https://doi.org/10.46344/JBINO.2021.v10i05.11

ESSENTIAL OILS AS A SOURCE OF BIOPESTICIDE

Suboohi Nasrin*, Mhd Shahid and Abduraheem.K

Department of Museology, Aligarh Muslim University, Aligarh- 202002,
LBRL, Department of Zoology, University of Lucknow, Lucknow- 22600

ABSTRACT

Insect pest gives their major contribution in biodeterioration. To control these pest synthetic chemicals were used but these chemicals are not safe because of their carcinogenic side effects. That's why it is very important to use alternative source for the control of biodeterioration and which are ecofriendly to the environment and the users. The botanicals which considered as insecticides and pesticides are now replaced by synthetics Essential oil products are natural compounds with insecticidal properties and is used in different fields for insect control. These act as alternative insect control agent, having negative side effects such as animals and human toxicity, environmental contamination and toxicity to non target insects. Plant species with known insecticidal actions are being promoted and research is being conducted to find new sources of botanical insecticides. The present paper focuses on the work done in the field of essential oils as insecticides and their socioeconomic impacts and sustainability.

Keywords: **Nil**

INTRODUCTION

It is a very serious concern on the increasing use of chemical pesticides for Pest management. These methods were not safe because of their toxicity and potential explosion hazards to the curators, researchers as well as general public. The chemicals used for the purpose were generally toxic, very difficult to degrade and constant into the environment, that's why banned by the government. The natural product with biocidal activity had shown alternative and useful source for the control of biodeterioration and are ecofriendly. In the past the traditional method were not used for the protection and preservation of collections but now a days these methods are in use on the other hand the synthetic chemicals has been restricted because of their carcinogenicity, high and acute residual toxicity, long degradation period, environmental pollution and their adverse effects on materials and user (Unnikrishnan and Nath, 2002; Xavier, *et al.*, 2004; Feng and Zheng, 2007). Use of botanical insecticides such as essential oils has now increased due to environmental concerns and resistancy of insect population to Chemicals. The plant derieved botanical insecticides are naturally occurring biocides (Isman, 2000). Seeing their carcinogenicity and resistancy of insect population there is a need to develop another safe alternative herbal product which are convenient to use (Ayvaz, *et al.*, 2008).

The essential oils are controlling agent of insecticides having a strong odor, volatile natural complex secondary metabolites (Bruneton, 1999) among higher plants and approximately 3,000 essential oils are known out of which 300 are commercially important for pharmaceuticals, cosmetics and perfume industries (Bakkali et al., 2008) apart from pesticidal potential (Chang and Cheng, 2002).

These plant based essential oils contain hundreds of individual compounds and their mixtures that shows physical, chemical and biological characteristics of them (Roger,*et al.,*2012) . Additionally, aromatic plants could be extracted by organic solvents to give oleoresins and by carbon dioxide to yield high-quality extracts free of solvents. Steam distillation is easier process than solvent extraction. The essential oils extracted by organic solvent produces volatile essential oil and non-volatile flavor components that used in wide applications in food, agriculture and pharmaceutical industries (Roger,*et al.,*2012).

Essential oil compounds and their derivatives are considered to be an alternative means of controlling many harmful pest and their rapid degradation in the environment have increased specificity that favours beneficial insects (Pillmoor et al., 1993). These plant extracted essential oils were broadly used in food and perfume industry as flavour and fragrances and also been known to repel insects. Scientists working a lot of work on plant

essential oils and found that the essential oils not only repel insects, but also have some insecticidal actions against pests. At the time of Middle Ages the essential oils were widely used as insecticidal, fungicidal, antiparasitic applications. Some researchers found that the compound produced from aromatic plants insects repellent properties. They also demonstrated that such compounds are showing larvicidal and antifeedant activity (Adebayo,*et al.*, 1999; Larocque,*et al.*, 1999; Gbolade, 2001). In this paper the author summarises the use of different essential oils as an insecticides and work done by many scientists.

