the yeast *Candida albicans*.

- Antifungal Activities

The anti-fungal constituents from Artemisia species include flavonoids, polyacetylenes, and sesquiterpenes, it have been found to exhibit antifungal activity against plant and human pathogenic fungi (Tan et al.,1998) .

- Anti-malaria Activities

Artemisinin and its derivatives have been highlighted for their potent activity against species of *Plasmodium* genus responsible for malaria, as well as in the treatment of leishmaniasis, schistosomia-sis and trypanomiasis (Antoaneta et al., 2021)

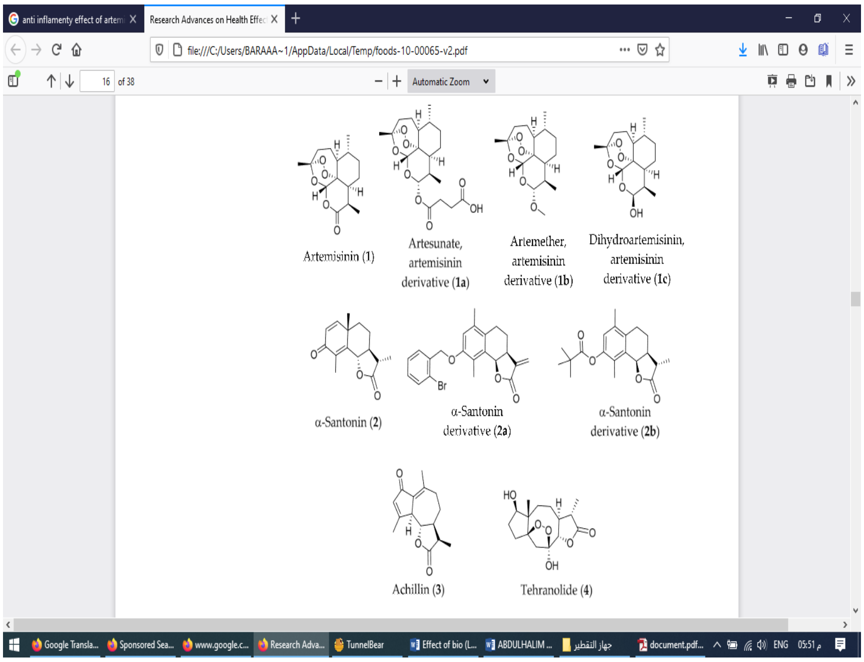

Figure 1. Chemical Structures of Some Sesquiterpene Lactones Constituents of Edible Artemisia sp. and Derivatives with Pharmacological Relevance. (Antoaneta et al., 2021)

2.2. Sweet Flag (Acorus Calamus)

Sweet flag (*Acorus calamus*) is an aromatic plant belonging to *Acoraceae* family, indigenous to Central Asia, Europe and North America, its rhizome is reported to contain active compounds potential therapeutic properties (Wilczewska et al., 2008). The essential oils of Sweet flag is obtained from leaves and rhizomes and have great variation in chemical composition. According to (Rimantas, 2003) β-Asarone and α-asarone were the major constituents in the rhizome oil, while β-asarone and linalool were the major constituents in the leaf oil. In the following some of its biological proprieties:

- Neuro-protective activity

Asarones isolated from Sweet flag have been evaluated for their neuro-protective properties, α and β asarone have been found to inhibit the toxicity induced by the N-Methyl-D-Aspartate in primary cortical cultures through the blockade of NMDA receptor function (Mythili et al., 2013)

- Sedative and hypnotic effect

β.-Asarone compound in volatile oils of Sweet flag showed potentiation of the sedative activity, the hypnotic potentiating action might be mediated through serotonin and catecholamines (Pulok et al., 2007) .

- Antioxidant activity

α.-Asarone had an effective protective role by normalizing the increased superoxide dismutase (SOD) and lipid peroxidation (LPO), and decreasing catalase (CAT), glutathione peroxidase (GPx) , glutathione (GSH) , vitamins C and E, and protein thiols due to noise exposure. (Manikandan & Devi ,2005).

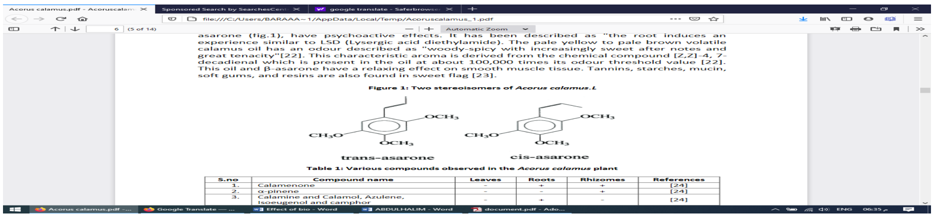

Figure 2. Two Stereoisomers of *Acorus Calamus*.L (Mythili et al., 2013)

2.3. Patchouli (Pogostemon Cablin Benth)

Patchouli (*Pogostemon cablin* Benth) is a perennial herbaceous plant belonging to *Lamiaceae* family, native to Philippines and growing wild in Malaysia, Indonesia, Singapore, China and India has been reputed for it's their sweet smelling leaves (Yogesh & Pawan, 2005). The essential oil of Patchouli is obtained by steam distillation or hydro distillation of the dried leaves. Patchouli alcohol is the major components of the oil, with other components such as Delta-Guaiene , Azulene , Trans Caryophellene , Seychellence (CAS) Nephtalene , Cycloheptane and Caryophyllene (Ermaya et al., 2019). These chemical components possess a wide range of biological activities, in the following some of the therapeutic benefits attributed to its aromatic oil:

- Improving Metabolic Parameters

A study by (Seong et al., 2020) demonstrate that the inhalation of Patchouli essential oil influenced certain markers related to metabolic diseases, may assist in regulating blood pressure.

