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Toxicity of Oils Formulation as a New Useful Tool in Crop Protection for Insect Pests Control

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Abstract

Oils remain an important tool to manage certain pest problems on fruit trees, shade trees, woody ornamental plants, flowering plants, vegetables and other herbaceous plants. Essential oils are particularly abundant in some families of plants such as Conifers, Rutaceae, Umbelliferae, Myrtaceae and Labiatae. This study investigates the effects of essential oil formulations as a new tool in crop protection against the most serious insect pest*s* around the world. Beside the domestic uses, essential oils present applications in agriculture and the food industry. Some oils have been developed and are eventually registered for crop use to suppress a variety of insect pests. Many plant essential oils show a broad spectrum of activity against insect pests (e.g., scales, aphids, mites). Mustard essential oil as part of a sustained release formulation containing insecticide, microbicide and repellent substances absorbed onto silica and silane compounds is used to prevent infestation of mites in feed. Attractant adhesive films with essential oils are prepared to control insects in agriculture and horticulture crops, and essential oils can also be incorporated with polymers. These natural chemicals have multiple modes of action, including antifeedant and repellent activities, moulting and respiration inhibition, growth and fecundity reduction and cuticle disruption, and can act as a contact, fumigant, repellent, antifeedant, and oviposition inhibition toxicants. Furthermore, the essential oils have been widely used as anti-parasitical, bactericidal, fungicidal, antiviral and insecticidal activities. These multiple modes of action are advantageous because they delay the development of resistance among arthropod pest populations. Efforts can be further focused on plant essential oils or phytochemicals as potential sources of commercial insect control agents, and significant relationships among adulticidal, nymphicidal and ovicidal activities of the test oils might be observed. Consequently, a diversified use of essential oils by the development of their use in the pest management sector could be of both economic and ecologic benefits.

Keywords

Chemical Ecology, Plant-Insect Relationships, Insecticidal, Repellent, Antifeedant, Pesticide Alternative

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1. Introduction

Crops loss due to insect pests varies between 10 and 30% for major crops. Management of agricultural pests over the past half century has been largely depending on the use of synthetic chemical pesticides for field and post-harvest protection of crops (Ferry et al., 2004). On the other hand, the main method to control insect pests is using of synthetic pesticides.But, the development of insect resistance to these products, the high operational cost and environmental pollution has created the need for developing of alternative approaches to control many insect pests. In this sense, the usages of essential oils are an alternative to control many field and household insect pests (Sarwar et al., 2005; 2012; 2013).

Over 2000 species of plants are known to possess some insecticidal activities. The essential oils are natural, volatile and complex compounds, and their characteristic odours are

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formed by secondary metabolites in plants. In the nature those compounds plays an important role in the protection of the plants against bacteria, fungi, virus, insects and others herbivores (Klocke, 1989). Certain oils, diluted with water and applied as sprays, can be effective controls of many plant pests, and horticultural oils are usually highly refined petroleum oils combined with an emulsifying agent and some plant-derived oils also are used. Some plant pests controlled by oils dormant season applications are aphids that curl leaves in spring, caterpillars that winter as eggs on the plant (leaf rollers, tent caterpillars), mites that winter on the plant (e.g., conifer-infesting species) and scale insects. Summer or foliar oil applications control plant pests such as adelgids, aphids, eriophyid mites, leafhoppers, scale insects, spider mites and whiteflies. Oils have different effects on pest insects and the most important is that they block the air holes (spiracles) through which insects breathe, and cause them to die from asphyxiation. In some cases, oils also may act as poisons, interacting with the fatty acids of the insect and interfering with normal metabolism. Formulations of oils are normally combined with an emulsifying agent that allows the oil to mix with water and this mixture usually is used at about a 2 percent dilution. Some researchers have demonstrated that essential oils have neurotoxic, citotoxic, phototoxic and mutagenic action among others in different organism, and the essential oils act at multiple levels in the insects, so the possibility of generating resistance is little probable (Bakkali et al., 2008).Advantages of oils include safety, effectiveness and limited effects on beneficial insects, but plants under drought stress may have increased risk of injury. Oils also are easy to apply with existing spray equipment and can be mixed with many other pesticides to extend their performance. In the present study, an examination has been made on the effects of different concentrations of essential oils for their efficacy as natural pesticides against important arthropod pests.