KEY WORDS

Essential oil, insecticide, toxicity, synthetic, natural compounds

ESSENTIAL OIL AS INSECTICIDE

Very limited literature was present on physiological actions of essential oils on insects, but treatments with various essential oils or their constituents cause symptoms that suggest a neurotoxic mode of action (Coats et al., 1991; Kostyukovsky et al., 2002). But several studies have focused on the potential use of essential oil applications in biological control of different insect pests. These essential oils may be more rapidly degraded in the environment than synthetic compounds, and some have increased specificity that favours beneficial insects (Pillmoor,*et al.*,1993). The natural derivatives are considered to be an alternative means of controlling harmful larvae of Lepidoptera. Recent research has demonstrated their larvicidal and antifeeding effects (Bathal.,1993) their capacity to delay development and adult emergence and cause egg mortality (Marimuth,1997) their deterrent effects on oviposition (Naumann,1995) and their arrestant and repellent action (Landolt,*et al.*,1999). Controlled-release formulations allowing smaller quantities of pesticide to be used more effectively over a given time interval shows good choice to meet multiple demands of efficacy, suitability to mode of application, and minimization of environmental damage (Kydonyeus,1980). Moretti, *et al*., 2002 stated that the effects of some essential oils on Limantriadispar (Lepi-doptera: Lymantridae, gypsy moth) larvae, one of the most serious pests of cork oak forests. The results showed that the tested oils (Thymus herba-barona Loisel, Rosmarinus officinalis L, Myrtus communis L, Eucalyptus globules Labill, Salvia officinalis L, Helichrysum italicum sub microphyllum G Don) possess interesting larvicidal effects that make them suitable for application in integrated control strategies.

The compounds of roots of vetiver grass shows some repellent properties against ants, cockroach, bedbug, headlices and moth (Handerson,*et al.*,2005). Vetiver oil and its constituents are also repellent and toxic against termites (Ibrahim,*et al.*,2004). The Vetiver oil compounds shows insecticidal potential in different ways and are ecofriendly. The ingredients of Vetivar plants also used in traditional medicine and as botanical pesticide. (Sujatha, 2010)

. (Batish, *et al*. 2008) reported that Eucalyptus essential oil possesses a wide spectrum of biological activity including anti-microbial, fungicidal, insecticidal/insect repellent, herbicidal, acaricidal and nematicidal activity.

Essential oils of lemon grass (*Cymbopogon flexuosus*), eucalyptus (*Eulcalyptus globules*), rosemary (*Rosmarinus officinalis*), vetiver (*Vetiveria zizanioides*), clove (*Syzygium aromaticum*) and thyme (*Thymus vulgaris*) are known for their pesticidal properties. While peppermint (*Mentha piperita*) repels ants, flies, lice and moths and Silverfish. Spearmint (Menthaspicata) and basil (*Ocimum basilicum*) are also effective in warding off flies. Moreover, essential oils of *Artemesia vulgaris, Melaleuca leucodendron, Pelargonium roseum, Lavandula angustifolia, Mentha piperita* and *Juniperus virginiana* are also effective against various insects (Kordali, *et al.,*2005) However, volatile oil constituents of Mentha species are highly effective against *Callosobruchus maculates* and *Tribolium castanum*, the common stored grain pests (Tripathi, *et al.,*2002).The lemongrass and eucalyptus oil has also been found effective as animal repellents, antifeedants, insecticides, miticides and antimicrobial products (Mohan, *et al* .,2011). Essential oil from *Cinnamomum zeylanicum, Cymbopogon citratus, Lavandula angustifoliasyn. L. officinalis, Tanacetum vulgare, Rabdosia melissoides, Acorus calamus, Eugenia caryophyllata, Ocimum spp., Gaultheriaprocumbens, Cuminumcymium, Buniumpersicum, Trachys permumammi, Foeniculum vulgare, Abelmoschus moschatus, Cedrus spp. and Piper spp*. are also known for their varied pest control properties (Mohan, *et al*.,2011) Citronella (Cymbopogon winterianus) essential oil has been used as an insect repellent and an animal repellent. The larvicidal activity of citronella oil has been mainly attributed to its major monoterpenic constituent citronellal (Mohan,*et al., 2011*). Vetiver (*Vetiveria zizanioides*) root essential oil is known to protect clothes and other valuable materials from insect attack when placed in closets, drawers, and chests. The essential oils of rhizomes of *Zingiber officinale* (Zingiberaceae) and *Piper cubebaberries* (Piperaceae) were exhibited insecticidal and anti-feeding activities against T. Castaneum and S. oryzae .(Chaubey, 2012).

