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Essential Oils for Pest Control

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Essential Oil of Thymus vulgaris L. for Pest Control

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Thymus vulgaris is a flowering plant of the mint family Lamiaceae. It grows up to 15–30 cm tall by 40 cm wide. Thyme is cultivated in most European countries, including France, Switzerland, Spain, Italy, Bulgaria, Portugual, and Greece. The yield and quality of oil obtained from the thyme plant varies in line with the genetic variations. The essential oil distilled from the thyme plant is mostly used in preservation (meat and butter) and in making chewing gum and ice cream. Thyme oil is also known for its antibacterial, anti-inflammatory, antiviral, antioxidant, antifungal, and insecticidal activities.

17.1 Classification

Kingdom: Plantae
Class: Magnoliopsida
Order: Lamiales
Family: Lamiaceae
Genus: *Thymus*
Species: *vulgaris*
Scientific name: *Thymus vulgaris* L.

17.2 Vernacular Names

The vernacular names of *T. vulgaris* L. are wild thyme, creeping thyme, mountain thyme, common thyme, farigola, garden thyme, herbatimi, herbathymi, mother of thyme, red thyme, rubbed thyme, thick leaf thyme, thym, thymian, thyme, timi, and tomillo.

17.3 Origin and Distribution of *Thymus vulgaris* L.

The general name for the many herb varieties of the *Thymus* species is thyme. Each variety is native to Europe and Asia. Garden thyme or common thyme is considered the principal type, and is used commercially for ornamental and flowering purposes. Thyme is also distributed to the western Mediterranean region, extending to southeastern Italy. In Greek, the name *thyme* was first given to the plant as a derivative of a word that meant "to fumigate," because of its use as incense, for its balsamic odor. Others derive the name from the Greek words *thyo*, meaning "perfume," and *thumus*, meaning "courage." In ancient and medieval days, the plant was held to be a great source of invigoration, with its pleasant qualities inspiring courage. Another source quotes its use by the Sumerians as long ago as 3500 BC, and to the ancient Egyptians, who called it tham.

17.4 Production of *Thymus vulgaris* L.

In South Africa, some producers distill thyme for essential oil production. Most of the thyme produced is for the fresh and dried market. Yields of *T. vulgaris* for fresh herb production can be 5–6 t/ha, and for dry herb, production can be 2 t/ha. Thyme will yield about 15 tons of plant material per hectare per year, at an oil recovery rate of 0.5%–1%, or 75 to 150 kg/ha/year under irrigation conditions. Under dry land conditions, considerable variation in yields is found. Internationally, thyme is produced from cultivated and wild harvested plants in most European countries, including Switzerland, France, Spain, Bulgaria, Italy, Portugal, and Greece. The quality and yield of the essential oil vary according to the genetic material of the plant, harvesting at crop maturity, the environment, and the distillation process. About 90% of the production of thyme oil for world trade is obtained from Spain. In southern Europe, farmers and herb growers benefit from the longer growing season, according to climate advantages. Therefore, most thyme is produced in Europe. Cultivation of the herb for trade mainly occurs in Spain, France, Italy, and Bulgaria. In hot summer conditions, essential oil yields approximately 1.0% (10 ml of oil/kg fresh thyme) from wild thyme, while it may decrease to 0.10% in the winter. As per variety, essential oil yields from cultivated material range from 0.05% to 0.50%. However, herbage yields under cultivation far exceed production in the wild, so more oil is produced per hectare in cultivated crops. Selected cultivars in Switzerland yield 3% essential oil from fresh herbage of more than 15 t/ha. Thyme can be grown in most provinces of South Africa. The Western Cape is climatically the closest to the Mediterranean area, where thyme grows naturally in the wild. The plant is very adaptable and therefore performs well in other climatic zones, for example, Kwa Zulu-Natal, Gauteng, and Mpumalanga. It does well in drier parts, such as the Karoo, but irrigation is needed.

