REVIEW OF LITERATURE

The use of herbs in the treatment of various human ailments has been known to mankind since ancient times. The term traditional medicine is interchangeably used with herbal medicine and natural medicine (Hazan and Atta, 2005). The aromatic plants containing essential oils are used not only as traditional medicine for their therapeutic properties but also in food, flavour and fragrance industry on account of the strong, spicy and exotic aroma of the essential oils. India being one of the mega biodiversity centres of the world has about 1500 species of aromatic plants of which only about 65 have great demand in the world market and are accordingly grown in different parts of the world (Paroda, 2000). The excessive and unscientific collection has led to the gradual depletion and disappearance of the wild species of aromatic plants. Therefore it is imperative to attempt exploration, collection, maintenance, evaluation, multiplication and conservation of the aromatic plants for the present and future use (Singh, 2004).

Historically, India has been known as a rich repository of aromatic plants and also for the use of essential oils in indigenous medicine and natural perfumes. During the Greek and the Roman period, essential oil trade flourished between India and the western countries (Chauhan, 2004).

*Majorana hortensis* Moench is an aromatic plant whose importance as a natural medicine has been known since time immemorial. Its essential oil is used in perfumery because of its spicy herbaceous notes and also in the manufacture of fungicides, pharmaceutical and industrial products (Vera and Chane-Ming, 1999).
Though native to Cyprus and the Eastern Mediterranean (Novak et al., 2000) it is grown almost all over the world for its use in the flavour, fragrance and pharmaceutical industry. It is grown all over Asia, Arabian Peninsula, Africa, and Europe (El-Asmawy et al., 2007). *Majorana hortensis* is much recognised by its common names such as Sweet Marjoram and Oregano (Al-Howiriny et al., 2009 and Christman, 2010).

Many workers in the past have contributed to the better understanding of the plant, its uses, its phytochemistry and related aspects. In the present study, the information available about *Majorana hortensis* Moench with regard to the following aspects is being reviewed

- Medicinal and other uses
- *In vitro* multiplication
- Phytochemistry
- Anti-microbial effects
- Antioxidant activities
- VAM studies

**MEDICINAL AND OTHER USES**

Perusal of literature reveals that there was a reference to the medicinal properties of *Origanum majorana* (*Majorana hortensis*) even during the times of Dhanvantari (11th Century), Narahari Pandita (14th Century) and Bhava Mishra (16th century), all scholarly medical practitioners of great repute (Priyavat Sharma, 1992). During their times the medicinal properties used to be deduced (identified) by observing the quality, taste and the physical appearance of the drug.
Dhanvantari (11th Century) in his Dhanvantari Nighantu (Compendium) refers to the medicinal effects of Marjoram as follows—

Maruvakaha (marjoram) Kaphaharo (reduces kapha) Ruchya (improves taste) Mukha sugandha krut (mouth freshner).

Narahari Pandita (14th Century) in his Raja Nighantu (Compendium) made the following observations about the medicinal effects of the plant—
Maruvaha (maruga) Katu thikthoshnaha (pungent, bitter, hot in potency) Krimi (worms) Kushtha (skin disorder) vinashanaha (alleviates, destroys) Vitbandha (constipation) Aadhma (flatulence) Shulagho (colic pain) Maandhya (digestive disorder) Thwakdosha (skin disorder) nashanaha (destroys)

Similar observations were also made in Bhava Prakasha Nighantu of Bhava Mishra (16th Century) which reads as follows—
Maruth (Vata) Agniprado (digestive) Hrudya (good for the heart) Teeshloshnaha (penetrating, hot potency) Pitthalo laghuhu (increases Pittha, light in quality)
Vrischikadi visha (scorpion poison) Shleshma vata (kapha and vata) Kushtha (skin disorder) Krimi (worms) pranat (reduces)
Katu paka raso (pungent taste) Ruchya (improves taste) Thiktaruksha (secondary taste is bitter, dry) Sugandhikaha (aromatic).

Nadkarni (1908) reported that Marjoram is a common herb of the Temperate Himalayas and Western Asia. The drug contains a volatile essential oil ‘Oleum Marjoranae’ consisting mainly of terpenes. The plant is used in some parts of Punjab as a pot herb like Mint. It is a carminative, stimulant, diaphoretic, emmenagogue and a tonic. Volatile oil is used as an aromatic stimulant in colic, dyspepsia, flatulence and dysmenorrhoea.
It is used locally in rheumatism, to the abdomen in colic, to the temple in hemicrania and to the ear in earache. Infusion of the plant is also useful for internal administration.

Marjoram is reported to possess anticancer properties (Hartweel, 1969). According to Porsolt et al. (1977) *Majorana hortensis* has been widely employed in herbal medicine and aromatherapy. It is pungent, bitter, hot and anthelminthic, useful against diseases of the heart and blood, fevers, leucoderma and inflammation (Kirtikar and Basu, 1985).

In the food industry it is mainly used as a spice in sausages but its use in baked goods, processed vegetables, condiments, soups, snack foods and gravies is also reported (Burdock, 1990).

Bremness (1994) while discussing growing and using of herbs noted that Marjoram is a well-liked home remedy for chest infection, cough, sore throat, rheumatic pain, nervous disorders, cardiovascular diseases, epilepsy, insomnia, skin care, flatulence and stomach disorders. *M. hortensis* is used in traditional medicine as an astringent, diuretic, anti-hysterical, anti-asthmatic and anti-pyretic drug (Yadava and Khare, 1995).

Marjoram is well known for its medicinal properties (Chevallier, 1996). It was reported by Vera and Chane-Ming (1999) that *Majorana hortensis* is an appreciated herb species and its essential oil is used in perfumery because of its spicy herbaceous note. In addition, it is utilized in the manufacture of fungicides, and various pharmaceuticals and industrial products.

Compounds from Marjoram essential oil have shown therapeutic effects such as analgesic, aphrodisiac, antioxidant, antiseptic, antispasmodic,
carminative, cephalic, diaphoretic, digestive, diuretic, emmenogogue, expectorant, hypotensive, laxative, nerve, sedative, stomachic, tonic, vasodilator, fungicidal, bactericidal and antiviral (Julia Lawless, 1999).

Chung et al. (2001) studied the inhibitory effect of Ursolic acid from *Origanum majorana* on acetyl cholinesterase in Alzheimer’s disease. Ursolic acid, carnosic acid and carnosol isolated from Marjoram possess free radical scavenging properties.

