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PLANT AND FOOD PHENOLICS – CHEMISTRY, FUNCTIONALITY AND PRACTICAL APPLICATIONS

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Review Based Book Chapter

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REVIEW BASED BOOK CHAPTER

PHENOLIC COMPOUNDS AND BIOACTIVITY APPLICATIONS OF ESSENTIAL OILS IN AGRICULTURE

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Abstract

Essential oil is considered to be the best alternative approach as natural pesticide against various noxious weeds, pathogens and agricultural pests that damage crops. The global annual use of pesticides on crops is estimated approximately to be 2.5 million tons annually producing the global $100 billion harms. Excessive use of synthetic pesticides is the main cause of environmental problems due to their toxic and non-biodegradable residue which ultimately affect the humans and mammals. Now-a-day scientists are shifting toward green pesticides in which they are using plant products comprising of essential oil as an alternative means against synthetic pesticides. Essential oil extracted from plants by performing different extraction techniques are rich source of bioactive compounds still safe for human and other organisms. Essential oil components are classified into two categories: hydrocarbons and oxygenated compounds. Hydrocarbons mainly consist of terpenes such as monoterpenes, diterpenes and sesquiterpenes. While oxygenated compounds are mainly comprised of phenols, alcohols, aldehydes, ketones, oxides and esters. Essential oil phenolic compounds include vanillic acid, carvacrol, carnosol, thymol, eugenol and chavicol etc. Among these, phenolic compound thymol and carvacrol disrupt the cell membrane of insects resulting in reduced permeability. Phenols, alcohols and aldehydes are oxygenated bioactive compounds of essential oil that possess strong toxicity against various pathogens. Various research indicated that essential oils containing bioactive components offer anti-fungal and anti-bacterial properties against toxic bacteria and fungi. Essential oil due to their phenolic components can perform various functions as bio-pesticide, bio-fertilizer and can result in crop protection against various pathogens with safe environmental impact rather than synthetic alternates.

Keywords
Essential Oil, Phenolic Components, Herbicide, Bio-pesticide, Anti-microbial, Green Pesticide

Introduction

Essential Oil as Natural Herbicide

Weeds in the agriculture system compete for sunlight, nutrients, and water leading to lower crop output. Weed interference is expected to reduce by 34% agricultural output [1-3]. To get rid of this unnecessary growth of weed farmers relies on synthetic herbicides. Main disadvantage of using synthetic herbicides is that these often persist in the environment for a long time being non-biodegradable. As a result, it contaminates the environment and poses risk to non-targeted plants, animals and human also. Due to these challenges associated with synthetic herbicides, people are shifting towards the use of natural source like essential oils as an alternative source. Advantage of using plant product as herbicide is that these compounds are easy to be decompose and also harmless for other organisms [4]. Due to these properties essential oils are considered the best alternative approach to synthetic herbicides (Table 1, Figure 1).

Bioactive Compounds in Essential Oils having Herbicidal Properties

Essential oils contain bioactive components comprising of phenols, esters and terpenes. Maltol, 1,2-benzene dicarboxylic acid mono(2-ethylhexyl) ester, and trans-2-hexen-1-ol are important bioactive components of essential oil which are effective against weeds. These bioactive components break cell membrane of weeds, blocking biological catalyst and interrupting with essential biopathway. Essential oil obtained from plants (*Origanum vulgare*) inhibits aspartate and glutamate metabolism by disrupting photosynthesis [5]. For example, *Lavandula hybrida* (Eugenol), *Pinus halepensis* (a-Pinene and ß-Pinene), *Thymus vulgaris* (Thymol) and *Targetes erecta* (Linalool).

Mechanism of Action

Allelochemicals mainly terpenes like monoterpenes and sesquiterpenes inhibits the growth of weeds by interfering with their biochemical and molecular pathways. These allelochemicals disturb key processes in weeds like mitosis, respiration and photosynthesis [6]. Monoterpenes lipophilic nature of monoterpene changes the fluidity of cell membrane which causes cell demolition [7]. For example, ß-pinene inhibits the growth of weeds by blocking key processes like preventing elongation of roots and shoots, disrupts internal respiration and controlling the activity of amylase [8]. Camphor