17.5 Botanical Description of the Plant

17.5.1 Stem

The stem is perennial, aromatic, and a subshrub, 20–30 cm in height, with ascending, quadrangular, grayish-brown to purplish-brown lignified and twisted stems bearing oblong-lanceolate to ovate-lanceolate grayish green leaves with pubescence on the lower surface. The flowers have a pubescent calyx and a bilobate, pinkish or whitish corolla, and are borne in verticillasters. The fruit is made of four brown ovoid nutlets. It has both horizontal and upright habits. With age, the stems become woody.

17.5.2 Leaves

Leaves of thyme are tiny, usually 2.5–5 mm in length, and differ considerably in shape and hair covering, depending on the cultivar, with each species having a slightly different scent. It is sessile or has a very short petiole. The lamina is entire, tough, and covered on both surfaces by a gray to greenish-gray indumentum; lanceolate to ovate, the edges

are markedly rolled up toward the abaxial surface. The adaxial surface of the midrib is depressed and is very prominent. The calyx is green, regular with violet spots, and is tubular. At the end are two lips, of which the upper one is bent back and has three lobes on its end; the lower is longer and has two hairy teeth. After flowering, the calyx tube is closed by a crown of long, stiff hairs. The corolla, about twice as long as the calyx, is usually brownish in the dry state and is slightly bilabiate. *T. vulgaris* leaves are oval to oblong in shape and somewhat fleshy. Leaves are almost stalkless, with margins curved inward and highly aromatic. The fragrance of its leaves is the result of an essential oil, which gives it its flavoring value for culinary purposes, and is the source of its medicinal properties.

17.5.3 Flowers

The flowers terminate the branches in whorls. The calyx is tubular, striated, closed at the mouth with small hairs, and divided into two lips, the uppermost cut into three teeth and the lower into two. The corolla consists of a tube about the length of the calyx, spreading at the top into two lips of a pale purple color, the upper lip erect or turned back and notched at the end, and the under lip longer and divided into three segments.

17.5.4 Seeds

The seeds are round and very small and retain their germinating power for 3 years.

17.5.5 Thyme Cultivars

The genus *Thymus* consists of approximately 215 species with several hybrids. Three principal varieties, the broad-leaved, narrow-leaved, and variegated varieties, are usually grown for use. The narrow-leaved type, with tiny, gray-green leaves, is more aromatic than the broad-leaved thyme (winter or German thyme). Broader leaves than the ordinary garden thyme differentiates it from others; the fragrant lemon thyme has a lemon flavor. It is not curved at the margins, and is marked as a variety of *Thymus serpyllum* (the wild thyme). Dominating all thyme with a strong flavor is silver thyme. The most cultivated thymes used for culinary and essential oil extraction are as follows:

- *Thymus vulgaris*: Common thyme; prostrate form; yellow, silver, and variegated foliage available; used in cooking
- *Thymus zygis*: Like above; mostly distilled for essential oil
- *Thymus* × *citriodorus*: Lemon thyme; upright form; golden and variegated silver foliage available; strong lemon scent

Varico, a robust cultivar, has an erect growth form with grayish-blue foliage and a great herbage yield. It contains thymol concentrations up to 50% and higher, as well as more than a 3% essential oil yield. It is immune to frost and can be propagated with seeds. Other promising new cultivars are currently being developed in various countries. Approximately 66 different species and hybrids have been selected for the color of their leaves and flowers, and are mainly used as ornamental shrubs.

17.6 Soil and Climatic Requirements

Thyme grows well in temperate to warm, dry, sunny climates. It does not grow well under shade. It needs full sunlight for best growth. Extreme moisture makes thyme more susceptible to rot diseases. Rainfall in the Mediterranean region is 500–1000 mm/year, mainly in winters, where thyme is cultivated in the majority. Thyme grows well in appropriately drained soils with a pH of 5.0–8.0. Thyme species do excellent in coarse, rough soils. Although thyme grows easily, especially in calcareous light, dry, stony soils, it can be cultivated in heavy wet soils, but it becomes less aromatic.