Heo et al. (2002) reported that different chemical compounds present in Marjoram exhibit different biological activities including antioxidant and radical scavenging properties. Ursolic acid in Marjoram oil was found to reduce Abeta-induced oxidative injury.

*Origanum* species have been attributed with mood enhancing properties by aroma therapists. Volatile oils isolated from the whole plant of *Majorana hortensis* are often used in the treatment of anxiety (Rogoz et al., 2003). An infusion of the plant is used as a stimulant, sudorific, galactogogue and against asthma, hysteria and paralysis (Farooqi and Sreeramu, 2004). According to Vagi et al. (2005), the essential oil of *Origanum majorana* has medicinal properties because of the presence of biologically active compounds like terpinen-4-ol. They also reported that due to the presence of Ursolic acid and other compounds, they exhibit antioxidant properties.

Arts and Hollman (2005) while conducting epidemiological studies observed that fresh as well as dry Marjoram is one of the most popular culinary herbs used for flavouring salad, meat and vegetable dishes. It serves as a natural antioxidant thereby avoiding the use of synthetic antioxidants in food.
Faleiro et al. (2005) studied the antibacterial and antioxidant activities of the essential oil of *Origanum vulgare* and observed that it is used against a number of ailments like chest infection, cough, sore throat, rheumatic pains, nervous disorders, cardio-vascular diseases, skin care, epilepsy, stomach disorders and flatulence.

Shan et al. (2005) while working on the effects of Marjoram treatment observed that Marjoram species offers protection against H$_2$O$_2$-induced DNA damage showing its antioxidant potential. Further, Marjoram possesses free radical scavenging and a dose dependent anti-proliferative effect on human leukemic cell line due to the presence of various active chemical constituents. They suggested that it is a culinary herb which can be used as a natural antioxidant in salad, meat and vegetable dishes for flavour thus avoiding the use of synthetic antioxidants in food.

According to El-Ashmawy et al. (2005; 2007a, b) the alcoholic and aqueous extracts of Marjoram as also the essential oil could protect against liver and kidney damage and lead acetate injury. Marjoram volatile oil was also found to control oxidative damages induced by ethanol toxicity to brain, liver and fertility.

D’Antuono and Elementi (2006) while studying the flavour, health and industrial exploitation of edible aromatic herbs of Lamiaceae noted that fresh as well as dry Marjoram is one of the most popular culinary herbs and is used globally in salads, meat and vegetable dishes for flavour and as a natural antioxidant.

Hazzit et al. (2006) studied the chemical composition, antioxidant and antimicrobial activities of the oil. They reported that Marjoram oil mixed with other substances is used in aromatherapy.
Yanishlieva et al. (2006) studied the Natural antioxidants from herbs and spices used as flavouring agents in food and noted that Marjoram species offers protection against H$_2$O$_2$-induced DNA damage showing its antioxidant potential. They also observed that due to the presence of various bioactive chemical compounds the plant possesses antioxidant properties and a dose dependent anti-proliferative effect on human leukemic cell line.

Aheme et al. (2007) studied the effect of plant extracts on antioxidant status and oxidant induced stress in Caco-2 cells and observed that Marjoram volatile oil was found to control oxidative damages induced by ethanol toxicity to brain, liver and fertility. It also offers a clear cut protection against H$_2$O$_2$-induced DNA damage showing its antioxidant potential.

*Majorana hortensis* is used worldwide as a spice and a medicinal source in the form of essential oil in aromatherapy due to its stimulant and antispasmodic properties (Gharib et al., 2008). Yazdanparast and Shahriyary (2008) during a comparative study of the effects of essential oils from different herbs noted that the Marjoram is a good home remedy for a number of ailments like cough, sore throat, chest pain, cardio-vascular disease, insomnia, epilepsy, skin infections, rheumatic pain, stomach disorders, flatulence etc.

Hossain et al. (2008) studied the antioxidant activity of spice extracts and phenolics in comparison to synthetic antioxidants and stated that *Origanum majorana* is a natural antioxidant and is an aromatic culinary herb whose fresh or dry leaves can be used to flavour salads, meat and vegetable dishes. McCarrol et al. (2008) reported that Marjoram is added to mouth rinse and it cures inflamed skin wounds and infections.
Papageorgiou et al. (2008) investigated the antioxidant behaviour of air and freeze-dried aromatic plant materials in relation to their phenolic content and vegetative cycle. Further they confirmed the anti-proliferative activity of Marjoram in human lymphoblastic cell line Jurkat.

It was reported in Indian Food (2009) that the leaves and seeds of Marjoram provide a ready remedy for Colic. Marjoram is also known for its insecticidal values (Abbassy et al., 2009).

Ramy Romeilah (2009) investigated the anticancer and antioxidant activities of *Majorana hortensis* essential oil obtained by the hydro-distillation of dry leaves of the plant. The essential oil showed anticancer effects against two species of human leukaemia cells, HL-60 and NB4. The anticancer effects of Marjoram oil on NB4 cells were more than the effects on HL-60 cells. They suggested that the oil might help prevent oxidative damage in the human body such as lipid peroxidation which is associated with cancer, premature aging, atherosclerosis and diabetes. The results of their work showed that the essential oil could be used as a potential natural antioxidant and anticancer agent.

Machado et al. (2010) studied the effects of essential oils of *Origanum virens* and found that it functions as a natural antioxidant. They stated that the fresh and dry leaves of the plant can be used for flavouring food.

Abdel-Massih et al. (2010) while studying the apoptotic and anti-proliferative activity of *Origanum majorana* extracts on human leukemic cell line observed their antimycotic, antibacterial, insecticidal and bio-herbicidal properties. They reported that the *Origanum* essential oils are well known for their antioxidant characteristic and are used to inhibit lipid peroxidation thus preventing food spoilage and as chemo-protective agents in the treatment of various diseases including cancer. They
reported that the free radical scavenging and a dose dependent anti-proliferative effect of Marjoram on human leukemic cell line are due to the presence of various active chemical constituents.

It was reported by Verma (2010) that the aerial parts of *Majorana hortensis* plant are utilized for the isolation of essential oil, which has a lot of uses in flavour, perfumery and pharmaceutical industry. He observed that the essential oil is employed for external application in bruises, sprains, stiffs, paralytic limbs, toothache and for hot fomentation in acute diarrhoea. In food industry, it is mainly used as a spice in sausages.

Mossa and Nawwar (2011) studied the free radical scavenging and antiacetylcholinesterase activities of *Origanum majorana* essential oil. Suntar et al. (2011) exploited the wound healing properties of Marjoram essential oil in the formulation of a novel skin ointment along with other medicinal oils based on traditional Turkish knowledge. Naif Obaid Al-Harbi (2011) reported that Marjoram was initially used by Hippocrates as an antiseptic agent.