- Antimicrobial Activities

H. pylori is a Gram-negative bacterial species that colonizes the gut of ~50% of the human population worldwide, Patchouli alcohol is a critical pharmacological agent isolated from patchouli that exhibits antimicrobial activity against H. pylori both in vitro and in vivo (Junren et al., 2021).

- Anti-oxidative Effect

According to (Bhanuz et al., 2017) P. cablin extracts contain antioxidant properties that should be exploited for possible clinical application. That it showed moderate inhibition of superoxide inhibition (O_2) and nitric oxide (NO) production in concentration-dependent manner

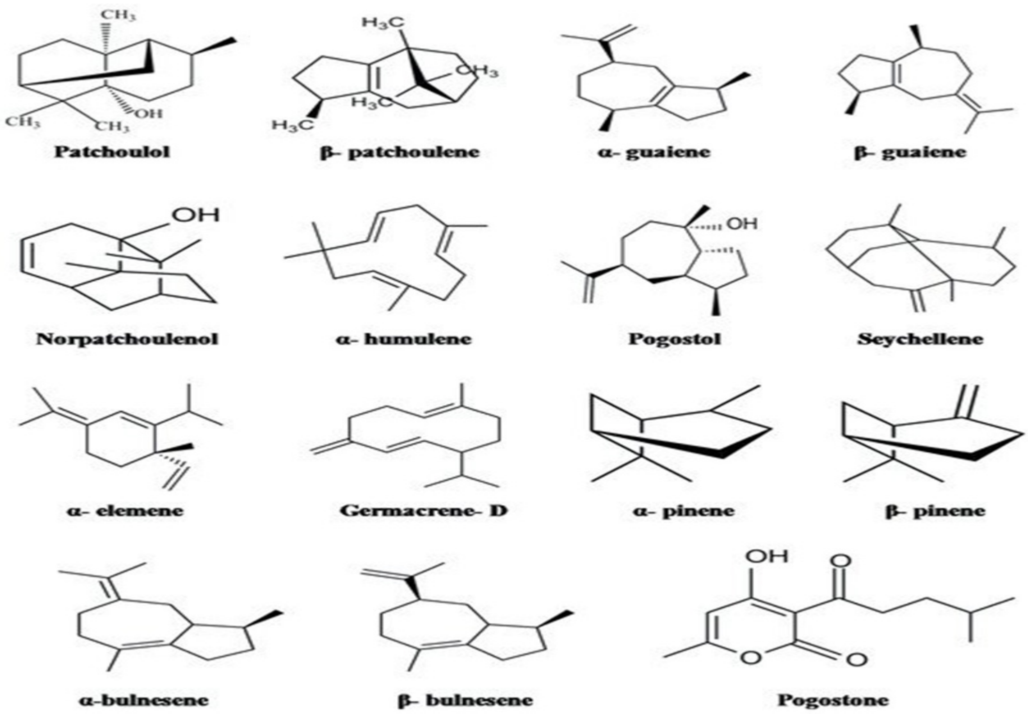

Figure 3. The Structures of Some of the Volatile Chemical Constituents of PO (Mallappa and Uma 2015)

2.4. Lemon Grass (Cymbopogon Citratus)

Lemon grass (*Cymbopogon citratus*) is an aromatic plant belonging to *Gramineae* family the plant is a native herb from India and is cultivated in other tropical and subtropical countries. (Figueirinha et al., 2008). Plants are utilized as therapeutic agents since time immemorial in both organized (Ayurveda, Unani) and unorganized (folk, tribal, native) form (Vanisha, 2012). The essential oil of Lemongrass is obtained by hydro distillation of the dried leaves, geranial (citral-a), neral (citral-b) and myrcene are considered the main components (Mohamed et al., 2012). and here is some studies about health benefits of lemon grass based on its most important chemical components:

- Anti-oxidant properties

Oxidation is a fundamental process in human cells, tissue and systems leading to formation of reactive oxygen species (ROSs). Sharma and Bhat, 2009 identified antioxidant potentials of lemongrass extracts and documented their abilities to reduce ROSs. Such mechanism include inhibition of lipoperoxidation and decolorization of 2, 2-diphenyl-1-picrylhydrazyl (DPPH)

- Anti-inflammatory properties

Oral administration of lemongrass oil showed dose-dependent anti-inflammatory activity. In addition , topical application of oil at doses of 5 and 10mL/ear significantly reduced acute ear edema induced by croton oil in 62.5 and 75% of the mice (Mohamed et al., 2014) .

- Antibacterial properties

According to (Oluwole et al., 2019) α-citral (geranial) and β-citral (neral) are active antibacterial compounds with predominant activities against gram positive and negative bacterial isolates.

