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USE OF ESSENTIAL OILS FOR INSECT PEST MANAGEMENT - A REVIEW

Review Article

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ABSTRACT

Indiscriminate use of chemical insecticides has created different types of environmental and toxicological problems. Its intensive use in agriculture has caused adverse effects to the environment. It also cause harmful effect on natural enemies and result in the development of insect resistance. To overcome this problems the scientists have looked for less persistant and biodegradable alternatives, which includes the use of plant essential oils. Essential oils have been used effectively to control preharvest and postharvest phytophagous insects. Essential oils have a pronounced effect on the development period, growth and adult emergence of insect. The expanding literature on the possibility of the use of these volatiles is reviewed in the present time. It focuses on the oils effect on oviposition, repellency, ovicidal, pupicidal, larvicidal, insecticidal and antifeedant activities of insects. Possible attractive effect of essential oils to pests may offer novel application in management of insects.

Introduction

Insects are one of the major causes of grain losses during stored (Scotti, 1978). Crops loss due to insect pests varies between 10 and 30% for major crops (Ferry *et al.*, 2004). 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. However, The indiscriminate use of synthetic pesticides has given rise to many serious problems, including toxicity to non target organism, development of pest resistance and resurgence and environmental contamination, so during past three decades, the scientist have looked for less persistant and biodegradable alternatives. Essential oils from aromatic plants are recognized as proper alternative. It has been suggested that essential oils are less hazardous than synthetic compounds and rapidly degraded in the environment (Isman, 2000). Essential oils are naturally produced by plants as secondary compounds, being obtained for commercial use by various forms of distillation. They are notably diverse in terms of chemistry, containing up to 60 separate components (per oil) primarily composed of terpenes, terpenoids and other aromatic compounds. It has been reported that essential oils are complex mixture of volatile compounds isolated from a large number of plants (Dussault *et al.*, 2014). Among the alternatives for pest control, biopesticides had a global market value of approximately US$ 1 billion in 2010. This market is expected to grow to US$ 3.3 billion in 2014 (Lehr, 2010). Biopesticides encompass a large number of technologies, from microbials to botanicals. Among the botanicals, essential oils are a major category that began to develop with research in the 1980s (Regnault-Roger, 1997). Essential oils have been used to control pests of the stored products as alternative insecticides in various parts of the world (Buchbauer, 2000; Isman, 2000; Ngamo *et al.*, 2007). Recent studies have indicated how various essential oils efficient against Insect pest.

Essential oils and their constituents

Essential oils and their derivatives are considered to be an alternative means of controlling many harmful insects (Tripathi *et al.*, 2009). Essential oils are volatile, natural, complex compounds characterized by a strong odour and are formed by aromatic plant as secondary metabolites. They are lipophilic in nature and protect plants from herbivores and microorganisms through their antimicrobial or insecticidal properties.Nearly 3,000 essential oils are known out of which about 300 are commercially important for pharmaceuticals, pesticide or flavour industries (Bakkali *et al.*, 2008; Chang and Cheng 2002).They are generally recognized as safe by the US Food and Drug Administration.

Mode of action of essential oils

Essential oils are presumed to interfere with basic metabolic, biochemical, physiological and behavioral functions of insects. However little is known about the true mode of action of essential oils on insects. The rapid onset of toxic signs suggests a neurotoxic mode of action involving competitive inhibition of acetylcholine esterase (Kostyukovsky *et al.*, 2002). Linalool a constituent of several essential oils has been demonstrated to act on the nervous system, affecting ion transport and the release of acetylcholine esterase (Re *et al.*, 2000). Whereas eugenol has been shown to mimic octapamine in *Periplaneta americana.* Toxic, repellent, ovicidal or growth retardant activity of large number of essential oils or their constituents have been demonstrated on large number of insect.

Toxicology and environmental impact of essential oils

Essential oils are in general low risk products. Their mammalian toxicity is very low and they are relatively well studied experimentally and clinically because of their use as medicinal products. The majority of essential oils including chamomile, citronella, lavender, clove and eucalyptus have an oral LD_{50} value ranging from 2,000 to 5,000 mg/kg in rats. But some are moderately toxic to very toxic. For example essential oils of Boldo, cedar and pennyroyal have LD_{50} values of 130, 830 and 400 mg/kg respectively. Although most essential oils are need to be handled with caution and not be ignored simply because it is a botanical, i.e. natural product. It is therefore recommended that applicators carefully observe the labeling recommendation given for each situation.