Aromatic plants and their essential oils have been used since antiquity in flavour and fragrances, as condiment or spice, in medicines, as antimicrobial/insecticidal agents, and to repel in sector protect stored products (Theis,*et al.2020)*.. These give their contribution in effective alternatives to synthetic pesticides without producing adverse effects on the environment (Dorman, *et al* 2000, Bakkali, *et al.,*2008). However, the attempts to characterize their pest control activity under in vitro conditions started in 1900s (Theis,*et al., 2003)*. Moreover, the interest in the development of essential oils has increasing day by day primarily due to their fumigant and contact insecticidal

activities and the less stringent regulatory approval mechanisms for their exploration due to long history of use (Isman, 2000). These essential oils are being tried as potential candidates for weed (Isman, 2006) and pest and disease management (Bakkali, *et al., 2008)*. It is primarily because essential oils are easily extractable, eco-friendly being biodegradable and get easily catabolized in the environment (Abad, *et al.,* 2008), do not persist in soil and water (Bakkali,*et al.,*2008) possess low or no toxicity against vertebrates-fishes, birds and mammals (Mishra,*et al.,*1997) and play an important role in plant protection against pests (Bakkali, *et al.,2008)*. *Cacopsylla chinensis* (Yang and Li) (Hemiptera: Psyllidae) is an important pest of pear in China. This pest is controlled by the essential oil of clove buds (*Syzygium aromaticum*) which was obtained by hydrodistillation process and showed insecticidal property (Bao liang Tian,*et al.,2015)*. Essential oil used as insect/pest repellent and as a pesticidal agent (Enan, 1998). The pesticidal activity of eucalyptus oils has been due to the components such as 1,8-cineole, citronellal, citronellol, citronellyl acetate, p-cymene, eucamalol, limonene, linalool, a-pinene, ϒ-terpinene, aterpineol, alloocimene, and aromadendrene(Fooley,*et al.,*2015). The various components of eucalyptus essential oil actsynergistically (and not additively) to bring the overall pesticidal activity (Maden, 1996). Among the various components of eucalyptus oil, 1,8-cineole is the most important one and, in fact, a characteristic compound of the genus Eucalyptus, and is largely responsible for a variety of its pesticidal properties (Cimanga,*et al., 2002)*. Eucalyptus oil shows its activity as a natural insect repellent to provide protection against mosquitoes and other harmful arthropods or serves antifeedant activity against herbivores. (Yang,*et al.,*2004) reported that essential oils from E. globules and its major monoterpene 1,8-cineole showed toxicity against human head lice, *Pediculus humanuscapitis*. The pediculicidal activity of essential oil and its major component 1,8-cineole was more than that of commercially used pediculides-delta-phenothrinor pyrethrum (Batish,*et al., 2006)*. So, essential oils could be used for the development of new products for control of human head lice (Yang,*et al.,2004)*.. Eucalyptus oil has also been used as an antifeedant, particularly against biting insects (Caferino,*et al.,2004)*. (Trigg, 1999a) reported that the products which is based on used on humans as insect repellent can protect from biting insects. (Lucia, *et al*. 2007) demonstrated that essential oil from E. globulusis toxic to Aedes aegypti larvae. Eucalyptus oils rich in cineole have been shown to be effective against varroa mite, *Varroa jacobsoni*- an important parasite of honey bee (Calderone, *et al., 1995)*. Choi *et al*.,2004 concluded that eucalyptus essential oils could be used as a natural acaricide for the control of T. urticae. Chagas *et al*., 2002 evaluated the biocidal activity of essential oils from Eucalyptus