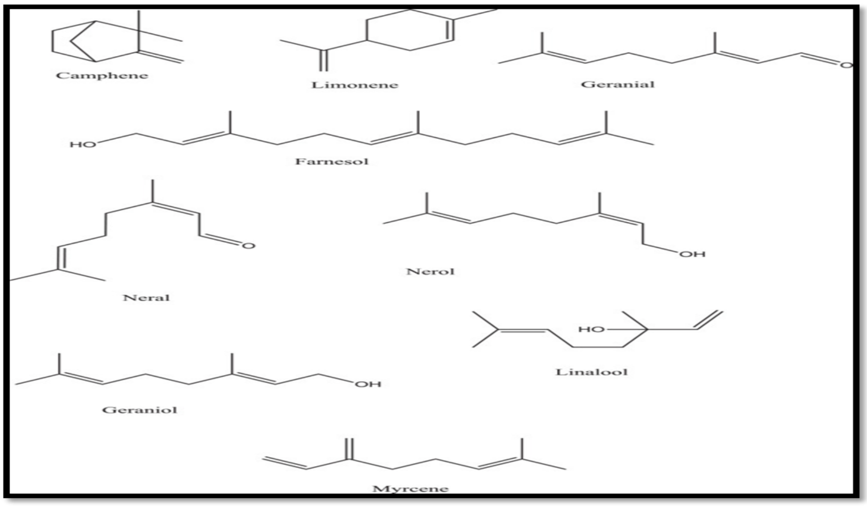

Fig. 4. Chemical Structures of Important Constituents of Lemongrass Essential oil (Oluwole et al., 2019)

2.5. Thyme (Thymus Vulgaris)

Thyme (*Thymus vulgaris*) is an aromatic and culinary herb belonging to *Lamiaceae* family, native to southern Europe from the western Mediterranean to southern Italy. Its aromatic, grey-green leaves have therapeutic characters (Miraj &. Kiani, 2016). The essential oil of thyme is obtained by hydro distillation of the dried leaves, thymol and carvacrol, are considered the main phenolic monoterpenes of it. Also, phenolic acid (rosmarinic acid) and flavonoids (quercetin, eriocitrin, luteolin and apigenin) are proposed to be the polyphenolic compounds responsible for the antioxidant effects of aqueous extracts (Kulisic et al., 2007). Several pharmacological studies have been performed on thyme, and its medicinal functions are attributed to its components, on the following some of them:

- Antimicrobial Activity

Imelouane et al. (2009) evaluated the essential oil of thyme for its antibacterial activities against six Gram-positive and Gram negative pathogenic bacteria:

Staphylococcus aureus, *S. epidermidis*, *Streptococcus sp*., *Pantoa* sp.and *Escherichia coli*, The results obtained in this study showed that the Gram-negative bacteria were more sensitive to the essential oil of thyme.

- Anti-oxidant Activity

Goncalves et al., 2017 showed that the chemical structure of the phenolic compounds of essential oil of thyme allows them to donate hydrogen to free radicals and explains their antioxidant activity.

- Anti-fungal Activity

Essential oils thyme were tested by (Soliman and Badeaa, 2002) for inhibitory activity against Aspergillus flavus, A. parasiticus, A. ochraceus and Fusarium moniliforme. The results also showed that the essential oils of thyme, have effect on fungal development and subsequent mycotoxin production in wheat grains.

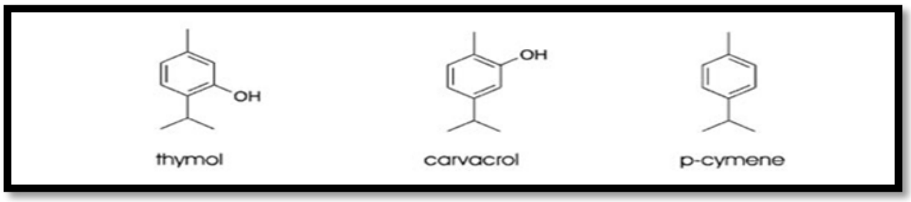

Figure 5. Chemical Structures of Most Important Compounds of Thyme Oil (Taheri et al., 2015)

2.6. Syrian oregano (Origanum syriacum L.)

Syrian oregano (*Origanum syriacum* L.) is perennial aromatic culinary herb belonging to *Lamiaceae* family, mainly native to Syria and Lebanon. Its therapeutic characters related to chemical compounds that found in its leaves (Farhat et al., 2012). The essential oil of Syrian oregano is obtained by hydro distillation of the dried leaves. The two dominant constituents identified in Syrian oregano leaves were carvacrol and thymol (Farhat, et al., 2012). In the following some of its important biological activities:

- Antimicrobial effect :

The main compounds identified in Syrian oregano oil are carvacrol and thymol. These substances are considered as antibacterial agents make the cell membrane permeable due to its impregnation in the hydrophobic domains, this effect is higher against gram positive bacteria (Rodriguez et al., 2016).

- Antioxidant effect :

Luna et al. (2010) evaluated the effects of thymol (150 mg/kg) and its isomer carvacrol (150 mg/kg) on lipid oxidation when supplemented to the feed chickens. Lipid oxidation was determined by the analysis of 2-TBA reactive substances (TBARS). After 5 and 10 days of storage, increasingly higher values of TBARS were detected in thigh samples of the control group in comparison to the supplemented groups. Interestingly, the same lower values of TBARS were detected between those feed-supplemented groups effecting positively on poultry meat quality.