2. Usage of Oils in Controlling Insect Pests

Among the multitude of plant species, some are called aromatic because of the volatile compounds they contain, which give them an odour and a characteristic flavour. Subsequently, they have been known for many industrial applications, particularly in perfumery, cosmetics and detergents, pharmacology and fine chemistry as well as aromatics for the food industry. One of the fractions of aromatic plants, most frequently used for industrial applications, and which has shown promise for use in integrated pest management (IPM), is the fraction of volatile fragrant compounds commonly called essential oils. Among the alternative strategies, the use of plant's insecticidal allelochemicals appears to be promising. Their activities are manifold and they induce fumigant and topical toxicity as well as antifeedant or repellent effects. They are toxic to adults, but also inhibit reproduction. Although mechanisms depend on phytochemical patterns and are not yet well known, this widespread range of activities is more and more being considered for both industrial and household uses. Aromatic plants and their essential oils are among the most efficient botanicals wherein essential oils are presently regarded as a new class of ecological products for controlling of insect pests (Regnault-Roger, 1997). A study investigated the effects of some essential oils on gypsy moth *Limantria dispar* (Lepidoptera: Lymantridae) larvae, which is one of the most serious pests of cork oak forests. The essential oils are first formulated as oil in water (o/ w) emulsions and used in laboratory bioassays to assess their lethal concentration (LC_{50}). Microcapsules containing the most promising, oils (*Rosmarinus officinalis* and Thymus *Herbabarona*) are then prepared by a phase separation process, followed by freeze-drying. The formulations thus obtained, characterized in terms of essential oil content and composition, morphology, storage stability and release profile, are tested on gypsy moth larvae. The results showed that the tested oils possess interesting larvicidal effects that make them suitable for application in integrated control strategies. The microencapsulation process gave high encapsulation yields (over 98%) with both essential oils, which have different chemical compositions. The microcapsules have toxic effects at a concentration similar to that usually employed for localized treatments with microgranular synthetic pesticides. Toxicity appeared to be maximized when the microparticles adhered to the typical hair structures of several defoliator families. These formulations seem to be able to protect the core material against environmental agents and could be considered for use in controlled drug release systems. The natural active principles they contain could provide an alternative system in insect pest control (Mario et al., 2002).

A total of 53 plant essential oils have been tested for their insecticidal activities against eggs, nymphs and adults of whitefly *Trialeurodes vaporariorum* Westwood, using impregnated filter paper bioassays without allowing direct contact. Responses varied according to oil type and dose, and developmental stage of the insect. Bay, caraway seed, clove leaf, lemon eucalyptus, lime dis 5 F, pennyroyal, peppermint, rosewood, spearmint and tea tree oils are highly effective against *T. vaporariorum* adults, nymphs and eggs at 0.0023, 0.0093 and 0.0047 l/ ml air, respectively. These results indicate that the mode of delivery of these essential oils is largely a result of action in the vapour phase (Won-Il et al., 2003).

The study conducted determined the toxicity of *Azilia eryngioides* (Pau) Hedge et Lamond (Apiaceae) essential oil against 1 to 7 day old *Sitophilus granaries* (L.), (Curculionidae) and *Tribolium castaneum* (Herbst) (Tenebrionidae) adults. The essential oil is obtained from aerial parts of the plant using a Clevenger apparatus and analysed by gas chromatography and mass spectrometry. The major constituents of the oil are α-Pinene and bornyl acetate. Fumigation bioassays revealed that *A. eryngioides* oil has a strong insecticidal activity on adult test insects that have been exposed to 37.03, 74.07, 111.11 and 148.14 µ L L^{-1} to estimate mean lethal time (LT_{50}) values. Mortality increased as concentration and exposure time increased, and reached 100% at the 39 h exposure time (Ebadollahi and Mahboubi, 2011). A further experimental work shows the main essential oils from 30 botanical families with activity against coleopterans insect pests in stored grains. Out of that 22 species have been found belong to the family Lamiaceae, 17 of Asteraceae and 10 of Myrtaceae (Perez et al., 2012).