While studying the effect of Marjoram extract treatment on cytological and biochemical changes induced by cyclophosphamid (CP) in mice it was observed by Naif Obaid Al-Harbi (2011) that marjoram significantly reduced the intensified increase in micronucleated polychromatic erythrocytes caused by CP-treatment without affecting its cytotoxicity. It also inhibited the biochemical changes induced by CP-treatment in mice. Marjoram was found to possess antimutagenic, antioxidant potential and low toxicity. His findings also demonstrated that treatment with marjoram alcoholic, aqueous extracts and essential oil could protect liver and prevent kidney damage and genotoxicity induced by Lead Acetate treatment. In addition, the findings of the study by Naif Obaid Al-Harbi
substantiated the earlier reports that the different chemical compounds present in Marjoram possess different biological activities including antioxidant potential and free radical scavenging properties. It was also observed that Marjoram possesses free radical scavenging and a dose dependent anti-proliferative effect on human leukemic cell line due to the presence of various active chemical constituents. The high antioxidant capacities of Marjoram and other Oregano species were found to be dependent on the total phenol contents.

Babili et al. (2011) observed that treatment with different extracts of Marjoram exerted antimalarial, antioxidant and protective activities. They attributed such properties of Marjoram to the presence of terpenes, polyphenols, phenolic glycosides, phenolic derivatives, flavonoids, tannins, sitosterol and essential oil.

According to Radha Palaniswamy and Padma (2011) *Majorana hortensis* is a good scavenger of free radicals and is an effective antioxidant. The easy availability and perennial growth of this plant is an added advantage in traditional Indian medicine. They reported that apart from its culinary uses, the plant has several therapeutic uses like a cure for digestive disorders, fevers, as an expectorant etc.

While studying the effect of *Majorana hortensis* leaf extracts on the apoptotic events in *Saccharomyces cerevisiae* cells subjected to oxidative stress, Radha and Padma (2011) conducted cytotoxicity assay in the presence and absence of *M. hortensis* leaf extract. The oxidative stress in yeast cells was induced by H$_2$O$_2$ which caused a significant increase in apoptotic cells. Treatment with leaf extract brought down the apoptosis-inducing effect of H$_2$O$_2$ with the methanolic extract being more effective than the aqueous and the chloroform extracts. Thus the cytotoxicity of
H$_2$O$_2$ was counteracted by the administration of the leaf extract of Marjoram. Their observation indicated that the leaf extract of *M. hortensis* exerted anticancer effect on cancer cells and rendered protection to non-cancer cells. The study showed that the extract of leaves of *M. hortensis* can alleviate the oxidative stress imposed on healthy cells. They reported that it is also used against headaches and digestive disorders. They also observed that due to its aroma the plant finds use in culinary preparations and during religious ceremonies.

Rupesh Kumar et al. (2011) carried out the evaluation of Anxiolytic and Antidepressant activities of *Majorana hortensis* and concluded that the ethanol extract of the plant possesses Anxiolytic and Antidepressant activity.

**IN VITRO MULTIPLICATION THROUGH DIRECT AND INDIRECT REGENERATION**

In Tissue Culture, Direct regeneration is the formation of shoot buds from propagules cultured on nutrient media supplemented with different concentrations and combinations of various growth regulators, which on elongation form multiple shoots.

Indirect regeneration is the formation of multiple shoots from the callus produced by culturing the propagules on nutrient media supplemented with various growth regulators. Differentiation and organogenesis from callus can be accomplished by further manipulation of growth regulators and culture conditions.

Sitakanta and Pradeep (1996) developed an efficient protocol for the rapid multiplication of *Origanum americanum* using axillary buds on MS
medium supplemented with BAP 2.0 to 4.44 µM and 0.5 mg l⁻¹ of GA₃. It was further observed that the shoots rooted on ½ strength MS medium supplemented with 2.0 µM IBA. Plantlets were hardened and successfully established in natural soil.

Multiple shoots were obtained from sweet Marjoram (*Majorana hortensis*) nodal stem explants when cultured on Murashige and Skoog medium supplemented with 6-benzyl amino purine at 2 mg/l. Shoots were rooted on MS medium supplemented with IBA at 0.2 mg/l (Iyer and Pai, 1998).

Iyer and Pai (2000) were able to achieve rapid multiplication of *M. hortensis* through plant regeneration from nodal stem explants and callus. Nodal stem explants cultured on Murashige and Skoog’s medium supplemented with 2 mg/l Benzyl amino purine and maltose as source of carbon, yielded up to 40 shoots. The shoots produced roots in the presence of 0.2 mg/l IBA. Callus was induced in stem explants in medium containing 0.4 mg/l 2, 4-D. This callus showed organogenesis on MS medium containing 3 mg/l BAP and 0.2 mg/l IBA.

An efficient method for the *in vitro* multiplication of *Oreganum* was established by Goleniowski et al. (2003) from apical meristems on MS medium supplemented with BAP and NAA at various concentrations.

Leelavathi (2009) has observed that MS basal medium supplemented with BAP (8.88 µM) is the best medium for direct regeneration of multiple shoots from apical bud, axillary bud and leaf explants of *Origanum vulgare*. The lowest number of shoots was observed on
MSBM+KIN (13.92 µM). Indirect regeneration of multiple shoots was observed when the explants were cultured on MSBM fortified with BAP (8.88µM) + 2, 4-D (2.26 µM). It was further reported that MSBM supplemented with BAP (8.88 µM), NAA (2.68 µM) and IBA (4.92 µM) was very effective in root formation in in vitro regenerated shoots. It has also been reported that callus can be successfully induced from apical bud, axillary bud, leaf and root explants on MSBM supplemented with different concentrations of NAA, IAA and 2,4-D.

Yashoda Bai et al., (2011) reported that in *Origanum majorana*, MSBM fortified with KIN (9.28µM) is ideal for the initiation of multiple shoots from axillary bud explants. It was also observed that MSBM supplemented with KIN (9.28 µM), IBA (4.92 µM) and NAA (2.68 µM) is the most suitable rooting medium.

Tejavathi and Padma (2012) developed an efficient protocol for the direct and indirect regeneration of *Majorana hortensis* using nodal explants. It was observed that Phillips and Collins (L2) medium fortified with various hormones showed better response than MS medium with the same hormonal combination. It was reported that L2 medium supplemented with kinetin at the concentration of 9.30 µM promoted the formation of highest number of multiple shoots and best rooting was induced on L2 medium fortified with IBA (4.92µM).