- Anti-inflammatory effect :

The antioxidant activities of oregano due to its main components appear to contribute to its preventive effects against inflammatory diseases, such as stress-induced gastritis and contact hypersensitivity in mice according to (Kyoji et al., 2006).

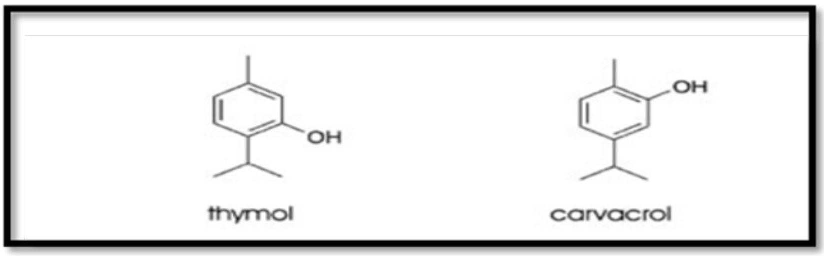

Figure 6. Chemical Structures of Most Important Compounds of Syrian Oregano Oil (Taheri et al., 2015)

2.7. Peppermint (Mentha piperita)

Peppermint (*Mentha piperita*), is perennial aromatic herb belonging to *Lamiaceae* family, growing to throughout Europe and North America. Menthol that presented in its leaves is one of its main phytochemicals that responsible for its traditional uses (Catherine et al., 2007). The essential oil of Peppermint *(Mentha piperita*) is obtained by hydro distillation of the dried leaves, menthol, menthofuran, methone and menthyl acetate are considered the main oil components (Jorge & Pedro, 2002). Peppermint could be used for various commodities of medicinal and pharmacological attributes, in the following some of its therapeutic properties:

- Antimicrobial activities

Mentha piperita L.(Peppermint oil), widely applied for microbial activity against different microbial species; Menthol is bactericidal against *Staphylococcus pyogenes*, *Staphylococcus aureus*, *Streptococcus pyogenes*, *Serratia marcescens*, *Escherichia coli*, and *Mycobacterium avium*. (Akbari et al., 2015).

- Treatment of Mental Fatigue:

Study by Toyoshi et al. (2001) determined the effects of peppermint oil on behavior in mice. The present study revealed that intraperitoneal administration of natural peppermint oil, which is used for medicinal purposes in aromatherapy, caused a significant dose dependent increase in ambulatory activity. This result demonstrated that peppermint oil produces an apparent effect on behavior in mice.

- Prevention of chronic degenerative diseases

Sandra et al. (2011) examined the effects of this plant on human biochemical and anthropometric profiles and blood pressure, based on the administration of peppermint juice twice daily for 30 days. Results indicated that 41.5% of the subjects showed a reduction in glycemia, 66.9% in total cholesterol levels, 58.5% in triacylglycerides, 52.3% in LDL-c (low-density lipoproteins) indices, 70% in GOT (glutamic-oxaloacetic transaminase) levels, 74.5% in GPT (glutamic-pyruvic transaminase) levels, and that 52% presented an increase in HDL-c (high-density lipoprotein cholesterol) indices. Also, 52.5% showed a decrease in blood pressure and 48.7% in BMI. According to these results, it could be concluded that peppermint is beneficial in the prevention and treatment of risk factors of chronic degenerative diseases.

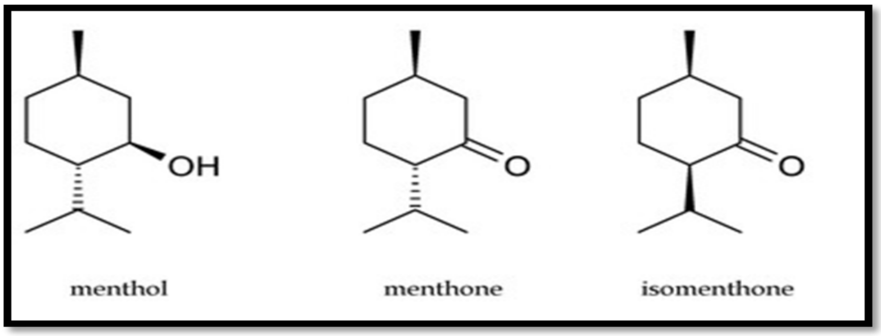

Figure 7. Chemical Structures of Some Important Compounds of Mint Essential Oil (Danuta and Agnieszka, 2020)

2.8. Sage (Salvia Officinalis L.)

Sage (*Salvia Officinalis* L.) an aromatic herb belonging to the *Lamiaceae* family grow in many parts of the world . and it was as discovered by Linneu in 1753, in the East-Mediterranean region its leaves has been used for a long time in traditional medicine to fight disease due particularly to the quantity and quality of the phenolic compounds it contains (Lemle , 2017). The essential oil of *Salvia officinalis* is isolated by hydro-distillation. The main compounds are 1, 8-cineole and camphor (Abu-Darwish et al., 2013). Several medicinal applications for Sage have been identified due to its various biomolecules, in the following some of these biological effects:

- Antibacterial activity

A study conducted on the antibacterial effect of sage against selected food spoiling bacteria in vitro indicates that the sage aqueous extract exerted significant antibacterial activity and it was most effective against *Bacillus mycoides*, *Bacillus subtilis*, *Enterobacter cloacae*, and *Proteus* sp. This has made sage essential oil a good alternative to the traditional antibiotics as well as food preservatives (Stanojevic et al., 2010).