The chemical composition of the two oils has been characterized by GC-MS (gas chromatography and mass spectrometry). The most abundant component in the *Santolina africana* (Jord. & Fourr) oil is terpinen-4-ol (54.96%), while thymol (61%) is prevalent in the *Hertia cheirifolia* (L.), oil. Mortality and fecundity are measured upon treatment with oil concentrations ranging from 0.07 to 6.75 mg L^{-1} with a Potter spray tower. Mite mortality increased with oil concentration, with LC_{50} values of 2.35 mg L^{-1} for *S. africana* and 3.43 mg L^{-1} for *H. cheirifolia* respectively. For both oils, a reduction in fecundity is observed at concentrations of 0.07, 0.09 and 0.29 mg L^{-1}. Artificial blends of constituents of oils are also prepared and tested with individual constituents missing from the mixture. The results showed that the presence of all constituents is necessary to equal the toxicity of the two natural oils. The *S. africana*and *H. cheirifolia*oils can provide valuable acaricide activity with significantly lower LC_{50} values. Thus, these oils cause important mortality and reduce the number of eggs laid by adult females (Attia et al., 2012).

In a study, the toxic effects of three different natural essential oils of medicinal plants, namely garlic (*Allium sativum)*, mint (*Mintha pipereta)* and eucalyptus (*Eucalyptus globulus*) are tested on 1st nymphal instar of the grasshopper (*Hetera crislittoralis*). The LC_{50} values of the tested oils are estimated after 14 days from feeding on treated diet mixed with different concentrations of the oil. The LC_{50} of the tested oils are arranged as follows as 0.067, 0.075 and 0.084 ml/ 100 ml diet for garlic, eucalyptus and mint, respectively. The effect of LC_{50} concentration of the oils on the biological aspects and histological changes that observed on the alimentary canal and fat bodies are recorded. The normal development of the grasshopper is exhibited and results cleared that there is statistical variable numbers of increased nymphal periods, life cycle, adults longevity and life span comparing with the control test. Garlic oil inhibited egg lying by the resulting females offspring of the treated 1st instar nymphs. High reduction in the deposited eggs and egg fertility caused by eucalyptus or mint oil and marked malformation are observed. Histological changes on the alimentary canal and fat bodies of the remaining nymphs after treatment with garlic oil (the most effective oil) are detected by the light microscope and have been recorded. The results suggest that the natural plant essential oils of garlic, eucalyptus and mint may be used in IPM control program against *H. littoralis* grasshopper (Sharaby et al., 2012).

Canola oil is an edible refined vegetable oil obtained from the seeds of four species of rape plants, *Brassica napus, Brassica juncea, Brassica rapa* and *Brassica campestris* of the family Cruciferae (mustard family). Canola oil is considered safe for human consumption and scientists believe that canola oil repels insects by altering the outer layer of the leaf surface or by acting as an insect irritant. Canola oil can be used on a wide range of plants, including citrus, corn, fruit trees, nut trees, sugar beets, soybeans, tomatoes, vegetables, figs, melons, olives, small fruits, alfalfa, bedding plants, ornamentals and houseplants (Sarwar, 2008; 2011; 2013; 2014; Sarwar and Sattar, 2013; Sarwar et al., 2011).