citriodora, E. globulus and E. staigeriana against the tick- Boophilus microplus and concluded that eucalyptus oils could be used as an ecologically and environmentally safer acaricide. Gardulf, *et al*.,2004 demonstrated the Citriodiol1, a Eucalyptus essential oil based commercially available product, significantly reduced the number of tick bites in humans and concluded that it could be used to reduce tick-borne infections. Sweet basil (*Ocimum basilicum)* was reported by (irwine,1995) for its potential as a pesticide. Basil essential oils which are repellent, toxic or growth inhibitory to many insects (Grainge, *et al.,1988)*. The principle compound of the essential oils from basil plant was eugenol which was shown to have a strong repellent effect on mosquitoes (Choge, *et al.,*1981). Also, linalool is another terpenoid found in basil which responsible for the toxic effect to the storage pests (Weaver,*et al.,1981)*.The plant was going to be in focus for future evaluation of botanical pesticides in stored grain at the village level (Hassanali,et al.,1998) Recent studies demonstrated the wide range of insect taxa that are affected by essential oils. (Ben Jemba, *et al*.2012) found that Laurus nobilis essential oil was toxic activities against Rhyzopertha dominica and Tribolium castaneum. The Insecticidal action of Lavandula hybrida, Rosmarinus officinalis and Eucalyptus globulus oils and of their 16 major constituents on Acanthoscelides obtectus adults was evaluated by Papachristos et al.,2004. The main compound of clove bud was (83%) was 2-methoxy-4-(2-propenyl)-phenol the second most common compound (12%) was trans-caryophyllene. These two pure compounds and clove oil were tested for toxicity and repellency against *Rhyzopertha dominica, Sitophilus oryzae* and *Tribolium castaneum* (Zeng,*et al.,*2010).

HISTORY OF ESSENTIAL OIL AS PESTICIDE AND INSECTICIDE

The history of essential oil were known after a long period of time. Some plants showed their insecticidal and caricidal property which can compete with synthetic chemicals (Bell, *et al.,1990* and Sahayaraj,*et al.,*2000). The pesticidal property of many plant and plant extracts have been known during the earlier half of this century. However, after the second world war, the natural products lost their importance with the introduction of synthetic organic chemicals. The organic chemicals showed their concentrated property, that's why give high knock- down effect on pest organisms. These chemicals gives good result over other pesticides in 1950s (Berger, 1994). After a period of time the use of DDT and acute toxic organo phosphorous compounds shows adverse effects on environment and human beings. In developing countries the yearly consumption of pesticides was estimated at 600000 tons in 1988 with a drastic increase of 184% during 1980-1884 (WHO, 1990). But after some time it regained the interest in plant products with pesticidal properties (Jacobson, 1975, 1971). In the

beginning it was noted that some plants protect themselves better than others. About 4000 years ago many scientist considered neem tree belong to the family Meliaceae as a pesticides (Philogene,2005). The neem tree is the most promising example of plants currently used for pest control. This holy tree in India used for many purposes such as shade tree, poles for construction, medicine, tooth sticks and as a source of insecticides (National research council, 1992). After this different studies were carried out on the pesticidal property of neem tree (Schmutterer, 1981). At the end of nineteenth century it is considered as toxic plants (Whittaker, 1971). After time passes there is a increase in botanical pesticides day by day and is considered as one of the safest method having ecofriendly approach.