17.7 Cultivation Practices

17.7.1 Propagation

Propagation of thyme proceeds from seeds, layering, and stem cuttings. Plantations are enhanced by dividing the plants at their roots. Seeds are sown in the spring below 6 mm or less from the soil level. Seeds germinate in about 2 weeks. Seeds planted in trays take 6–8 weeks to reach transplant readiness. The seedlings are transplanted outdoors after the danger of frost has passed. If established and growing well before winter, the small plants can withstand frost. The source of thyme seed has to be known, as there are possibilities of hybridization. To have homogeneous plants, it is advisable to make cuttings. Thyme grows easily from 5 to 10 cm cuttings taken in the spring. Promoting hormones for roots may be beneficial. Take care not to use this method if any harmful soil organism is present.

17.8 Soil Preparation

Thyme can be planted successfully in very shallow soil, where other crops cannot grow. High-quality yield products are obtained from herbal and essential oil crops grown in natural soils. Soil analyzed at the laboratory can be checked for mineral deficiencies and excesses, carbon ratios, and organic status. A soil analysis will lead farmers to correct the nutrient composition of the soil. It provides the crop with optimum growing conditions, like balanced mineral status and correct pH. Soil fertility levels should be within acceptable ranges. Soil parameters like pH and minerals contained should be corrected accordingly to cultivate *T. vulgaris*. Fertilizer use has to be planned according to whether the crop will be grown inorganically or organically. Organic soil preparation practices are encouraged to ensure that the organic matter and soil microorganisms are present.

17.8.1 Pest Control

The volatile oils of the plants have pest-repellent properties; therefore, pests on thyme are not very frequent. However, whitefly, scale, and spider mites may infest the plants. For prospective

producers of herbal and essential oil crops, some of following pest control guidelines are recommended.

- The preliminary option is to choose natural pest control measures.
- A pest management program should be strictly followed.
- Regular inspection of the crop is needed.
- Major problems can be prevented by early detection and management of pest control.
- Exact identification of pests for natural beneficial predators is necessary.
- Introduce and use biological controls, natural predators, parasites, nematodes, fungi, bacteria, and beneficial microorganisms. Use of chemicals that kill such organisms should be avoided.
- Other organic methods, such as insecticidal soaps, reflective mulches, traps, plant extracts, and handpicking of pests, water sprays, and vacuum may be used.

Effective controls may be used that target specific taxonomic groups, eating habits, or life stages: insecticidal soaps, horticultural oils, pheromones, and growth-regulating natural substances such as neem oil. For pest control, knowledge of certain herbs that repel or attract insects can be used in companion plantings. If organic practices will be used, make sure that products are certified for use. For more information on the identification of insects and for recommended controls, contact agricultural institutes. In wetter environments with improper soil drainage, *Rhizoctonia* root rot can cause problems. Thyme plants can get a few diseases, like rust, *Alternaria* blight, and *Botrytis*.

17.9 Harvesting

Thyme is harvested for essential oil once per year, during the late summer, when flowering begins. In certain conditions, two harvests per year are achievable. For dried produce, harvest stems and leaves just as flowering begins, cutting the entire plant back to about 10–15 cm above the ground. For fresh produce, harvest only the tips of the branches, so the plants are strong enough to produce enough young shoots. To produce a uniform product, the dried product should be processed to remove the leaves from the stems, and then sieved to remove dirt. Numerous methods exist for drying, from natural sunrays to human-made sophisticated driers. The use of sun-drying methods results in poor-quality essential oil. Artificial drying methods result in better control of product quality. A forced-airflow drier is a suitable system to dry better-quality leaves. To reduce loss of flavor through volatilization of essential oil, and to maintain a good green color, thyme should be dried at temperatures lower than 40°C. After drying, the leaves should be separated further from the stems, sieved, and graded. Fresh product has to be clean of foreign material and look fresh and crispy, with a good color and flavor.