- Memory improvement

Study was conducted by (Akhondzadeh et al., 2003) to assess the efficacy and safety of *Salvia officinalis* extract using a fixed dose (60 drops/day), in patients with mild to moderate Alzheimer's disease, over a 4-month period. The results of this study indicate the efficacy of *S. officinalis* extract in the management of mild to moderate Alzheimer's disease. That, at 4 months, *S. officinalis* extract produced a significant better outcome on cognitive functions than placebo (ADAS-cog: $F = 4.77$, d.f. = 1, $P = 0.03$) (CDR-SB: $F = 10.84$, d.f. = 1, $P < 0.003$).

- Antioxidant activity

The phenolic compounds can either stimulate endogenous antioxidant defense systems or scavenge reactive species (Mohsen et al., 2011). In a study conducted on the antioxidant activity of many plant extracts, like sage (*S. officinalis*), it was found that the phenolic and flavonoid compounds are mainly responsible for the antioxidant and free radical scavenging effects of these plants (Yadav et al., 2011).

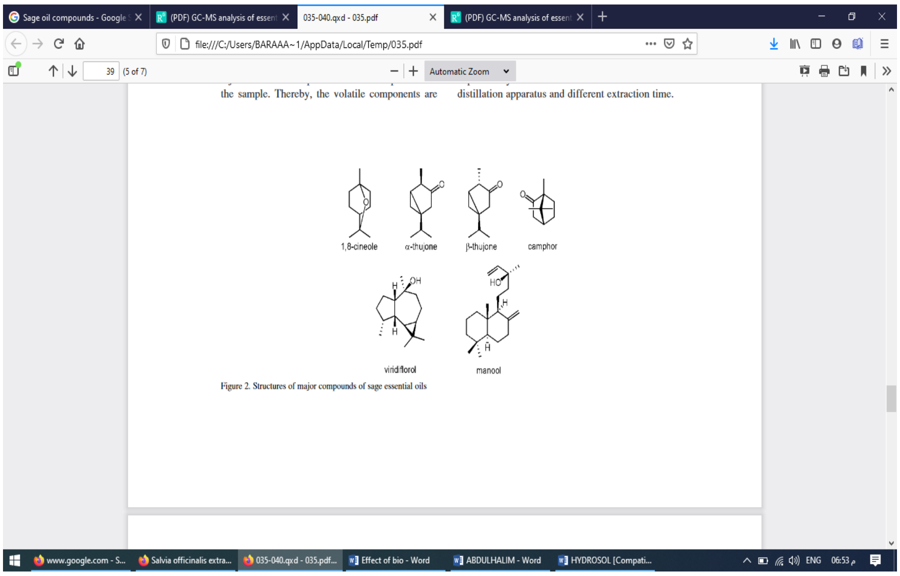

Figure 8. Chemical Structures of Some Important Compounds of Sage Essential Oil (Tomasz et al., 2013)

2.9. Lavender (Lavandula angustifolia L.)

Lavender (*Lavandula angustifolia* L.) is perennial aromatic herb belonging to the *Lamiaceae* family native to the Mediterranean, the Arabian Peninsula, Russia, and Africa. It flowers has been used cosmetically and medicinally through-out history (Ethan et al., 2014). The essential oil Lavender (*Lavandula angustifolia* L.) oil is extracted mostly from the flowers through steam distillation, and the major constituents are linalool, linalyl acetate, geraniol, β-caryophyllene, lavandulyl acetate, 1,8-cineole, limonene, trans-β-ocimene, cis-β- ocimene, 3-octanone (Krzysztof et al., 2013). Linalool is considered the primary active constituent responsible for the pharmacological effects of lavender, including its supposed calming and sedative activity (Basch et al., 2004) In the following some of Lavender biological proprieties:

- Antiviral effect :

Lavender essential oil is popular as a complementary medicine. According to (Nadjib, 2020) essential oils (EOs) and their chemical constituents are known to be active against a wide range of viruses. Oxygenated monoterpenes and sesquiterpenes present in lavender oil contribute to their antiviral effect.

- Anti-inflammatory activity.

Lavender essential oil presented anti-inflammatory activity. According to (Cardia et al. , 2018) topical application at concentrations of 0.25, 0.5, and 1 mg/ear reduced edema formation, myeloperoxidase (MPO) activity, and nitric oxide (NO) production in croton oil-induced ear edema model. In carrageenan-induced paw edema model, LEO treatment at doses of 75, 100, and 250 mg/kg reduced edema formation, MPO activity, and NO production.