**PHYTOCHEMISTRY**

Oberdieck (1981) and Franz (1990) working on the analytical quality of marjoram oil have observed that in Marjoram essential oil, Cis- sabinene
trans-sabinene hydrate has no typical ‘marjoram’ properties.

GC examination of the leaf oil of *M.hortensis* by Yadava and Saini (1991) revealed that the major constituents of the oil are carvacrol (36.70%), eugenol (26.00%) and β-cymene (14.00%).

Deans and Svoboda (1992) studied the effect of drying regime on volatile oil content and microflora of aromatic plants. Seven herb species were harvested and immediately dried at temperatures between 40 and 100°C for 24 hours. The dried material was then steam distilled. The volatile oil content decreased with increasing temperature and this was also accompanied by changes in oil composition. The composition of *Majorana hortensis* oil changed significantly at 80°C. Drying resulted in the reduction of microflora and higher temperatures killed most of the microorganisms.

Komaitis et al. (1992) investigated the composition of the essential oil of *Origanum majorana* and reported 45 compounds by Gas Liquid chromatography. The most prominent component was 4-terpineol.

Yadava and Khare (1995) isolated a triterpenoid glycoside from the stems of dried plants of *Majorana hortensis* and its chemical structure was elucidated by spectral analysis. Thimen et al. (1995) analysed the water distilled oil from the aerial parts of *Origanum saccatum*.

Stella et al. (1997) analysed the essential oils of *Origanum vulgare ssp. hirtum* plants collected in late autumn from six localities of three distinct geographical areas of Greece by GC and GC/MS and compared with the essential oils obtained from plants collected from the same localities in
mid-summer. Oswaldo et al. (1998) studied the essential oil from micropropagated *Origanum bastetanum* and the results were compared with the oil obtained from the wild plants. Maria Teresa et al. (1999) analysed the essential oil from the inflorescence of *Origanum vulgare ssp. hirtum* growing wild in Calabria by Gas chromatography/Mass spectrometry.

Ozguven and Tan (1999) studied the influence of development periods on the yield and quality of the essential oil in *Majorana hortensis*. The fresh and dry herbs, as also the essential oil yield were highest at the post flowering stage. The main components of the oil were gamma-terpinen, p-cymol and terpineol. The content of geraniol, p-cymol and cineole were found to be influenced only by the development stage of the plant at the time of harvest whereas sabinene, myrcene, borneol, terpineol, thymol and carvacrol contents were influenced by both development stage and the harvest time of the year.

Vera and Chane-Ming (1999) investigated the chemical composition of the essential oil of Marjoram from Reunion Island and reported that 45 compounds were recorded by GC. The essential oil was rich in terpinen-4-ol, cis-sabinene-hydrate, p-cymene and γ-terpinene.

Johannes Novak et al. (2000) studied the composition of essential oil from two species of *Origanum viz. O. majorana* and *O. microphyllum*. They observed that essential oil obtained from the flowering heads of Marjoram had aromatic smell and contained high percentage of polyphenols and monoterpenes which are established antioxidants. They reported that the main components of the essential oil of Marjoram are the epimeric monoterpenic alcohols trans-sabinene hydrate, cis-sabinene
hydrate and cis- sabinene hydrate acetate. It was observed that the synthesis of sabinene hydrate in marjoram is performed by the enzyme sabinene hydrate synthase. Further, after analysing 20 different genotypes of *Origanum majorana* it was found that cis-sabinene hydrate and trans-sabinene hydrate are produced by the same enzyme in the ratio of 20:1. They also observed that the bioactive chemicals in the essential oil are responsible for the antioxidant properties of the plant.

Damute et al. (2001) investigated the composition of the essential oil of *Origanum vulgare ssp vulgare* growing wildly in various localities of Vilnius district (Lithuania).

Kamel et al. (2001) reported the isolation of three new and two known monoterpene glucosides from the aerial parts of *Origanum syriacum* L. and the structure of these isolated compounds were verified by MS and NMR spectral analysis.

Economakis et al. (2002) studied the effects of three different concentrations of phosphorus used in the nutrient solution for the cultivation of *Origanum dictaminus* L. hydroponically by nutrient film technique and the chemical composition of the essential oils obtained from the leaves and bracts were analysed by GC-MS. The essential oils were tested for their antibacterial activity against Gram +ve and Gram -ve bacteria.

Chromatographic analysis of the essential oil of *Majorana hortensis* by Rodrigues et al., (2003) led to the identification of cis-sabinene hydrate, terpineol-4, alpha-terpineol and cis-sabinene hydrate acetate as the main
volatile components present in both commercial and cultivated samples of the plant.

Edris et al. (2003) and El-Ghorab et al. (2004) reported that the essential oil components of Marjoram are terpinen-4-ol, gamma-terpinene, trans-sabinene hydrate, linalool, thujanol and thymol.

A total of 24 components were identified by Omidbaigi and Bastan (2005) in the essential oil of *M. hortensis* by GC-MS. The main components representing 99.2% of the oil were identified as terpinen-4-ol (21.3%), trans-sabinene hydrate (14.8%), cis-sabinene hydrate acetate (10.7%), alpha-terpinene (7.3%), sabinene (5.7%), alpha-terpineol (4.7%), cis-sabinene hydrate (4.5%), limonene (3.0%), linalylacetate (3.0%) and terpenolene (2.6%).

Costas et al. (2005) studied the chemical composition of the essential oils obtained from the leaves and bracts of hydroponically cultivated *Origanum dictamus* growing under various electrical conductivity levels using the nutrient film technique. The essential oil content was analysed by GC-MS technique.

Vagi et al. (2005) studied the phenolic and triterpenoid antioxidants from *Origanum majorana* herb and extracts obtained from different solvents. They observed that Ursolic acid, carnosic acid and carnosol isolated from Marjoram possessed free radical scavenging properties. Further, they noted that, in the terpenen-4-ol/sabinene hydrate chemotype of *Origanum majorana*, the characteristic flavour and fragrance of marjoram oil are due to the two major constituents namely terpenen-4-ol and sabinene hydrate.
Politeo et al. (2006) reported that the major constituents of marjoram oil are terpinen-4-ol (40.8%), γ-terpinene (16.3%) and α-terpinene (11.0%).