17.9.1 Grading of *Thymus vulgaris*

Grading of dried thyme depends on the quality requirements prescribed ISO 6754:1996. The standard prescribes certain requirements of the finished product. The essential oil content of the dried herb is an important factor contributing to the flavor intensity. To meet

the requirements, whole thyme leaves should contain a minimum of 0.5% essential oil, which equals 5 ml/kg dried herb, and ground thyme should contain at least 0.2% essential oil. For essential oil production, there is a different range of chemotypes occurring in thyme. There are at least six different chemotypes of importance: thymol, carvacrol, linalol, geraniol, thuyan-4-ol, and α-terpinyl acetate. The most frequent are thymol and carvacrol, which are generally extracted from plants growing near sea level, and linalool, which is generally extracted from plants occurring at higher altitudes. The geraniol, thuyan-4-ol, and α-terpinyl acetate chemotypes are rare and found mixed with the first three chemotypes. There is a current recovery in the demand for thymol used in the pharmaceutical industry, owing to its powerful properties as a disinfectant.

17.10 Storage

Essential oil of thyme should be stored in a cool, dry area until it is used. Oil should be kept in dark, airtight glass bottles and not be exposed to heat or heavy metals. Once opened, the vial of essential oil should be refrigerated, and tightly closing the cap will prolong its shelf life. Deterioration begins if the liquid is much darker or more viscous than normal.

17.11 Extraction of Oil

Dried and ground parts of plants are cut into small pieces and subjected to hydrodistillation for 3 hours using a Clevenger-type apparatus; the oils obtained are dried using anhydrous sodium sulfate. Essential oil yielded from the air-dried plant parts of *T. vulgaris* was 1.6%. For extraction of essential oil, Ivan (2013) used different green solvents, namely, ethanol, limonene, and ethyl lactate, to extract thymol from thyme plants. Ethyl lactate and limonene are agrochemical solvents, easily biodegradable, with polarities in the range of acetonitrile and hexane, respectively. Both solvents are generally recognized as safe (GRAS) and approved by the U.S. Food and Drug Administration as pharmaceutical and food additives. Further, the high solubility of thymol in ethyl lactate has been recently determined and reported by the authors. They used pressurized liquid extraction (PLE) in an ASE 350 system with the three green liquid solvents at different extraction temperatures (60°C, 130°C, and 200°C), employing *T. vulgaris* as the model thyme variety. Then, the extraction of thymol from other thyme varieties (*T. zygis* and *Thymus citriodorus*) was studied. The extraction yield and thymol recovery obtained from the different extracts were quantified and compared. The three green solvents have shown good capacity to extract thymol from thyme plants.

17.12 Chemical Composition of the Essential Oil

The essential oil from *T. vulgaris* shows a high content of oxygenated monoterpenes (56.53%) and low contents of monoterpene hydrocarbons (28.69%), sesquiterpene hydrocarbons

(5.04%), and oxygenated sesquiterpenes (1.84%). The predominant compound among the essential oil components is thymol (51.34%), while the amount of all other components of the oil is less than 19%. Thyme oil monoterpene hydrocarbon content is made up of p-cymene and g-terpinene. Alcohols such as linalool, a-terpineol, and thujan-4-ol are also present (Thompson et al. 2003; Khan and Abourashed 2010). Gas chromatography–mass spectrometry (GC-MS) analysis identified the two primary constituents of thyme oil as thymol (57.8%) and p-cymene (28.6%), with all other constituents making up <5% of the total. The aerial parts of *T. vulgaris* collected from Western Ghats of India were analyzed for essential oil by gas chromatography. Forty-eight compounds were detected, among which 36 compounds, constituting 98.63% of the oil, were identified, with thymol (61.6%), p-cymene (11.2%), ϒ-terpinene (7.4%), methyl thymol (3.9%), methyl carvacrol (3.3%), and β-caryophyllene (2.3%) being the major chemical constituents (Syamasundar 2008). El-Nekeety et al. (2011) reported that the oil contains carvarcrol (45 mg/g), thymol (24.7 mg/g), β-phellandrene (9.7 mg/g), humuline (3.1 mg/g), α-phellandrene (2.3 mg/g), and myrcene (2.1 mg/g). However, α- and β-pinene, myrcene, α-thyjone, tricyclene, 1,8-cineole, and β-sabinene were found in very low concentrations. The density and refraction index of the essential oil of thyme at 20°C are 0.944 g/ml and 1.507, respectively (Viuda-Martos et al. 2008).