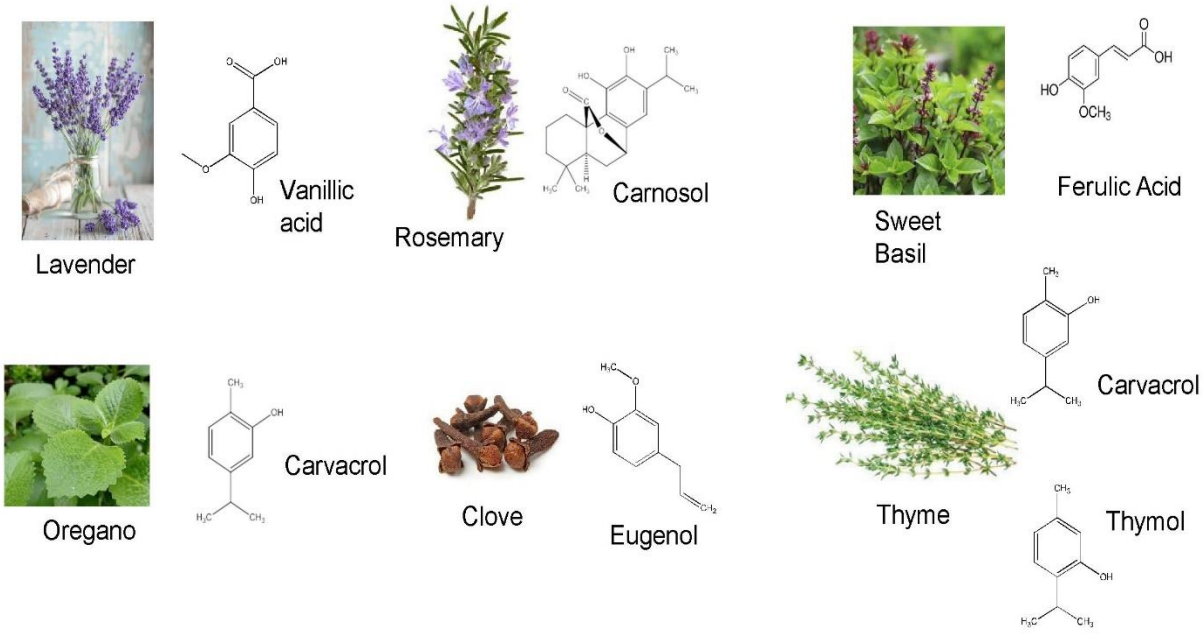
is also a highly phytotoxic chemical to germinate seed and disrupt actin filaments and microtubules [9]. 1,8-Cineole also acts as growth inhibitor. It disrupts mitosis, preventing microtubule organization and manufacturing cell wall thus limiting the growth of weeds [10]. Sesquiterpenes have a greater inhibition for roots in contrast to shoots. They also diminish chlorophyll concentration and disrupt cell division [11]. Various methods have been developed for controlling the growth of weeds. Applying essential oil directly on leave surfaces is considered as best approach for using essential oils for weed management. Essential oils like clove, eucalyptus, and peppermint effectively prevent growth of weed when these oils are directly sprayed on the foliar surfaces [12]. Oil of rosemary and oregano also exhibits highest efficiency against weeds when sprayed over a $5m^2$ area. This method is considered as best method for controlling unnecessary growth of weeds.

Various studies have been conducted on applying in encapsulated form and found to be effective against various weeds [13]. One of the purposes of essential oil encapsulation is that it inhibits essential oil interaction with surrounding chemicals. Various classes of essential oil contain bioactive compounds that are effective in controlling weeds. For example, limonene belongs to chemical class of monoterpene obtained from *Citrus aurantiifolia* plant is effective against weeds by inhibiting their coleoptile growth [14]. Caryophyllene belongs to the chemical class of sesquiterpene obtained from *Melissa officinalis* plant exhibit negative effect toward germination of weeds and reduce their growth and development [15]. Eugenol belongs to a chemical class of phenol obtained from buds of clove suppress the growth of roots [16]. Citral belongs to a chemical class of aldehydes obtained from *Backhousia citriodora* is tested against various weeds and found that this chemical inhibits the germination of weeds [17]. Carvone belongs to the chemical class of ketone and obtained from *Mentha spicata* species is also tested against weeds and it also inhibits the germination of weeds [18]. Linalool belongs to a chemical class of alcohol obtained from *Eucalyptus globulus* plant species which is also effective against weeds. Linalyl acetate belongs to a chemical class of ester obtained from lavender plant species which shorter length of root and prevent it from germination [19]. 1,8-Cineole suppress the germination of weeds completely [20].

Table 1. Herbicidal, Antimicrobial and Pesticide Activity of Some Essential Oils and their Phenolic Components