Banchio et al. (2008) observed that two chemotypes characterize *Origanum majorana* essential oil namely terpinen-4-ol/sabinene hydrate chemotype and thymol (or carvacrol) chemotype.

Gas chromatography-mass spectrometry analysis of *Majorana hortensis* essential oil conducted by Abbassy et al. (2009) revealed the presence of 31 compounds and the main components were terpinen-4-ol (30.0%), gamma-terpinene (11.3%) and trans-sabinene hydrate (10.8%). Terpinen-4-ol and gamma-terpinene exhibited significant insecticidal activity against *Spodoptera littoralis* and *Aphis fabae*.

Ramy Romeilah (2009) extracted the essential oil from the dried leaves of *Majorana hortensis*. The hydro-distillation of dried leaves yielded a colourless oil of 1.7% (v/w). GC/MS analysis of the essential oil revealed the presence of 24 compounds and the major components were terpinen-4-ol (35.33%), γ-terpinene (15.0%), α-terpinene (10.72%), α-terpineol (5.89%) and linalool (3.81%) which perhaps have imparted anticancer properties to the essential oil. In addition, β-phellandrene, sabinene, α-terpinolene, α-thujene, caryophyllene, β-cymene, bicyclogermacerene and α-pinene were also found in quantities higher than 1% of the essential oil.

Leelavathi (2009) compared the *in vivo* and *in vitro* leaf and stem of *Origanum vulgare* with respect to the major compounds. The gas chromatography analysis revealed a higher percentage of Thymol in the *in vivo* leaf and stem than in the *in vitro* sample.
Phytochemical studies on *Origanum vulgare* L. by Prathyusha et al. (2009) revealed the presence of carbohydrates, proteins, amino acids, fixed oils, fats, alkaloids, flavonoids, saponins, glycosides, tannins, phenolic compounds, triterpenoids, resins, gums, mucilage, steroids and sterols in the vegetative parts of the plant. Their analytical studies on the plant sample showed the presence of fluorescence compounds in them.

Ibtissem Hamrouni Sellami et al. (2009) studied the variation in the content and composition of the essential oil of *Origanum majorana* harvested at four phonological stages (early vegetative, late vegetative, budding and full flowering). They observed that the essential oil yield varied from 0.04 to 0.09% reached during the full-flowering stage. They conducted the analysis of the essential oils by GC and GC/MS which revealed the presence of 38 components represented mainly by oxygenated monoterpenes, monoterpane hydrocarbons and sesquiterpene hydrocarbons. The major components in the essential oils were terpinen-4-ol, cis-sabinene hydrate, trans-sabinene hydrate, \( \gamma \)-terpinene, bornyl acetate and linalool. The phenolic contents were highest at the late vegetative stage. The RP-HPLC analysis of the methanolic extract of the dried aerial parts showed the predominance of phenolic acids during the early vegetative stage whereas flavonoids predominate during the other stages of growth. They reported that the bioactive compounds were highest at late vegetative stage and therefore it could be considered the best stage for harvesting Marjoram plants.

Hossain et al. (2010) conducted phytochemical analysis and characterization of phenolic compounds in *Origanum majorana* and reported that the bioactive compounds are responsible for the antioxidant properties of the aromatic herb. A total of 31 polyphenols were analysed
by LC-MS and it was observed that flavonoids constituted the largest number of polyphenols in Marjoram.

A study was conducted by Verma (2010) to observe the influence of harvest cut height on essential oil yield and composition of *Majorana hortensis* cultivated in the temperate zone of western Himalayas. It was observed that the essential oil yield and terpenoid composition varied with respect to harvest cut height. The top 1/3 portion of the plant produced higher yield of essential oil (0.47%) as compared to the top 2/3 (0.38%) and the whole herb (0.33%). They suggested that it could be due to variation in the essential contents of the upper, middle and lower leaves and basipetal increase of stem percentage. A total of 35 constituents representing 98.31% of the total oils were identified by GC-MS and the major constituents were (Z)-sabinene-hydrate, terpinen-4-ol, (E)-sabinene-hydrate, sabinene, α-terpinene, γ-terpinene and α-terpineol. He concluded that a good yield of high quality essential oil can be obtained from Sweet marjoram by harvesting the top 1/3 portion instead of harvesting the whole herb which is a common practice among growers in most countries. It was suggested that upper and lower portions of the plant could be processed separately to get essential oils of two different qualities.

Ram Verma et al. (2010) studied the essential oil content and composition of Sweet Marjoram cultivated in the Kumaon region of western Himalayas harvested at different ages of the crop. The samples were taken after 60 days (early vegetative stage), 90 days (late vegetative stage), 120 days (flower initiation stage) and 150 days (flowering stage) of transplanting. The essential oil content varied from 0.20% to 0.70% with the highest yield at 150 days indicating that the dynamics of
essential oil content in Marjoram is metabolically regulated during the vegetative and flowering stages of crop growth. They opined that in most aromatic plants, the essential oil preferentially accumulates during the flowering stage, probably due to its ecological role in attracting the pollinators and as a defence mechanism. Based on the essential oil content, it was suggested that the flowering stage (150 days) could be considered as the best harvesting time for *Majorana hortensis*. GC-MS analysis revealed the presence of twenty eight components representing 96.53% - 98.44% of the total oil content. The major essential oil components were (Z)-sabinene hydrate, terpinen 4-ol, (E)-sabinene hydrate, sabinene, α-terpinene, γ-terpinene and α-terpineol. It was observed that there was considerable variation in the qualitative composition of the oils obtained from crops of different ages which could be due to variation in enzyme levels and their pool sizes in response to changing weather conditions during different months. As the content of (Z) - sabinene hydrate, the major flavour compound is lowest at day 150, it was suggested that it is judicious to harvest and distil Marjoram crop at the flower initiation stage (120 days) under sub-temperate conditions of North India in order to obtain a good yield of high quality oil.

Olfa Baatour et al. (2010) indicated that the most represented class of essential oil components of *Origanum majorana* native to Canada was that of oxygenated monoterpenes, followed by monoterpene hydrocarbons and esters. Olfa Baatour et al. (2010), while studying the salt effects on the growth, mineral nutrition, essential oil yield and composition of Marjoram showed that Canadian *Origanum majorana* can tolerate a moderate NaCl concentration (50 mmol L\(^{-1}\)) without modification in the essential oil yield and composition. However, at a high NaCl concentration (100 mmol L\(^{-1}\)), there was a significant
modification in the essential oil yield and quality (Olfa Baatour et al., 2012). It was thus concluded that the effect of salt on essential oil yield depends on the salt concentration, culture medium, and tolerance of the species.