17.13 Essential Oil Market

The world major market for thyme essential oils is the United States, Japan, and Europe. Production continues to be concentrated in Europe, with seven of the world's largest essential oil processing firms. In the United States, the major users of essential oils are the soft drink companies. Japan accounts for 10% of the world demand. The Canadian market is dominated by the U.S. perfume and flavoring industry. France dominates the world perfumery market, and Switzerland is one of the leaders in the pharmaceutical field. Britain and India are known to feature strongly in the flavoring sector. Most countries import all their dried thyme mainly from Spain and Morocco, the major world producers. Most bulk dried herbs are produced in countries with low labor costs, so the challenge to producers in South Africa is to produce crops of superior quality at a competitive price. The essential oil component, thymol, has a wide range of uses in the manufacturing of liqueurs, perfumes, pharmaceutical products, and toilet articles. The essential oil of thyme is used to preserve processed meat and butter, and in making chewing gum, ice cream, candy, and Benedictine liqueur.

17.14 Various Properties of Thyme Oil

17.14.1 Medicinal Properties

Thyme is prescribed with other herbs for asthma and hay fever, and is often used to treat worms in children. Thyme has been thought of as an antiseptic, antimicrobial, astringent, anthelmintic, carminative, and tonic. Thyme is incredibly useful in cases of assorted intestinal infections and infestations, like hookworms, ascarids, gram-positive and gram-negative bacterium, fungi, and yeasts, as well as *Candida albicans*. Its active constituent, thymol, is active against enterobacteria and cocci bacteria. Thyme may also improve liver functioning,

and act as an appetite stimulant. It can be used in the treatment of cartilaginous tube, bronchial, and urinary infections. Used as a gargle, thyme is helpful in the treatment of laryngitis and inflammation. It is used for skin issues like oily skin, sciatica, acne, dermatitis, and bug bites. The thymol-rich *T. vulgaris* essential oil, known as "red thyme oil," has strong antiseptic activity; the linalool-rich essential oil, known as "garden thyme," has potent antiparasitic and antifungal properties; and the thujanol-rich essential oil, known as "sweet thyme," has antiviral properties. These essential oils are used in aromatherapy to stimulate the mind, strengthen memory and concentration, and calm the nerves. "White thyme oil" is also used, and it is milder on the skin. Applied to the skin, thyme relieves bites and stings and rheumatic aches and pains (Prasanth et al. 2014). Other authors have reported the medicinal uses of thyme species (Zarzuelo and Crespo 2002; Saleh et al. 2015).

17.14.2 Anti-Inflammatory Activity

T. vulgaris oil is a combination of monoterpenes. The main compounds of this oil are the natural terpenoid thymol and its phenol chemical compound carvacrol (Namsa et al. 2009), which have antioxidative, antimicrobial, medicinal drug, antitussive, antispasmodic, and antibacterial effects. Terpenoids, flavonoid aglycones, flavonoid glycosides, and synthetic resin acids were additionally found in *Thymus* spp.