Scientific Name Of Plant	Common Name	Essential Oil Phenolic Compounds	Tested against Weed/Pathogens/Pest
Lavandula spp	Lavender	Vanilic acid Ferulic acid Rosemarinic acid Caffeic acid	*Lolium rigidum* *Cladosporium cladospoioides*
Origanum vulgare	Oregano	Carvacrol Thymol	*Rumex crispus* *Chenopodium album* *Erwinia carotovora* *Xanthomonas vesicatoria* *Pseudomonas spp*
Rosmarinus officinalis	Rosemary	Rosmanol Carnosol Carnosic acid Epirosmanol Isorosmanol	*Trifolium incarnatum* *Phalaris minor* *Aspergillus flavus* Effective against pests
Syzygium aromatisum	Clove	Eugenol Chavicol	Redwood pigweed *Erwinia amylovora* *Xanthomonas vesicatoria* *Pseudomonas syringae* Effective against pests
Ocimum basilicum	Sweet basil	Eugenol Ferulic acid Sinapic acid	*Pseudomonas aeruginosa*
Thyme vulgaris	Thyme	Thymol Carvacrol	*Pseudomonas syringae* *Alternaria alternate* Effective against pests
Zataria multiflora	Shirazi thyme	Carvacrol Thymol	*Xanthomonas campestris*
Cinnamomum zeylanicum	Cinnamon	Eugenol	*Aspergillus spp* Used against pests
Mentha piperita	Peppermint	Hesperidin Rosemarinic acid Eriocitrin Chlorogenic	*Penicillium verrucosum* Ward off ants Mosquitoes and flies

Figure 1. Few Essential Oil Plants and their Bioactive Phenolic Compounds having Herbicidal, Anti-microbial and Pesticide Activity



Anti-microbial Potential of Essential Oils

One of the advantage of application of essential oil to plants is it helps suppressing the growth of fungi and bacteria (Table 1, Figure 1). These toxic bacteria and fungi are responsible for severe problems in various parts of plants like wilting, spots, rots and cankers. Various researches have been done to find the activity of essential oils against bacteria and fungi that are damaging fruits and vegetables. Different plants species, spices and herbs species are used for medicinal purposes, as a preservative and against pest management in ancient civilization like Egypt, Rome and Greece. The properties of essential oils are also studied at laboratory scale since the early century. Essential oils contain various bioactive components in its composition that target to the cells of bacteria and fungi that are affecting crops.

Essential oils are one of the best methods for inhibition of fungal infections. The antifungal properties of essential oils are due to their lipophilic nature. These fungal infections cause different alterations in plants like morphology, disturbing their normal functioning like photosynthesis and cellular respiration. Usually very low amounts of

essential oil are considered good for antifungal infections because many oils show phytotoxic effects to plants when their concentration is slightly higher than normal amount. Geraniol belongs to monoterpene class of chemical compound present in peppermint oil and exhibits antifungal properties against *A. flavus* and *A. ochraceus* [21]. Neral is another chemical compound obtained from peels and leaves of Zambetakis hinder the growth of filamentous fungus. Citronellal extracted from Citronella grass also inhibits Mycotoxins growth [22]. Oils obtained from *Thymus vulgaris*, *Syzygium aromaticum*, *Rosemarinus officinalis*, *Lamiaceae*, *Salvia officinalis*, and *Rutaceae* block the growth of fungi [23]. Among them, thyme and clove essential oil exhibit broad antifungal activity.

Essential Oils as Growth Regulator

For obtaining good yield of crops growth regulators are very important. Various research has been done to determine biologically active compounds that increase the overall yield of crops. Concerning about, much agriculture farmers are moving towards the use of essential oil as natural growth regulator for crops.

For example, oil extracted from *Pimpinella anisum*, *Foeniculum vulgare*, *Prunus armeniaca* found its applications as a growth regulator for winter wheat crops [24]. Thus, the use of essential oils as growth regulators on wheat crops has been found that overall yield of wheat crops has been increased [24]. Quality of grain and photosynthetic activity is also reported to increase in plants by essential oils.

Essential Oils as Green Pesticide

Essential oil founds its application as green pesticides. EOs are used as pesticides for agricultural pests that are damaging crops and reducing the yield of crops (Table 1, Figure 1). For example, EOs extracted from clove, lemon grass, *Eucalyptus globulus*, rosemary, thyme and vetiver are recognized for pest- repellent properties [25]. In addition to penny royal (*Mentha piperita*) repels ants, fleas, mosquitoes and butterflies. *Mentha piperita* L. oil is used to repel flying insects, ants and moths [26]. Essential oils can also be used as repellents, suppressants, or deterrents to prevent insects from feeding. For example, oil obtained from some plant species are effectively repels

tobacco cutworm larvae. Turmeric leaf essential oil is effective towards adult and larvae stages of grain, rice and flour beetles [27].

Conclusion

It is obvious from detailed review that essential oils hold much impact in the field of agriculture against weeds, fungi, bacteria, pests as well as growth regulator. Essential oils extraction process from hydro distillation method is cheap and environment friendly alternate of synthetic pesticide being non-polluting without toxicological effects. These essential oils being economic bio-pesticide could be exploited commercially as fumigant for stored products and can be used for packaging purpose. Insolubility of essential oils in water renders its use in field that can be overcome by emulsifying using surfactant or by adjuvants usage for convenient adsorption in plants.

Conflicts of Interest

The authors declared no conflict of interest.

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