Essential oil as alternative insecticides

Many plant essential oils are alternative source for insect control because they constitute a rich source of bioactive chemicals. Plant essential oils have neurotoxic, cytotoxic phototoxic and mutagenic actions to a variety of organisms and act at multiple levels in the insects (Isman, 2000; Bakkali *et al.*, 2008). Essential oils themselves or products are largely nontoxic to mammals, birds and fish (Stroh *et al.*, 1998). These property of plant essential oils are worthy of consideration as a natural alternative in the control of insect pests. Most of all, they are suitable alternatives to control insect pests generating economic damage. Essential oils could act as contact poison, fumigants, repellents, antifeedants or oviposition inhibitors.

Table 1. Mammalian toxicity of some essential oil compounds.

Compound	Animal tested	Route	LD_{50} (Mg/Kg)
2-Acetonaphthone	Mice	Oral	599
Apiol	Dogs	Intravenous	500
1,8-Cineole	Rats	Oral	2480
Cinnamaldehyde	Guinea pigs	Oral	1160
Citral	Rats	Oral	4960
Dillapiol	Rats	Oral	1000–1500
Eugenol	Rats	Oral	2680
Linalool	Rats	Oral	> 1000
Maltol	Rats	Oral	2330
Menthol	Rats	Oral	3180
Methyl chavicol	Rats	Oral	1820
2-Methoxyphenol	Rats	Oral	725
Methyl eugenol	Rats	Oral	1179
Pulegone	Mice	Intraperitoneal	150
Terpinen-4-ol	Rats	Oral	4300
Thujone	Mice	Subcutaneous	87.5
Thymol	Mice	Oral	1800
	Rats	Oral	980

Source: Dev and Koul, 1997; FAO, 1999; Koul, 2005

Table 2. Toxicity of plant essential oils against insect pests.

Insect	Essential oil	Activity	Refs.
Rhyzopertha dominica	Spearmint (*Mentha spicata)*	Insecticide	Khalfi *et al*., 2006
Callosobruchus chinensis	Chaste Tree (*Vitex negundo)*	Antifeedant	Rana *et al*., 2005
	Palmarosa (*Cymbopogon martini)*	Repellent	Rajesh *et al*., 2007
Callosobruchus maculatus	Palmarosa (*Cymbopogon martini)*	Insecticide	Pereira *et al*., 2008
	Marigold species (*Tagetes minuta & Tagetes patula)*	Fumigant &contact	Alok *et al*., 2005
Sitophilus oryzae	Sweet Flag (*Acorus calamus)*	Inhibition of F_1 progeny	Sharma and Meshram, 2006
	Basil (*Ocimum canum)*	Insectcide	Ngassoum *et al*., 2007
	Lemon Grass (*Cymbopogon citratus)*	Contact	Stefanazzi *et al*., 2011
Sitophilus zeamais	Ram Tulsi (*Ocimum gratissimum)*	Knock down effect	Jirovetz *et a*l., 2005
	West African black pepper (*Piper guineense)*	Contact toxicity	Tchoumbougnag *et al*., 2009
Tribolium castaneum	Black Pepper (*Piper nigrum)*	Reppellent	Upadhyay and Jaiswal, 2007

	Palmarosa (*Cymbopogon martini)*	Repellent	Rajesh *et al*., 2007
Plutella xylostella	Pongam (*Pongamia pinnata) and* Neem *(Azadirachta indica)*	Antioviposition and Insecticide	Pavela, 2007
Aphis gossypii	Cumin *(Cuminum cyminum*) Anise*(Pimpinella anisum*) oregano(*Origanum vulgare*) and *Eucalyptus spp*	Fumigants	Tunc and Sahinkaya, 1998
Myzus cerasi	Rapeseed (*Brassica napus)*	Reduced damage	Jaastad, 2007