CONCLUSION

Essential oils are best method to control insect pest. They show insecticidal, fungicidal and repellent activities against a broad spectrum of insects. These are complex chemical compounds with multiple mode of action that enhance their activity due to the synergistic action between constituents. The essential oils are volatile in nature that's why used as fumigant in agriculture and storage food insect. The essential oil are very active against a variety of insects showing their non toxic residues in the treated products. Finally the essential oil based products shows low toxicity, easily degradable and are ecofriendly.

REFERENCES

Abad M J, Ansuategui. M, Bermejo. P (2007). Active antifungal substances from natural sources. *ARKIVOC* 116-145.

Bathal S S, Singh D, Dhillon R S. (1993). Effect of crude root oils of Inularacemosa and Saussurealappa on feeding, survival and development of Spodopteralitura (Lepi-doptera: Noctuidae) larvae. Eur. *J. Entomol*., 90(2):239-240.

Batish D R, Singh H P, Kohli R K, Kaur S. (2008). Eucalyptus essential oil as a natural pesticide. *Forest Ecology and Management*, 256:2166–2174.

Batish. D R, Singh. H P, Setia. N, Kaur. S, Kohli. R K (2006). Chemical composition and phytotoxicity of volatile essential oils from intact and fallen leaves of Eucalyptus citriodora. Z. Naturforsch. C., 61: 465–471.

Bakkali F, Averbeck S, Averbeck D, Idaomar M (2008). Biological effects of essential oils -A review. *Food and Chem. Tox*. 46: 446-475

Bao-liang Tian, Qi zhi Liu., (2015). Insecticidal potential of clove essential oil and its constituents on cacopsylla chinensis in laboratory and field. *Journal of economic entomology.108,3,957-961*

Berger A. (1994)., Using natural pesticides: Current and future perspectives: A Report for the plant protection improvement

programme in Botswana, Zambia and Tanzania. Department of Entomology, Swedish University of Agricultural Sciences, P. O. Box 7044 S-750 07 Uppsala, Sweden.
Bell AE, Fellows LE, Simmonds SJ. (1990)., Natural products from plants for the control of insect pests. In: Hodgson, E. and R. J. Kuhr (Eds.), safer insecticide development and use. Marcel Dekker, USA.

Ben Jemba JM, Tersim N, Toudert KT, Khouja ML. (2012). Insecticidal activities of essential oils from leaves of Laurus nobilis L. from Tunisia, Algeria and Morocco, and comparative chemical composition. *Journal of StoredProducts Research*, 48: 97–104.

Bruneton J, (1999). Pharmacognosy, Phytochemistry, Medicinal Plants: Essential Oils, 2nd ed. *Lavoisier Publishing, New York*, pp. 461-780

Calderone N W, Spivak M., (1995). Plant extracts for control of the parasitic mite Varroajacobsoni (Acari: Varroidae) in colonies of the western honey bee (Hymenoptera: Apidae*). J. Econ. Entomol*., 88: 1211–1215.

Ceferino. T A, Julio. Z, Mougabure. C G, Fernando. B, Eduardo. Z, Maria. I P. (2006). Fumigant and repellent properties of essential oils and component compounds against permethrinresistant Pediculus humanus capitis (Anoplura: Pediculidae) from Argentina. *J. Med. Entomol*., 43: 889–895.

Chagas. A C S, Passos. W M, Prates. H T, Leitem. R C, Furlong. J, Fortes. ICP. (2002). ,Acaricide effect of Eucalyptus spp. essential oils and concentrated emulsion on Boophilus microplus. *Braz. J. Vet. Res. Anim. Sci.,* 39: 247–253.

Chang. S T, Cheng. S S, (2002). Antitermite activity of leaf essential oils and their constituents from Cinnamomum osmophloeum. *J. Agric. Food Chem*. 50: 1389-1392.

Chaubey M K. (2012). Responses of Tribolium castaneum (Coleoptera: Tenebrionidae) and Sitophilus oryzae (Coleoptera: Curculionidae) against essential oils and pure compounds. *Herba Polonica,* 58 (3): 33-45.