Rupesh Kumar et al. (2011) conducted preliminary Phyto-chemical analysis of the ethanol extract of *Majorana hortensis* whole plant which showed that the plant contains Alkaloids, Steroids, Triterpenoids, Amino acids, Flavonoids, Reducing sugar, Tannins and Saponins.

Miron et al. (2011) studied the chemical composition of bioactive extracts of Romanian aromatic plants and observed that the amount of phenolic acids, flavones, flavonones, and flavonols play a vital role in the antioxidant capacity of Marjoram extracts. They reported that Ursolic acid, Carnosic acid and Carnosol isolated from Marjoram possessed free radical scavenging properties.

Vaghasiya et al. (2011) conducted the phytochemical analysis of 53 traditionally used medicinal plants from Western region of India to investigate the total content of Alkaloids, Phenols and flavonoids. The plant/plant parts were extracted by cold percolation method in acetone and methanol. The methanol extract of *Origanum majorana* showed high phenolic content and moderate amounts of flavonoids and tannins.

Olfa Baatour et al. (2012) investigated the shoots of *Origanum majorana* for the essential oil composition under two different culture conditions: one on a hydroponic medium in a culture chamber and the second on inert sand in a greenhouse. It was observed that under the culture chamber conditions trans-sabinene hydrate transformed into cis-sabinene hydrate and under greenhouse conditions cis-sabinene hydrate converted to trans-
sabinene hydrate suggesting that the culture conditions activated the enzyme sabinene hydrate synthase in a particular direction.

Olfa Baatour et al. (2012) studied the essential oil composition of *Origanum* shoots under culture chamber conditions and the GC analysis of the essential oil revealed the presence of 44 compounds accounting for 99.86% of the total essential oil. The main compounds were *cis*-sabinene hydrate followed by terpinen-4-ol, *trans*-sabinene hydrate and α-humulene. Salt addition induced a decrease in the quantity of these compounds compared to the control. The essential oil was of *cis*-sabinene hydrate/terpinen-4-ol chemotype, which is responsible for the characteristic flavour and fragrance of Marjoram.

Olfa Baatour et al. (2012) also studied the essential oil composition in *Origanum majorana* shoots under greenhouse conditions and 32 compounds were identified, representing 99.55% of the total essential oil. The main components of the essential oil were terpinen-4-ol followed by *trans*-sabinene hydrate and α-terpineol. In the presence of NaCl (100 mmol), a small increase was observed in terpinen-4-ol percentage, while percentages of *trans*-sabinene hydrate and α-terpineol were not affected. The essential oil was of *trans*-sabinene hydrate/terpinen-4-ol chemotype.

The results of the experiments performed by Olfa Baatour et al. (2012) showed that NaCl modified the composition of the essential oil of *Origanum majorana*. In fact, new compounds like eicosane, spathulenol, eugenol and phenol appeared. However, myrcene, present in the control, disappeared under saline conditions.

The study conducted by Olfa Baatour et al. (2012) indicated that Marjoram cultivated in the greenhouse produced essential oil of a higher
quality than that cultivated in the culture chamber because of its high terpinen-4-ol concentration.

Badee et al. (2013) analysed the essential oil of *Origanum majorana* by GC/MS which revealed that the oil was dominated by monoterpane hydrocarbons, oxygenated monoterpenes and sesquiterpenes. The major components of the oil were γ-terpinene, α-terpinene terpinen-4-ol, α-terpinolene, sabinene hydrate, p-cymene, α-phellandrene and limonene constituting 85.51% of the essential oil indicating that the Egyptian Marjoram oil belonged to terpinen-4-ol/sabinene hydrate chemotype. The total phenolic content in the plant revealed that it is a rich source of polyphenols which are known natural antioxidants. They conducted DPPH radical scavenging assay which showed that the oil exhibits strong antioxidant activities and thus can be a potential source of natural antioxidants with possible applications in food systems.

Barbara et al. (2013) studied the chemical composition and bioactivity of different extracts and essential oil Oregano (*Origanum vulgare*) and reported that the major components of the oil were Carvacrol, β-fenchyl alcohol, Thymol and γ-terpinene. They observed that hot water extract had the strongest antioxidant activity and highest phenolic content. The extracts were ineffective in inhibiting growth of the tested bacteria but the oil was found to be an effective antimicrobial agent.

**ANTI-MICROBIAL ACTIVITY**

Marjoram is reported to possess antifungal properties (Afifi and Dowidar, 1976; Pruthi, 1980).
Deans and Svoboda (1990) evaluated steam distilled volatile oil from *Origanum majorana* for its antibacterial and antifungal activities. A range of 25 bacteria and five fungal species including animal and plant pathogens, food poisoning bacteria and mycotoxigenic fungi were used in the study. It was observed that the oil exerted considerable inhibitory powers against several of the bacteria, with the food poisoning bacterium *Staphylococcus aureus* being least affected. The most susceptible organisms were *Beneckea natriegens, Erwinia carotovora, Moraxella species* and *Aspergillus niger*.

Yadava and Saini (1991) reported that the essential oil obtained from the leaves of Marjoram has antimicrobial properties against several pathogenic bacteria.

Abdel-Mallek et al. (1994) studied the *in vitro* anti-yeast activity of some essential oils and showed that the oil of Marjoram has inhibitory effect against five pathogenic yeast species – *Candida albicans, Candida stellatoidea, Candida tropicalis, Torulopsis candida* and *Torulopsis versitilis*.

Afroditi et al. (1996) reported the comparative study of the antimicrobial properties of three representative *Origanum* essential oils and their main chemical constituents.

Konstantia et al. (1998) reported the antifungal activities of four essential oils from *Origanum, Mentha, Lavendula* and *Salvia* against three widely spread pathogenic fungal strains that cause superficial skin infections in humans.

Russo et al. (1998) studied the essential oil chemical composition of wild populations of Italian Oregano spice (*Origanum vulgare* ssp. *hirtum*) and their use in Chemotaxonomy and observed that major components of the
extract which include terpenoid phenols - carvacrol, thymol and eugenol have potent antifungal activity.

Force et al. (2000) reported that the emulsified oil of marjoram possesses strong antiparasitic activity.

Dimitra et al., (2000) determined the chemical composition of the essential oils from some Greek aromatic plants like Oregano, Thyme, Marjoram, Lavandula, Rosemary and Sage by GC-MS analysis and evaluated the efficacy of the oils and their major components on the radial growth and conidial germination in *Penicillium digitatum*. Ben Hamida et al. (2001) evaluated the antibacterial activity of *Origanum majorana* oil from Tunisia using agar diffusion and broth micro dilution methods.