17.14.3 Antibacterial Activity

The essential oils obtained from *T. vulgaris* L. harvested at four biological process stages were evaluated for their biological activity and chemical components. The thyme volatile oils were studied for their inhibition effects against nine strains of gram-negative bacteria and six strains of gram-positive bacteria. The bioimpedance methodology was used for antibacterial activity of the essential oils, and the parameter chosen for outlining and quantifying the antibacterial activity of the thyme oils was the detection time. The plate-counting technique was used to study the inhibitory effect by direct exposure. All the thyme essential oils examined had a significant bacteriostatic activity against the microorganisms tested. This activity was additionally marked against the gram-positive bacteria. The oil from full thyme flowers was the most effective at stopping the growth of the microorganism species examined. The oils tested were conjointly shown to possess smart antibacterial activity by direct contact against the gram-negative microorganism. The main component of the essential oil of thyme, thymol, is active against *Salmonella* and *Staphylococcus* bacteria. The antiseptic and tonic properties of thyme make it a useful tonic for the immune system in chronic, especially fungal, infections, as well as an effective remedy for chest infections such as bronchitis, whooping cough, and pleurisy. Thyme and thyme oil have been used as fumigants, disinfectants, and mouthwashes. The pleasant-tasting infusion can be taken for minor throat and chest infections, and the fresh leaves may be chewed to relieve sore throats (Viuda-Martos et al. 2008).

17.14.4 Antiviral Properties

Nolkemper et al. (2006) conducted an experiment with aqueous extracts from species of the Lamiaceae family. These were examined for their antiviral activity against herpes simplex virus (HSV). Extracts from thyme (*T. vulgaris*) showed inhibitory activity against herpes simplex virus types 1 and 2 (HSV-1 and HSV-2), and an acyclovir-resistant strain of HSV-1 was tested *in vitro* on RC-37 cells in a plaque reduction assay.

17.14.5 Antioxidant Properties

Antioxidants are those compounds that inhibit the oxidation of different molecules. Oxidation is a chemical process that transfers electrons or hydrogen from a substance to an oxidizing agent. This reaction produces free radicals. In turn, these radicals begin chain reactions. Once the chain reaction happens in a cell, it causes damage or death to the cell. Antioxidants stop these chain reactions by removing free radical intermediates, and inhibit different oxidation reactions. The leafy parts of thyme and its oil are utilized in foods for flavor, aroma, and preservation, and additionally in folk medicines. El-Nekeety et al. (2011) conducted an experiment to work out the elements of *T. vulgaris* L. oil and evaluate the protecting effects of this oil against aflatoxin-induced oxidative stress in rats. Treatment with aflatoxins alone disturbs the lipid profile in blood serum, decreases the total antioxidant capability, and increases creatinine, uric acid, and nitric oxide in blood serum and lipid peroxidation in the liver. Amiri (2012) reported that thyme has potential antioxidant activity.

17.15 Insecticidal Activity

The insecticidal activity of thyme volatile oil, thymol, and carvacrol was evaluated in the laboratory against completely different larval stages of lesser mealworm. The first and later larval stages were reared on diets containing one or two acetone solutions of tested compounds. The insecticidal activity of thyme volatile oil and pure monoterpenes against *Alphitobius diaperinus* larvae relied on the dose and age of the larvae. The growth of younger larvae was considerably affected, whereas that of the older larval stage was less influenced, and only by pure oil components. In young larvae, the application of 1% thyme oil, thymol, and carvacrol caused mortality of 50.0%, 86.67%, and 85%, respectively. Choi et al. (2003) tested the efficacy of oil against greenhouse whitefly adults, nymphs, and eggs. At the highest rate of 9.3×10^{-3} concentration, thyme oil caused 100% mortality in adults and 88% mortality in eggs. However, there were many other oils in this study, including clove and peppermint, which provided greater mortality when tested at lower rates. In a study by Shaaya et al. (1991), thyme oil had highly toxic fumigant toxicity against the stored grain pest sawtoothed grain beetle (*Oryzaephilus surinamensis*). Among constituents tested in the same study, carvacrol, linalool, and a-terpineol were also highly toxic. Machial et al. (2010) tested 17 essential oils for their toxic effect on two Lepidopteran species, the oblique-banded leafroller (*Choristoneura rosaceana*) and the cabbage looper (*Trichoplusia ni*), in which thyme oil was the second most toxic on first-instar *C. rosaceana* larvae, with 64% mortality at a concentration of 5.0 µl/ml, superseded only by the 97% mortality with patchouli oil at the same concentration. Despite thyme oil's potency on *C. rosaceana*, it was one of the least toxic essential oils on first-instar *T. ni*. Leila et al. (2014) reported that the greatest toxicity was observed at 250 µg/L of essential oil, with the LC_{50} values of 134.1 µg/L after 24 hours using essential oil of *T. transcaspicus*. It exhibited strong insecticidal activity against *Anopheles stephensi*, which can be attributed to its constituents, especially carvacrol and thymol phenols. Maqtari et al. (2011) and Marino and Bersani (1999) studied the composition of essential oil and its potent effect on antimicrobial activity.