Effect of essential oil on insect

Ovicidal, larvicidal and pupicidal activity

Aromatic plant essential oils common as culinary herbs and spices, have often been found to be effectual in control of insects. They have proved their potentiality in killing the eggs, larvae and pupae of insects. Su *et al*. (1972) had reported that the non volatile portion of Citrus oil, 1% by weight protected peas from *C. maculates* infestation when applied to black eyed pea surfaces. Ho *et al*., (1997) determined that seeds treated with steam distilled oil from fresh garlic (*Allium sativum*), the eggs of *T. castaneum* and *S. zeamais* failed to produce F_1 progeny at application concentration of >2000ppm in rice and > 5000 ppm in wheat respectively. Recently Kumar *et al*., (2008) reported that the *Aegle marmelos* oil significantly reduced the oviposition and progeny emergence of *C. chinensis* in treated cowpea seeds. The oviposition by C. chinensis was completely checked at 10µl/ml while F_1 emergence was completely inhibited at 200µl/ml by Mentha oil (Kumar *et al*., 2009). Pal (2013) also reported that Neem (*Azadirachta indica*) and Patchouli (*Pogostemon cablin*) oil effect on fecundity and total reproductive period of *Brevicoryne brassicae* L. It has been reported that the two oil at different concentration reduce fecundity and reproductive period of *B. brassicae*, in comparison to water treatment and wetting agent treatment. The higher concentration of both the oil showed adverse effect on the reproductive period and fecundity of insect. Toxicity of plant essential oils towards larvae of insects has been reported by several authors. Fathi and shakarami (2014) reported that The essential oils of five species of Eucalyptus (Viz. *E. Camaldulensis*, *E. viminalis*, *E. microtheca*, *E. grandis* and *E. sargentii*) effectively killed 13 days old larvae of *Tribolium confusum* and *T. castaneum* after 24 hours and 48 hours of application.Among the five essential oils tested *E. viminalis* had the highest toxicity followed by *E. grandis* and *E. camaldulensis*. But essential oil of *E. sargentii* had the lowest toxicity. During the investigation of Huang *et al*. (2000a) it was observed that Cardamon oil adversely affected larval mortality at 2.34 mg/cm and no live larvae were observed after 9 days of hatching. Rahman and Schmidt (1999) did the experiment on ovicidal, larvicidal and pupicidal activity of Indian, Yugoslavian and Russian essential oils of *Acorus calamus* at 5 & 10 µl/400ml concentrations and reported that in all the oils vapours, the mortality increased when the period of exposure prolonged. However larvae and pupae were not affected by oil vapours. In other seed beetles, especially in *C. chinensis* by Risha *et al*. (1990) the larvae and pupae of *C. phaseoli* developing inside the seeds are not affected by *A. calamus* oil vapours which have a very low penetration through seed coat (Schmidt *et al*., 1991).

Antifeedant activity

Antifeedant chemicals may be defined as being either repellent without making direct contact to insects or suppressant or deterrent from feeding once contact has been made with insects (Koul *et al.*, 2008). According to Verma and Dubey (1999) antifeedants are substances which when tested can result in cessation of feeding, either temporarily or permanently, depending upon the potency. The essential oils had a slight inhibitory effect on feeding and growth of *T. castaneum* adults, the possible toxicity was observed at the highest concentration tested due to drop in the efficiency of conversion of ingested food (Blau *et al*., 1978; Xie *et al*., 1994).Feeding deterrency indices of dialyltrisulphide (Active constituent of Garlic species) against *S. zeamais* adult and *T. castaneum* larvae were 27 and 51% respectively, at concentration of 2.98 mg/g food, whereas feeding deterrency of 85% was achieved in *T. castaneum* adult at a much lower concentration of 0.75 mg/g food (Huang *et al*., 2000b). Similarly the feeding deterrency was 81.9% achieved in *T. castaneum* adults against *Artemisia annua* by using a concentration of 121.9 mg/g food, whereas larvae showed 68.8% FDI at same concentration (Tripathi *et al*., 2001). Benzi *et al*. (2009) evaluated the fruits and leaves essential oil of Pipper tree and observed that fruit essential oils had a strong feeding deterrent action (62%) while leaves had a slight effect (40.6%).

Table 3. LC_{50} values of essential oils of Eucalyptus species against *T. confosum* and *T. castaneum* larvae

Insect	Essential oil	N	LC_{50} value	
			After 24 h	After 48 h
T. confusum	*E. camaldulensis*	250	41.52	32.29
	E. viminalis	250	**20.67**	**16.74**
	E. microtheca	250	53.39	42.04
	E.grandis	250	26.40	22.48
	E. sargentii	250	110.52	85.97
T. Castaneum	*E. camaldulensis*	250	110.32	103.27
	E. viminalis	250	**48.06**	**35.48**
	E. microtheca	250	117.01	87.01
	E. grandis	250	71.87	63.06
	E. sargentii	250	155.77	122.20

Source: *Intt. J. Agri. Crop. Sci.* Vol., 220-224, 2014. A. Fathi and J. shakarami