Alma et al. (2003) investigated the chemical composition and *in vitro* antioxidant and antimicrobial activities of the essential oils from *Origanum syriacum* growing in Turkey and observed that the oil with Carvacrol, Thymol and Eugenol as the major components has antifungal potential. Salgueiro et al. (2003) studied the chemical composition and antifungal activity of the essential oil of *Origanum virens* on *Candida* species and stated that the antifungal property of the oil is due to the presence of Terpenoid phenols - Carvacrol, Thymol and Eugenol.

Dragland et al. (2003) studied several medicinal and culinary herbs and reported that Marjoram was effective against food-borne pathogens and spoilage bacteria. They also observed that many of these herbs were important sources of dietary antioxidants.

Farooqi and Sreeramu (2004) have reported the anti-microbial activity of *Majorana hortensis* against *Bacillus anthracis*, *Proteus vulgaris*, *Salmonella stanley*, *Salmonella newport*, *Streptococcus agalactiae*, *
Streptococcus guneus and Aspergillus fumigatus. Shahidi Bonjar (2004) screened some plants used in Iranian traditional medicine for antibacterial properties against two strains of Escherichia coli and found that Majorana hortensis Moench showed anti-E.coli activity.

Muneuver et al. (2004) have evaluated the essential oil and various extracts of herbal parts and callus cultures of Origanum acutidens for their antioxidative, antimicrobial and antiviral properties.

Tampieri et al. (2005) while studying the effects of various herbal extracts have stated that the essential oil derived from the genus Oreganum was the most effective against Candida albicans, with an in vitro MIC of 500 ppm.

Meschino (2005) reported that Oil of oregano is a rich source of the volatile oils Thymol and Carvacrol, which have been shown to be largely responsible for enabling Oil of oregano to kill various microorganisms under experimental conditions. Oil of oregano also contains other active constituents, including flavonoids and a host of vitamins and phytonutrients. The oil has the ability to kill various viruses, bacteria, yeasts and other microorganisms known to adversely affect human health.

Vagi et al. (2005) investigated the essential oil composition and antimicrobial activity of Origanum majorana extracts obtained with ethanol and supercritical carbon dioxide and reported that the extract obtained by supercritical fluid extraction was more effective than the ethanolic extract against tested food borne fungi and bacterial strains. The results support the view that the extracts could be used as preservatives in food and cosmetic systems.

Hazzit et al. (2006) reported that Marjoram species show significant antimicrobial activity and its prolonged use may reduce gut bacteria. The
composition of the essential oils of *Origanum* was determined and the oils were strongly characterized by p-cymene (16.8-24.9%), gamma-terpinene (16.8-24.9%), thymol (8.4-36.0%), and carvacrol (1.1-29.7%). A thymol chemotype for *Origanum floribundum* was described for the first time. Antioxidant and antibacterial activities of the isolated essential oils were also determined.

Leeja and Thoppil (2007) have reported the anti-microbial activity of the methanol extract of *Origanum majorana* L. against *Fusarium solani, Candida albicans, Aspergillus niger, Aspergillus parasiticus, Rhizopus oryzae, Rhizoctonia oryzae-sativae, Alternaria brassicicola, Bacillus subtilis, Bacillus megaterium, Escherichia coli, Proteus vulgaris, Pseudomonas aeruginosa* and *Staphylococcus aureus*. They suggested that the methanol extract of *Origanum majorana* because of its strong microbicidal property and superiority over commercial microbicides, may prove to be an effective, non-toxic and eco-friendly herbal protectant against a wide spectrum of pathogenic bacteria and fungi.

Busatta et al. (2008) reported the antimicrobial activity of Marjoram essential oil in fresh sausage against several species of bacteria, but noted that the addition of high concentration of the essential oil could alter the taste of the product.

Leelavathi (2009) has conducted a comparative study of the antibacterial activity of crude extract of in vivo and in vitro leaves of *Origanum vulgare* against *Staphylococcus aureus* and reported that in vitro leaf extract showed better antibacterial activity.

Barbosa et al. (2009) reported that essential oil from Marjoram was effective against food-borne pathogens and spoilage bacteria in minced meat.
Anjana Rao et al. (2010) tested the efficacy of Oregano oils against *Saccharomyces cerevisiae* by yeast toxicity assays. It was observed that the Oregano oil effectively prevented the growth of yeast up to a dilution of 1:8 and no colonies appeared even after prolonged incubation exhibiting potent fungicidal activity.

Olfa Baatour et al., (2012) investigated the composition of the essential oil of *Origanum majorana* and observed that terpinen-4-ol, α-terpineol and linalool exhibited high antibacterial activity. They also stated that the essential oil is known for its strong antimicrobial activity and could therefore be used in food applications.

Badee et al. (2013) investigated the antimicrobial effects of the essential oil of Marjoram by Agar disc diffusion assay and observed that all the microorganisms tested were susceptible to the action of Marjoram oil. *Candida albicans* was the most sensitive strain tested with the broadest inhibition zone and *Aspergillus flavus* was the most resistant with the smallest inhibition zone. The study concluded that the essential oil might be used as a natural preservative ingredient in food industry.

Tejavathi and Padma (2013) conducted a comparative study of the antibacterial activity of the crude extracts of normal and micropropagated plants of *Majorana hortensis* against *Serratia marcescens, Proteus vulgaris, Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa* and *Klebsiella pneumoniae* and reported that the methanolic extract of regenerates showed better antibacterial activity.
ANTIOXIDANT ACTIVITY

Assaf et al. (1987) while analysing the phenolic glycosides of *Origanum majorana* observed that the bioactive compounds in Marjoram are responsible for different biological activities including antioxidant potential and free radical scavenging properties.

Damien et al. (1995) evaluated the essential oil of *in vitro* plants of *Origanum vulgare ssp. hirtum* for their natural antioxidant properties.

Gerothanassis et al. (1998) reported the antioxidant activity of plant extracts of two species of Oregano. Nakatani (2000) studied the phenolic acids from herbs and spices and stated that the different chemical compounds present in Marjoram possess different biological effects including antioxidant and free radical scavenging properties.

Woo et al. (2001) isolated T3b, a purified compound with antioxidant properties from the methanol extract of *Origanum majorana* and investigated the *in vitro* scavenging activity of T3b on superoxide anion radicals. The results were compared with those of seven commercially available antioxidants and the strongest scavenging action was observed in T3b.