17.15.1 Antilarval Activity

The essential oil of *T. vulgaris* L. was studied by Elham et al. (2014) for its toxicity and physiological effects on the lesser mulberry pyralid *Glyphodes pyloalis* Walker in controlled conditions. The leaf disc method was used to study acute toxicity; the effects of LC_{10}, LC_{30}, and LC_{50} on the feeding efficiency of fourth-instar larva; and biochemical indices. The essential oil doses of LC_{10}, LC_{30}, and LC_{50} were estimated to be 0.107%, 0.188%, and 0.279% for *T. vulgaris*. The authors found that *T. vulgaris* was more toxic than other essential oils. The essential oil sublethal dose LC_{30} affected the nutritional indices of fourth-instar larvae of *G. pyloalis*. The essential oils reduced total protein, carbohydrate, and lipid. Some concentrations of essential oils changed the activity level of α-amylase, protease, lipase, general esterases, and glutathione S-transferase (GST), but others showed no effect on these enzymes. It was concluded that the essential oil concentrations used were toxic to *G. pyloalis* and showed irreversible effects on key metabolic processes; therefore, the used essential oil concentrations may be considered alternatives to the classic pest control agents. Fouad et al. (2016) evaluated the potential larvicide of essential oils from aromatic *T. vulgaris* cultivated in northeast Morocco on the malaria vector *Anopheles labranchiae*. The sample showed larvicidal activity against larvae in stages 3 and 4. The *T. vulgaris* essential oil demonstrated an LC_{50} of the order of 351.63 µg/ml and an LC_{90} of 621.34 µg/ml. According to the authors, the results open interesting perspectives for the application of essential oil of *T. vulgaris* in the production of biocides. Szczepanik et al. (2012) has reported the essential oil of thyme to be a powerful antilarval agent.

17.15.2 Acaricidal Activity

Mansour et al. (2015) have investigated acaricidal effects of thyme essential oil on *Dermanyssus gallinae*. The authors used a filter paper contact test. Thirty live adult female mites were exposed to different concentrations of each examined compound for 2, 4, 6, and 24 hours. The mortality rate of mites at each concentration and time was recorded, and each treatment was performed in triplicate. Thyme essential oil showed acaricidal activities, and the effects of exposure time and concentration on mortality rate were significant ($p < 0.05$). The highest mortality was achieved at 24 hours. The authors suggested that essential oil of thyme is a potent green pesticide.

17.15.3 Insect-Repellent Activity

T. vulgaris is a good companion crop that repels cabbage fly, whitefly, and aphids. Only a few thyme species are used as landscape ornamentals (Chintalchere et al. 2013). Thyme is excellent for rock gardens. Creeping thyme tolerates occasional foot traffic and can be used between stepping stones along garden paths. Thyme can also be utilized as an edging or border plant in herb gardens.

17.15.4 Antifungal Activity

Shazia and Muzafar (2011) reported that volatiles of thyme oil were extremely effective in reducing gray mold and soft rot incidence in strawberry fruits caused by *Botrytis cinerea* and *Rhizopus stolonifer*, respectively.

17.16 Conclusion

T. vulgaris is a good source of essential oil, having pesticidal, insecticidal, larvicidal, and mosquitocidal activity. These activities are attributed to the presence of thymol as a principal active compound. Apart from the above activities, the plant possesses various pharmacological activities, such as antioxidant, anti-inflammatory, and antimicrobial activities. All types of activities are attributed to the presence of biological compounds of therapeutic use. These biological activities make this plant economically important. Scanty information is available worldwide, opening a new vista of research and development in various areas.

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