3. Types of Oils Used

Dormant oil is used on woody plants during the dormant season, and these are heavier weight, less well-refined oils that are unsafe to use on plants after they broke dormancy. However, these older oils have been replaced with more refined, light-weight oils that have potential application to plant foliage. Horticultural oils are used to control a pest on plants; these products have been available for decades and are originally used by orchardists for insect pests that over-wintered or exposed on the trees, such as scale pests. The majority of these products are highly refined petroleum based oils. Originally, they could only be applied when the tree is dormant, typically in late winter. Consequently, these products are known as dormant oil sprays. Now, horticultural oils have become so highly refined that depending on tank-mix concentrations, they can be applied to trees and shrubs during the dormant and growing seasons, with some limitations. Horticultural oils also known as mineral oils are refined petroleum products, their impurities in the oil that are associated with plant injury, such as aromatic compounds and compounds containing sulfur, nitrogen or oxygen, are removed. Filtration, distillation and dewaxing complete the production of the finished base oil. Narrow-range oil is as highly refined oil that has a narrow range of distillation. Narrow-range oils fall in the superior oil classification, while mineral oil is petroleum-derived oil (as opposed to vegetable oils). Spray oil is designed to be mixed with water and applied to plants as a spray for pest control, whereas vegetable oil is derived from the seeds of some oil seed crops (e.g., soybeans, canola and cotton seed). Summer oil is used on plants when foliage is present (also called foliar oils), but supreme oils are distilled at slightly higher temperatures and over a wider range than the narrow-range oils. Superior oil includes a high proportion of paraffinic hydrocarbons and purification that allow year around use without phytotoxicity, and most superior oils are now better referred to as narrow-range oils. Vegetable oils also can be used as insecticides, although the type of oil can greatly affect its activity. Cottonseed oil is generally considered the most insecticidal of the vegetable oils. Soybean oil, the most commonly available vegetable oil used in cooking, has often provided fair to good control of some insects and mites. Extracts from seeds of the neem tree *Azadirachta indica* (Meliaceae) have notably azadirachtin, which have proven useful as insecticide and fungicide (Helmy et al., 2012; Cranshaw and Baxendale, 2014).

Oils work primarily by covering and suffocating the pest organism. In some cases, they can disrupt certain membranes of the exoskeleton. The target pest must be present and exposed at the time of application and the oil must cover the pest in order to be effective. Once oil sprays are dry (as little as 15-20 minutes after application) they have no insecticidal qualities whatsoever. Therefore, oils work best on pests such as scale insects, spider mites, certain adelgids and others with limited mobility. One attractive feature of oils is that they can kill all life stages, including eggs or nymphs, while many other pesticide products only kill the immatures and adults. Oils should not be applied near open water sources in order to prevent contamination. Extra care should be taken when applying horticultural oils (in this case, a summer-weight oil) when new foliage is just emerging from the buds. Phytotoxic reactions may occur on this tender new foliage. Also, oils should not be applied if freezing temperatures are predicted 24-48 hours after application and this also increases the chance of plant injury. In many states where high summer humidity is sometimes a harsh reality, care should be taken to avoid oil use at the times of peak heat and humidity. This includes both the time of day and the time of season. Some applicators in these areas do not apply oils during much of July and August. Note also that some plants are sensitive to oil application. And among oil sensitive plants are beech, black walnut, maples, hickory, smoke tree, azaleas, Japanese holly, redbud, spruces and Douglas fir. It is always obligatory to read the label for information on sensitive species (Kwaiz et al., 2004; Sarwar, 2015 a; 2015 b; 2015 c; 2015 d; 2015 e; 2015 f; 2015 g; 2015 h).