Kelly (2004) studied herbal medicines and reported that Marjoram possesses antioxidant and free radical scavenging properties due to the presence of bioactive chemicals in the essential oil. El-Ghorab et al. (2004) also reported that Marjoram possesses antioxidant properties.

Vagi et al. (2005) studied the antioxidant activities of various extracts of *Origanum majorana* obtained using different solvents. The antioxidants were quantified by High performance liquid chromatography.
Biljana et al. (2006) studied the antioxidant activity and antimicrobial effects of the essential oil extracted from the aerial parts of *Origanum vulgare* L. The chemical characterization of the essential oil was done by GC-MS.

Ramy Romeilah (2009) investigated the Anticancer and Antioxidant activities of *Majorana hortensis* and found that abundance of volatile compounds in the essential oil contributed to significant antioxidant activity. The antioxidant activity of the oil was determined by DPPH radical scavenging assay using vitamin C as the reference antioxidant compound. The radical scavenging activity was mainly attributed to the presence of Terpinen-4-ol, γ-terpinene and α-terpineol. They opined that the essential oil may help prevent oxidative damage in the human body like lipid peroxidation which is associated with cancer, premature aging, atherosclerosis and diabetes. The results showed that the essential oil could be used as a potential natural antioxidant and anticancer agent.

Ahmed et al. (2009) conducted biochemical and histo-pathological studies on the aqueous extracts of Marjoram and stated that the various phytochemicals in the plant are responsible for the antioxidant properties. Misharina et al. (2009) also reported that the various chemical compounds in the essential oil of Marjoram are responsible for the antioxidant and radical scavenging properties of the plant.

Radha Palaniswamy and Padma (2011) while investigating the free radical scavenging activity of *Majorana hortensis* leaves observed that the methanolic extract of leaves exhibited maximum scavenging activity followed by the aqueous extract and chloroform extract. The scavenging effects were evaluated against DPPH, ABTS, Hydrogen Peroxide, Superoxide, Nitric oxide and hydroxyl radicals. Among the various
oxygen derived free radicals, Hydroxyl radical is the most highly reactive and harmful one in living organisms. The extent of Thiobarbituric acid reactive substance (TBARS) produced is a measure of Hydroxyl radical formation as also H₂O₂- induced damage to deoxyribose. The efficiency of inhibition of TBARS formation was far superior in Methanolic extract followed by Aqueous and Chloroform extracts. They stated that the ability of *Majorana hortensis* leaf extracts to effectively scavenge Superoxide and Nitric oxide radicals reveals strong free radical scavenging potential of the leaves. The results of their study have proved that the plant can be used as an effective antioxidant to prepare any formulation which needs to be enriched with antioxidants.

Radha and Padma (2011) studied the effect of *Majorana hortensis* leaf extracts on the apoptotic events in *Saccharomyces cerevisiae* cells subjected to oxidative stress and observed that the methanolic extract of the leaves significantly increases the cell viability and conditions of oxidative stress. Their observations indicated that the leaf extracts exerted anticancer effects towards cancer cells and rendered protection to non-cancerous cells. They suggested that the leaves can alleviate the oxidative stress imposed on normal cells.

**APPLICATION OF AMF AND BIO-FERTILIZER TREATMENT STUDIES**

A few studies have been carried out to establish the role of Arbuscular Mycorrhizal Fungi in enhancing the productivity of essential oil bearing plants (Copetta et al., 2006; Khaosaad et al., 2006).

Information about the effects of AM Fungi on the production of essential oils in *Majorana hortensis* are scarce and only a few papers concerning a limited choice of species have been published up to now.
Edris et al. (2003) reported that the percentage of essential oil, fresh and dry matter of Marjoram plants positively responded to increased levels of composted manure compared to treatment with chemical fertilizers.

Study by Khaosaad et al. (2006) on Oregano showed that colonization by AMF increases the amount of shoot biomass and has an effect on oil yield.

Morone-Fortunato and Avato (2008) studied the influence of Mycorrhizal inoculation on micropropagated plant growth, development of secretory structures and production of essential oils. The Normal and Micropropagated plants of *Origanum vulgare* ssp. *hirtum* were inoculated with AM fungus, *Glomus viscosum* and the observations were recorded at different development stages. During the vegetative stage, the percentage of mycorrhizal colonization, fresh and dry shoot and root weight, leaf area index and root/shoot fresh weight ratio were determined. At the flowering stage, the number of spicasters, verticillasters, spikes and florets were noted. The positive effect of AM inoculation was evident on all growth parameters suggesting that the performance of regenerated plants was improved by the combination of two technological approaches, Micropropagation and Mycorrhization. The histological investigation of the plants revealed two types of secreting trichomes – capitate and peltate glandular hairs on the leaf surface which were identical in their structure in normal and regenerated plants but more in number in the AMF treated regenerated plants. The essential oils were extracted by steam distillation of aerial parts followed by analysis by GC and GC/MS. The essential oil yield was much higher in micropropagated AM treated plants than in normal control plants. Carvacrol was the main volatile compound in the essential oil along with other minor constituents like γ-terpinene, p-cymene, cis and trans-sabinene hydrate, linalool,
borneol etc. and the chemical profile between micropropagated and normal plants with and without AMF treatment was relatively uniform.

Gharib et al. (2008) studied the effect of compost and bio-fertilizers on growth, yield and essential oil of Sweet Marjoram and observed that inoculation of Marjoram with 15% and 30% aqueous extracts of compost and/or bio-fertilizers have beneficial effects on plant growth, essential oil content and dry matter yield due to hormonal stimulation of root development and by supplying combined nitrogen.

They suggested that increase in essential oil yield in *Majorana hortensis* on account of compost and bio-fertilizer treatment may be due to either increase in vegetative growth or changes in leaf oil-gland population and monoterpene biosynthesis. During the investigation, thirty compounds accounting for more than 98% of the total volatiles were detected and identified. The major compounds were Terpinen-4-ol, cis-sabinene hydrate, p-cymene, γ-terpinene, sabinene and α-terpinolene.

Gharib et al. (2008) also reported that Mycorrhizal root colonization, nitrogen-fixing bacterial population, protein content, macro element content and Nitrogenase enzyme activity in *Majorana hortensis* is enhanced by the application of aqueous extract of compost and bio-fertilizers. Compost at 15% significantly influenced the indigenous AMF infectious propagules in the soil.

Thus, the review of literature pertaining to various aspects of *Majorana hortensis* was useful in taking forward the study of the plant.