Choi W, Lee S G, Park H M, Ahn Y J. (2004). Toxicity of plant essential oils toTetranychus urticae (Acari: Tetranychidae) and Phytoseiuluspersimilis (Acari: Phytoseiidae). *J. Econ. Ent.,* 97: 553-558.

Chogo J B, Crank G. (1981)., Chemical composition and biological activity of the Tanzanian plant Ocimum suave. *J. Natural Products*, 44: 308-311.

Cimanga. K, Kambu. K, Tona. L, Apers. S, De. Bruyne T, Hermans N, Totte´ J, Pieters L, Vlietinck. AJ. (2002). Correlation between chemical composition and antibacterial activity of essential oils of some aromatic medicinal plants growing in the

Democratic Republic of Congo. *J. Ethnopharm*., 79: 213–220

Coats. J R, Karr. L L, Drewes. C D. (1991). Toxicity and neurotoxic effects of monoterpenoids in insects and earthworms. In: Hedin, P.A. (Ed.), *Naturally Occurring Pest Bioregulators, ACS Symposium Series*. 449: 305-316

Duke. J A. (2004). Dr. Duke's Phytochemical and Ethnobotanical databases. Available online at http://www.arsgrin.gov/duke/ (accessed on 9 June, 2008).

Dorman H J D, Deans. S G. (2000). Antimicrobial agents from plants: anti-bacterialactivity of plant volatile oils. *J. Appl. Microbiol*., 88: 308–316.

Enan. E, Beigler. M, Kende. A. (1998). Insecticidal action of terpenes and phenols to cockroaches: Effect on octopamine receptors. In: Proceedings of the International Symposium on Plant Protection, Gent, Belgium.

Foley. W J, Moore. B D. (2005). Plant secondary metabolites and vertebrate herbivores from physiological regulation to ecosystem function. Curr. Opin. *Plant Biol*., 8: 430-435.

Gardul. F A, Wohlfart. I, Gustafson. R. (2004). A prospective cross-over field trial shows protection of lemon Eucalyptus extract against tick bites. *J. Med. Entomol*., 41: 1064-1067.

Grainge M, Ahmed S. (1988)., Handbook of plants with pestcontrol properties. Resource systems institute, East-West center, Honolulu, Hawaii. John Wiley & Sons, New York.

Handerson G, Laine R A, Heuman D O, Chen F, Zhu B R. (2005a). Extracts of vetiver oil as repellents and toxicants to ants, ticks and cockroaches. *U.S. Patent.* No. 6.906,108B2

Handerson G, Laine R A, Heuman D O, Chen F, Zhu, B R. (2005b). Vetiver oil extracts as termite repellent and toxicant *U.S. Patent* 6,890, 960B1.

Harborne. J.B., 1993. Introduction to Ecological Biochemistry. 4th Edn., *Academic Press,* London

Hassanali A, Lwande W., (1989). Antipest secondary metabolites from African plants. In Arnason JT, Philogene BJR Morand P (eds.) Insecticides of plant origin. ACS symposium series 387, pp. 78-96. *American Chemical Society*, Washington, D.C.

Ibrahim S A, Handa G, Laine R A. (2004). Toxicity and behavioural effects of nootkatone, 1-10 dihydronootkatone and tetrahydronootkatone on the Formosan subterranean termite (Isoptera: Rhynotermittidae*). J. Eco. Entomol*., 97(1): 102-111. I

Isman MB. (2000). Plant essential oils for pest and disease management. *Crop Prot*., 19: 603–608.

Isman MB. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annu. Rev. Entomol*., 51: 45–66.

Irvine F R. (1955)., West African insecticides, Colon. Pl. *Anim. Prod*., 5: 34-38.

Jacobson M. (1975)., Insecticides from plants: a review of the literature, 1953-1971. USDA *Agricultural Handbook no. 461*.