Oviposional inhibitors

In spite of repellent, insecticidal, ovicidal, larvicidal and pupicidal action, essential oils have also capacity to reduced oviposition (egg laying capacity) of insects. Schmidt *et al*. (1991) confirmed that *Acorus calamus* oil vapours could reduce the progeny production of *S. granaries*, *S. oryzae* and *C. chinensis* by 89.0%, 47.0% and 58.9% respectively after 96h exposure. Stamopoulos (1991) has performed the experiment on effect of four essential oils (Almond, Cyperus, Eucalyptus and Geranium) on oviposition of Acanthocelides obtectus and observed that essential oil of Eucalyptus strongly reduced the oviposition and eggs hatchability of test insects. Recently Ibrahim (2012) reported that sesame seed, olive and sunflower oils at 7.5 ml/kg seeds concentration gave the highest percentage of oviposition deterrence of *Callosobruchus maculates* on chickpea seeds. Chaubey (2013) also reported that, *Z. officinale* and *P. cubeba* essential oils inhibit oviposition of pulse beetle in repellency assay in concentration dependent manner. Oviposition was reduced to 74.94, 57.59, 37.27, 26.31% and 66.52, 48.94, 31.57 and 15.86% at 0.31, 0.63, 0.94 and 1.26 µL cm^{-2}concentration of *Z. officinale* and *P. cubeba* essential oils respectively (Fig. 1.).

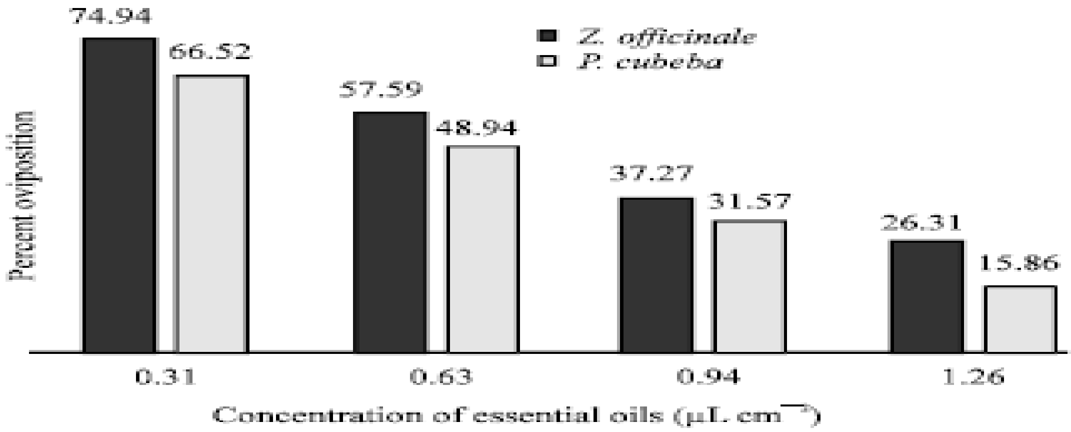

Fig. 1. Percent oviposition in repellency assay when *C. chinensis* adult were fumigated *Z. officinale* and *P. cubeba* essential oils by choice oviposition method

The future of essential oil products

The development of essential plant oils as plant protection product is especially suited to organic farming as well as to integrated pest management. They are natural in origin and biodegradable, have diverse physiological targets within insects and consequently may delay the evolution of insect resistance. As a result essential oils have been embraced by the public and organic growers as an alternative or complementary approach to synthetic pesticides. Isman identified three barriers to the commercialization of essential oils, viz. 1) The scarcity of the natural resource. 2) The need for chemical standardization. 3) Difficulties in registration. However, the advance in chemical and biological technologies combined with increasing need and environmental pressure are greatly increasing the interest in plant product as pesticides

Conclusion

We are facing challenges associated with the increasing global human population and also with the control of insect pests. This problem occurred by insect pests is not because their appearance period is much prior to the appearance of human beings on the earth, 500 million Vs 100,000 years. Thus, it should be reasonable results that we have not been able to manage completely the problems that a variety of insect pests caused. To control insect pests our ancestors have been using a variety of plant species. Based this knowledge farmers in developing countries often use naturally occurring plant materials for insect pest management. Some essential oils have demonstrated high efficacy against insect pests. However, the efficacy duration of these essential oils generally fall short comparing with that of conventional pesticides and then causes frequent application or greater application rate. To promote the potential of essential oils to reduce the use of synthetic insecticides in current agricultural practices, it needs to be studied on their selectivity to various insect pests and non-target invertebrates**.**

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