- Controlling Anxiety:

Anxiety is one of the uprising psychiatric disorders of the last decades (Bandelow and Michaelis, 2015), Lavender aromatherapy reduced preoperative anxiety in ambulatory surgery patients (Wotman et al., 2017). *Lavandula angustifolia* hydrosol exhibits also revitalizing and relaxing properties when consumed in the form of an additive to water or food (Rose, 1999)

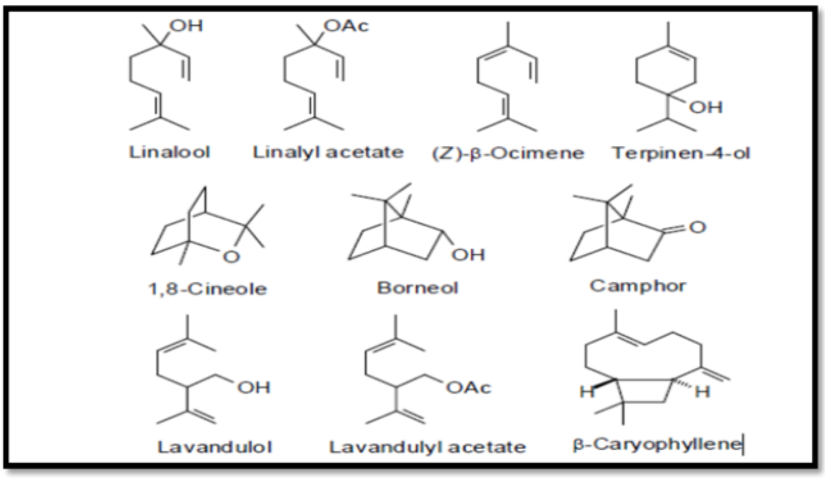

Figure 9. Chemical Structures of Some Important Compounds of Lavender Essential Oil (Cavanagh and Wilkinson 2002)

2.10. Sweet basil (Ocimum basilicum L.)

Sweet basil (*Ocimum basilicum* L.) an aromatic plant belonging to the *Lamiaceae* family, the main centers of diversity in the genus are Africa, America and Asia (Beltrame *et al*., 2014). Since ancient times sweet basil was cultivated as aromatic plant for its medicinal proprieties due to its phenolic acids and aromatic compound (Hussain and Przybylski, 2008). The essential oil of Sweet Basil (*Ocimum basilicum*) is obtained by hydro distillation of the dried and fresh leaves. The high economic value of its oil is due to the presence of phenyl propanoids, like eugenol, chavicol and their derivatives or terpenoids like monoterpen linalool, methyl cinnamate, and limonene (Louie et al., 2007). The following highlight on different implications of sweet basil

- Antioxidant activity

According to (Ademiluyi et al., 2016) the antioxidant and enzyme inhibitory effects of the essential oil could be attributed to the presence of its phytochemicals, which could be the principle responsible for the antidiabetic and antihypertensive properties of the essential oil.

- Anti -inflammatory activity

The anti -inflammatory effect of *Ocimum basilicum* L. and *Ocimum gratissimum* L xylene-induced ear edema as a model of inflammation was studied by (Festus , 2016) At 50 µg/ear OBV, OGV, exhibited significant ($P<0.05$) topical anti-inflammatory effect with edema inhibitions of 50.0, 63.3, 62.7 and 80 % respectively. The effects were comparable ($P<0.05$) with that of 100 µg/ear hydrocortisone (% edema inhibition of 54.8).

- Antifungal activity

The essential oils of different species of *Ocimum* L. (*Lamiaceae*) were studied by (Sethi et al., 2013) for their antifungal activity against a plant pathogenic fungus, *Rhizoctonia solani*. The essential oil of *Ocimum basilicum* L. (Lemon basil) exhibited maximum inhibitory effect with MIC (Minimum inhibitory concentration) of 31. 25 µg/Ml .However, *Ocimum sanctum* L.(Sri tulsi) and *Ocimum gratissimum* L.(Clove basil) exhibited strong inhibitory effects with the MIC of 62.5 µg/mL.

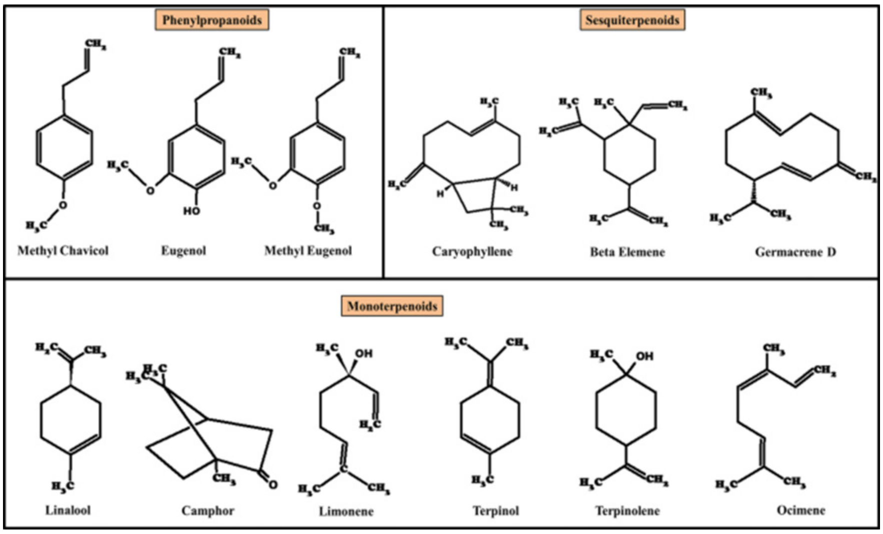

Figure 10. Chemical Structures of Some Important Compounds of Ocimum Species Essential Oil (Maurya, & Sangwan , 2020)