Jacobson M, Crosby DG. (1971)., Naturally occurring insecticides. *Dekker Inc*., New York.

Kanat M, Hakki Alma M. (2003)., Insecticidal effects of essential oils from various plants against larvae of pine processionary moth (Thaumetopoea pityocampa Schiff) (Lepidoptera: Thaumetopoeidae). *Pest Manag. Sci*., 60: 173- 177.

Kordali S, Cakir A, Mavi A, Kilic H, Yildirim A. (2005). Screening of chemical composition and antifungal and antioxidant activities of the essential oils from three Turkish Artemisia species. *J. Agric. Food Chem*., 53: 1408–1416.

Kostyukovsky M, Rafaeli A, Gileadi C, Demchenko N, Shaaya E (2002). Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. *Pest Mgt. Sci.* 58: 1101-1106.

Kydonieus A F. (1980). Controlled release technologies: Methods, theory, and applications. Vols. 1 and 2. Boca Raton, FL: CRC Press.

Landol.t P J, Hofstetter. R W, Biddick. L L. (1999). Plant essential oils as arrestants and repellents for neonate larvae of the codling moth (Lepidoptera, Tortricidae). *Environ. Entomol*., 28(6):954-960.

Larocque N, Vincent C, Belanger A, Bourassa J P. (1999). Effects of tansy essential oil from Tanacetum vulgare on biology of oblique-banded leafroller, Choristoneura rosaceana. *J. Chem. Ecol.*, 25(6):1319-1330.

Li. H, Madden. J L, Potts. B M. (1995). Variation in volatile leaf oils of the Tasmanian Eucalyptus species1. Subgenus Monocalyptus. *Biochem. Syst. Ecol*., 23: 299–318.

Li. H, Madden. J L, Potts. B M. (1996). Variation in volatile leaf oils of the Tasmanian Eucalyptus species II. Subgenus Symphyomyrtus. *Biochem. Syst. Ecol.,* 24: 547–569.

Liu. X, Chen. Q, Wang. Z, Xie. L, Xu. Z. (2008). Allelopathic effects of essential oil from Eucalyptus grandisE. urophylla on

pathogenic fungi and pest insects. Front. Forestry China, 3: 232-236.

Marimuth S, Gurusubramanian G, Krishna SS. (1997). Effect of exposure of eggs to vapours from essential oils on egg mortality, development and adult emergence in Eariasvittella (F.) (Lepidoptera: Noctuidae). *Biol. Agric. Horti.,* 14(4):303- 307.

Misra. G, Pavlostathis. S G. (1997). Biodegradation kinetics of monoterpenes in liquid and in soil-slurry system. *Appl. Microbiol. Biotechnol*., 47: 572–577.0

Mohan M, Haider S Z, Andola H C, Purohit V K. (2011). Essential oils as green pesticides: For sustainable agriculture. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 2 (4):100-105.

National Research Council (1992). Neem - a tree for solving global problems. *National Academy Press,* Washington.

National Research Council, (1993). Vetiver Grass: A thin green line against erosion. *National Academy Press,* Washington, DC.

Naumann K, Isman M B. (1995). Evaluation of neem Azadirachta indica seed extracts and oils as oviposition deterrents to noctuid moths. *Entomol. Experimental Appl*., 76:115-120.

Papachristos DP, Karamanoli K, Stamopoulos DC, Menkissoglu-Spiroudi U., (2004). The relationship between the chemical composition of three essentialoils and their Insecticidal activity against Acanthoscelides obtectus (Say*). Pest Manag. Sci*., 60: 514–520.

Pillmoor. J B, Wright. K, Terry. A S (1993). Natural products as a source of agrochemicals and leads for chemical synthesis. *Pest. Sci*. 39:131- 140

Philogène BJR, Regnault-Roger C, Vincent C., (2005) Botanicals: yesteday's and today's promises. In: RegnaultRoger C, Philogène BJR, Vincent C (eds*) Biopesticides of plant origin*. Lavoisier and Andover, UK, pp 1–15.