4. Target Insect Pests of Oils

Elucidation of the mode of action of chemicals is of practical importance for insect pestscontrol because it may give useful information on the appropriate formulation types. Volatile compounds of many plant extracts and essential oils consist of alkanes, alcohols, aldehydes and terpenoids, especially monoterpenoids, and exhibit fumigant activity (Kim and Ahn, 2001; Kim et al., 2003). Essential oils also show some usefulness for building materials, and a wood preservative solution is a mixed eucalyptus essential oils with pyrethroids and borax. The use of plant material for crop protection is worldwide on stored-product, household insects, but also for flying insects, bugs, grasshoppers, leafhoppers, termites, mosquitoes, flies, cockroaches and beetles. Essential oils extracted from common aromatic plants, prevent egg hatching and provoke prohibition or malformation of the puparium of the flies. Nevertheless, not all essential oils are repellent, but some have been found to be highly attractive. The uses of pine and fir essential oils increase settling in trap trees. The essential oils including ionone and ionol related compounds could be used to lure males of *Bactrocera latifrons* (Diptera: Tephritidae). However, some essential oils can exert quite opposite effects on different insect species; for instance, tansy essential oil is attractive and paralyzing in its action. From all these observations, it could be deduced that essential oils present a widespread range of activities on insects and could be used for environmentally safer pest management option (Sarwar, 2010; 2012; Khan et al., 2010; Sarwar and Sattar, 2012).

A specific example of the usefulness of horticultural oils is in the case of the hemlock woolly adelgid or *Adelges tsugae* that is an introduced species along much of the seaboard where *Tsuga canadensis* (hemlock) has its native range. This pest is quite destructive and can kill host plants, especially if additional stresses such as drought or soil compaction are present. Entomologists working in the range of woolly adelgid receive countless inquiries about this pest and its management. Horticultural oils are one of the best management tools for this pest, wherever application is practical. Total coverage is extremely important in controlling the woolly adelgid and any missed individuals can quickly re-establish the population to damaging levels. Larger trees, therefore, become a challenge and multiple applications of oil may be required. It is difficult to discern when an oil application has been effective against this pest. Normally, the woolly adelgid is not very visibly active or mobile. Pest managers must carefully inspect the insect under magnification and take note of what live hemlock woolly adelgids look like, nymphs and adults will be somewhat plump and should produce liquid when pierced with a fine probe. Viable eggs will be turgid (plump with moisture) and shiny. Two to three weeks after an oil application, affected nymphs, adults and eggs should appear duller, produce little or no liquid when probed, and eggs in particular may appear shrunken. These distinctions can be very subtle and making them is a challenge. In a survey on the usage of horticultural oils, these are found to be effective for controlling scale insects and mites. These oils are cheaper and less phytotoxic than their predecessors with no empirically demonstrated resistance by pests (Johnson and Caldwell, 1987; Beattie et al., 1989).

5. Conclusion

Results of this and earlier studies indicate that some essential oils could be useful toxicants for insects, certain botanic families have been evaluated and that provided good control against pests.The most promising botanical groups are Meliaceae, Rutaceae, Asteraceae, Annonaceae, Labitae, Aristolochiaceae and Malvaceae. Commonly, essential oils can be inhaled, ingested or skin absorbed by insects. For all these reasons, it may be inferred that the essential oils could be considered as a natural alternative in the control of crops, stored grains and household insects. The use of essential oils as alternative to control coleopterans insects in stored grains is a sustainable alternative because these come from natural resources. Essential oils are active against both adults and larvae, and frequently act to inhibit reproduction. The use of plant extracts, including allelochemical compounds such as essential oils, with known effects on insects, could be a useful complementary or alternative method to the heavy use of classical insecticides. This could improve the biodegradability of insecticide treatments and therefore decreases the quantity of toxic insecticide residues, increases insecticide selectivity and develops a better respect for the environment. In the course of the last few years, the utilization of essential oils has been modified, and there has been a steady increase in the production of the food aroma industry like citrus, rose, cedar and mints. On the contrary, the use of essential oils in hemi synthetic reactions (citronella, clove, eucalyptus, camphor and lemon grass) or in alcoholic perfumery (patchouli) has been decreased. Consequently, these plant extracts including essential oils must have a great potential for pest management, which has been reviewed in the light of recent literature. If the economical marketable problems are solved, essential oils obtained from plants can be effectively used as part of integrated pest management strategies. Given the rapid volatilization and low persistence of essential oils in the environment, it is likely that they will be used in field crops protection. This work might complement previous reports on the biological and antimicrobial activities of essential oils as well as plant allelochemicals, and their applications.

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