3. Concept of Bio-Fertilizers

The knowledge of applied microbial inoculums is long history which passes from generation to generation of farmers. Bio-fertilizers are rhizosphere colonies including plant root growth promoting bacteria. These bacteria help the plants via supplying nutrients, biological controlling, producing pseudo hormone substances of the plant, and making the plant resistant against different kinds of stress including water and nutrients deficiency and decreasing the contamination effect of plant's heavy metals (Shaharoona et al., 2006). Hence the term bio-fertilizers do not contain any chemicals which are detrimental to the living soil. They are extremely beneficial in enriching the soil with those micro-organisms, which produce organic nutrients for the soil, In large sense, These potential biological fertilizers would play key role in productivity and sustainability of soil and also protect the environment as ecofriendly and cost effective inputs for the farmers. They are cost effective, ecofriendly and renewable source of plant nutrients to supplement chemical fertilizers in sustainable agricultural system. (Khosro, 2012).

Organisms that are commonly used as bio-fertilizers component are nitrogen fixers (N-fixer), solubilizer (K-solubilizer) and phosphorus solubilizer (P- solubilizer), or with the combination of molds or fungi. It cause an increase in nitrogen and phosphorus uptake and consequently the promotion of roots growth of plants according to Violen, 2007.These bacteria may accumulate either in the rhizosphere or even in root or internal cellular space of the plants (Wu et al., 2005).

Azotobacter belongs to family *Azotobacteriaceae,* aerobic, represents the main group of heterotrophic, non-symbiotic free living nitrogen-fixing bacteria principally inhabiting the neutral or alkaline soils. These bacteria are Gram negative and vary in shape. The first representative of the genus, A. chroococcum was discovered and described in 1901 by the Dutch microbiologist and botanist Martinois Beijerinck. , it is used for studying nitrogen fixation and inoculation of plants due to its rapid growth and high level of nitrogen fixation (Jnawali et al., 2015).

For much of the history of life on Earth, biological nitrogen fixation (BNF) is considered to be an important process which determines nitrogen balance in soil ecosystem (Peter et al., 2015). Occurs naturally in the soil by N fixing bacteria (*Rhizobium* and legumes/ *Azotobacter*). It also occurs naturally in the air by means of lightning. N-fixers contribute to nitrogen accumulation in long term and bring N supply close to the equilibrium (Subba et al., 2017).

Microorganisms are able to solubilize and mineralize P pools in soils and are considered to be vital. Bacteria are among the predominant microorganisms that solubilize mineral P in soils, and most of them live in the plant rhizosphere (Barea and Brown, 2005). Phosphorous Solubilizing Bacteria (PSB) inoculants play an important role in making phosphorus available to crops. The use of phosphate-solubilizing bacteria (PSB) as inoculants simultaneously increases P uptake by the plant and crop yield (Igual et al., 2001)

Therefore, it uses in agricultural practice would not only offset the high cost of manufacturing phosphate fertilizers but would also mobilize insoluble fertilizers to soluble forms in soil (Banerjee et al., 2010).

Growth characters, yield, essential oil and its constituents of aromatic plants were significantly affected by adding the biological fertilizers. The following will concentrates on biological fertilization and its effects on the selected aromatic plants for this chapter.

3.1 Effect of Bio-Fertilizers on Growth and Yield of Selected Aromatic Crops

Kumar *et al*. (2009) observed that application of nitrogen and phosphorus at the rate of 93.75 kg/ ha along with *Azospirillum* gave the highest plant height, number of laterals, fresh and dry weight of shoot, dry matter production, fresh herbage yield and essential oil yield in davana.

Prakash and Karthikeyan (2015) declared that plant growth promoting *rhizobacteria* (PGPR) like *Azotobacter*, *Bacillus*, *Pseudomonas* and *Enterobacter* with concentration of 109 CFU/ml improved the plant height (95.05 cm), number of rhizomes per plant (16 rhizomes/plant) , rhizome length (45cm) and rhizome wet and dry weight per plant (75.011 and 37.893 g/plant) respectively in Sweet flag .

A study was conducted by Abdulhalim (2009) to evaluate the effect of enhancing bio-fertilizer with N-fixer bacteria on patchouli plant. The results showed improvement of leaves and branch growth up to 8% and 5%, respectively compared to original bio-fertilizer.

Ratti *et al*. (2001) investigated the effect of some strains of *arbuscular mycorrhizal fungi* (AMF) e.g. *Glomus mosseae* and *G. fasciculatum* on the yield of *Cymbopogon martini* and concluded that, the biomass yield increased by 3-10% compared to the control condition.

Fatemeh (2014) studied the effect of different types of fertilizers on growth, characteristics of *Thymus vulgaris*. The results indicated that application of nitroxin as liquid culture from each strain at the rate of 5ml/Liter along with compost (25t/ha) recorded highest fresh weight (605g), dry weight (130g) and number of inflorescences (26) followed by the plants treated by NPK chemical fertilizers (100:50:50 kg/ha) that recorded (535g, 116g and 19g) respectively.