Regnault-Roger, C., C. Vincent and J.T. Arnason,(2012). Essential oils in insect control: Low-risk products in a high-stakes world. *Annu. Rev. Entomol*., 57: 405-424

Sahayaraj K, Paulraj MG., (2000). Impacts of some plant products on the behavioural bioassay of Tribolium castaneum Herbst in groundnut kernels. *Int. Arachis Newslett*., 2(5): 12- 17.

Schmutterer H, Ascher KRS, Rembold H., (1981). Natural pesticides from the neem tree (Azadirachta indica) Rottach*Egern Neem Conference*, Deutsche Gesellschaftfür Technische Zusammenarbeit (GTZ), Eshborn, Germany.

Shepard H. (1951). The chemistry and action of insecticides. McGraw- Hill, New York, p 504.

Sujatha S. (2010). Essential oil and its insecticidal activity of medicinal aromatic plant Vetiveria zizanioides (L.) against the red flour beetle Tribolium castaneum (Herbst). *Asian Journal of Agricultural Sciences,* 2(3): 84-88.

Su. Y C, Ho. C L., Wang I C., Chang. S T. (2006). Antifungal activities and chemical compositions of essential oils from leaves of four Eucalypts. Taiwan *J. For. Sci*.,21: 49–61.
Theis N and Lerdau M. (2003). The evolution of function in plant secondary metabolites. *Int. J. Plant Sci.,* 164 (3 Suppl.), S93– S102

Tripathi A K, PrajapatiV, Aggarwal K K, Kumar S, Kukreja A K, Dwivedi S, Singh A K. (2000). Effects of volatile oil constituents of Mentha species against stored grain pests, Callosobrunchus maculatus and Tribolium castaneum. *J. Med. Arom. Plant Sci*., 22: 549–556.

Trigg J K., (1996a). Evaluation of eucalyptus-based repellent against Anopheles spp. In Tanzania. *J. Amer. Mosquito Cont. Assoc*., 12: 243–246.

Watanabe. K, Shono. Y, Kakimizu. A, Okada. A, Matsuo. N, Satoh. A, Nishimura. H. (1993). New mosquito repellent from Eucalyptus camaldulensis. *J. Agric. Food Chem*., 41, 2164- 2166.

Weaver. D K, Dunke.l F V, Ntezurubanza L, Jackson. L L, Stock. D T. (1991). The efficacy of linalool, a major component of freshly-milled Ocimum canum Sims (Lamiaceae), for protection against postharvest damage by certain stored product Coleoptera. *J. Stored Products Research*, 27: 213-220.

Whittaker RH, Feeny P., (1971). Allelochemicals: chemical interactions between species. *Science*, 171:757–770.
WHO (1990). Public health impact of pesticides used in agriculture. World Health Organization, Geneva, Switzerland.

Yang. Y C, Choi. H.C, Choi. W S, Clark. J M, Ahn. Y J. (2004). Ovicidal and adulticidal activity of Eucalyptus globulus leaf oil terpenoids against Pediculus humanus capitis (Anoplura: Pediculidae*). J. Agric. Food Chem*., 52: 2507–2511.

Zhu B, Henderson G, Chen F, Maistrllo E, Zaine R A. (2001a). Nootkatone is a repellent for Formosan Subteranean termites (Coptotermes formosanus). *J. Chem. Edu*., 27(3): 523-531.

Zhu B, Henderson G, Chen F, Maistrllo E, Zaine RA. (2001b). Evaluation of vetiver oil and seven insect-active essential oils against the Formosan subteranean termites. *J. Chem. Ecol.,* 27(8): 1617-1625.

Zeng, L, Lao C.Z, Cen Y.J, Liang G.W., Study on the insecticidal activity compounds of the essential oil from Syzygium aromaticum against stored grain insect pests. *10th International Working Conference on Stored Product Protection*
.