Abd El- Wahab (2013) studied the effect of bio-fertilizer and chemical fertilizers on *Origanum syriacum*. Plants received 3/4NPK dose (200:100:50 kg/fed) along with bio-fertilizer as mixture of 5 strains of bacteria namely (*Azotobacter chroococcum, Azospirillum lipoferum, Bacillus polymixa , Bacillus megatherium* and *pseudomonas fluorescence*) at (1X108 / c.f.) gave higher values of vegetative characters as plant height (32 cm), number of branches (21) and fresh weight of herb (80.20g).

Application of combination of FYM at 30 m3 /fed. + phosphorein (4kg/fed) and humic acid (6l/fed) in *Mentha piperita* plants recorded maximum plant hight (93.3cm), number of branches (23.80), herb fresh weight (806.8g) and dry herb weight (88.66g) comparing to control according to Sharaf el-din et al. (2013).

Nadjafi *et al.* (2014) conducted an experiment to study the effect of bio-fertilizers on growth and yield of sage (*Salvia officinalis* L.). Application of nitroxin at 50 ml /liter water recorded maximum plant height (33.08cm), fresh weight (70.43 g) and dry weight (1714.4g) compared to control.

Hadis *et al.* (2014) studied the effect of chemical and biological fertilizers on growth and essential oil content of lavender. Mean comparison showed that flower yield was the highest (3932.5 kg/ha) in application of P at 150 kg/ha along with the triple inoculation of *G. mosseae + G. intraradices + P. fluorescens*.

Shoae (2013) recorded that inoculation the seed of sweet basil with PGPRs such as *Pseudomonas putida* (1×109 CFU g-1) and *Azospirillum lipoferum* (2×1017) resulted in increase of shoot wet weight (34.9%), shoot dry weight (44.7%), essence yield (47.32%), plant height (15.85%), leaf area (22.04%), chlorophyll a (63.23%), chlorophyll b (61.86%) and chlorophyll a+b (62.96%) relative to control.

3.2 Effect of Bio-Fertilizers on Quality of Selected Aromatic Crops

According to Mohammad et al. (2012) application of biological fertilizers such as Nitroxin [include bacteria which stimulus growth (*Azotobacter* and *Azospirillum*)], Bio-phosphorus [include bacteria which stimulus growth (*Bacillus* and *Pseudomonas*)] lead to increase in active ingredient artemisinin and chlorophyll concentration in Artemisia annua.

According to (Kalyanasundaram et al., 2008) nitrogen fixing bacteria, promoted essential oil yield through the enhancement of yield attribute in sweet flag plant .

Application of 75% NP(100:50 kg/ha) + 100% K (50kg/ha) + *Azotobacter* + *Azospirillum* + VAM in patchouli recorded significantly superior values for Patchouli oil yield (1.231 g/g) which is 155% increase compared to control according to Manjunathatha (2002).

The interaction treatments between of nitrogen and bio-fertilizers led to significant increment for yield of lemon grass essential oil, that is using 150 kg N/fed + 1 kg Microbein/fed gave Maximum content of essential oil (35.62%) While, the maximum content of Citral A was observed in the essential oil of the herb that received 75 kg N/fed with 1 kg Rhizobacteren /fed.

Optimal nutrition along with non-stress conditions has a significant impact on the quantity and quality of thyme essential oil, the interaction between superabsorbent and thiobacillus significantly changed the percentage of thymol, borneol, and caryophyllene. (Pouneh et al., 2018).

According (Emad et al., 2019) to *mycorrhizal* inoculation increased carvacrol and reduced thymol productions in comparison to non-inoculated conditions.

According to (Pourhadi, 2011) the nitroxin and supernitroplus (8 kg/ha) on par with urea fertilizer had the most effect additive on qualitative and quantitative character of peppermint.

Eisa (2004) reported that microbein and nitrobein bio-fertilizers increased the essential oil content per plant and oil yield /ha in *Salvia officinalis*.

Results of (Hadis et al., 2014) indicated that the triple inoculation of *G. mosseae* + *G. intraradices* + *P. fluorescens* gave the best results of Lavender essential oil. The highest flower essential oil yield (114.27 kg/ha) was achieved in application of P (150 kg/ha) along with the double inoculation mycorrhiza fungi.

Nazanin et al. (2014) conducted an experiment with four treatments viz., *Azotobacter chroococcum* (A) *Azospirillum lipoferum* (B) *Bacillus circulans* (C). The maximum geranial and the minimum caryophyllene in essential oil were obtained by using two biofertilizers (A + C). The highest methyl chavicol was obtained after applying two biofertilizers (B + C).

4. Conclusion

The need for renewable sources of pharm- logical products as well as the need to protect plant biodiversity with trying to reach sustainability, creates an opportunity for farmers to produce aromatic crops. It have a great number of synthetic aromatic compounds have been developed and used in the food, beverage, and pharmaceutical industries, in perfumery and cosmetics industries. Knowing that, quality is one of the most important and critical factors in these crops cultivation, promotion ecologically sound plant protection measures is highly suggested such as bio-fertilizers. However, the current use of microorganisms in agriculture remains at a low level despite the significant investment in scientific work to understand and use natural microbial resources to improve plant growth and health. Keeping the above facts in view, this chapter is highlighting on the bio-fertilizer as an agricultural practice that have positive effect on yield and quality of aromatic crops.

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