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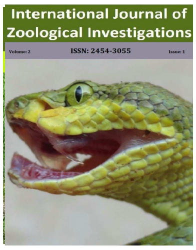

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Botanicals; Its Safe Use in Pest Control and Environmental Management

Ravi Kant Upadhyay

Department of Zoology, D U Gorakhpur University, Gorakhpur 273 009, U.P., India

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Abstract: Plants have a very long relationship with different groups of insects and pathogens. Since their existence plants have developed genotypic and chemotypic variations/adaptabilities according to climatic changes and biological infection and infestation they faced. It had modified and improved the plant genomes with necesscity to generate strong metabolites which are toxic, repellent or insect growth inhibitory in action so that, they could seek protection against herbivorous insects. Most of these chemicals are either available in host and non-host plants but have some target specificity to some insects. Primarily, plants possess anti-feedant or repellent chemicals, which deter insect pests from host and play defensive role. These plant derived chemicals operate through molecular interactions or responses generated and act at cellular level and make organogenesis defaulted, which results in formation of abnormal pupae with weak texture, weight loss and structural deformities. Plant generated natural products generate provoke irreversible, inhibitory effects on egg hatching, growth and development of insects. These phyto-chemicals extend postembryonic development of larvae, pupae and delayed the formation of adults, and reduced the F1 emergence. If these plant genetaed bio-chemicals are added in natural diets or insects are treated or exposed artificially, these impose various deleterious effects in insects. However, various natural plant products such as extracts/dusts/latexes/powder/essential oils, gums, oil-resins, tannins, waxes, vegetable and horticultural oils and plant and microbial toxins have shown wider insecticidal potential against agriculture, veterinary and medical pests. These botanicals are less low toxic, biodegradable and environmentally safe and can be used as herbal pesticides to control different types of insect pests. Due to compositional differences, low toxicity and target specificity, biopesticides are known to be the best control agent for a healthy environment. In the present review, different sources of natural products and their insecticidal effects have been discussed in detail to explore future possibilities for development of new pesticidal formulations to solve the problem of pesticide resistance, environmental damage and pest control.

Keywords: Botanicals, Insects, Biological control, Neem, Pesticides

Introduction

During last few decades, various synthetic pesticides have been applied to control agricultural, veterinary, medical and household insect pests. Due to massive and repeatitive use, synthetic pesticides have imposed so many detrimental effects on the environment and cause intoxication of non-targeting organisms (Forage-Elaver, 1989; Rajeskaran and Baker, 1994; Gupta *et al.*, 2001). These synthetic chemicals are declared ecologically unsafe because they persist for longer period in the environment, show residual effect and enter into the food chain. Thus, overuse of synthetic pesticide is responsible for poisoning of food chains and killing of non-target organisms. Due to long-term adverse effects of insecticides, insects have acquired resistance against most of the synthetic insecticides; however most of them are banned (Brattsten *et al*., 1986; Zettler and Cuperus, 1990). Due to very high toxicity, environemental damage and long term adverse effects in man, there is an emerging demand of botanical insecticides/pesticides to control insect pests (Ismam, 1955; Alkofahi, 1987). In the past, many natural products (Koshiya and Ghelani, 1993) such as pyrithroids, nicotine, Rhyania, Sbadilla, Quassia, Acorus, rotenone, azadirachtin (Barnby and Klocke, 1987; Ayyangar and Rao, 1989; Deota and Upadhyay, 2005), anthraquinone (Morimoto *et al*., 2002) and gallic acid (Mukherjee and Sharma, 1993) were used to control various insect pests (Kamaraj *et al*., 2008). Now-a-days explored tthere are so many plant origin chemicals which possess toxic, repellent/ antifeedant, oviposition, growth and development inhibitory potential against insects (Koshiya and Ghelani, 1993; Ballesta 2008). Still there is a scarcity of much potent insecticidal formulations. However, to resolve the problem of pesticide resistance, environmental damage, biodiversity loss, and human health hazards, mixed formulations are to be prepared to control rising insect pest population (Rao and Dhingra, 2000). Hence, bio-pesticides are best known positive alternative to synthetic pesticides used for safe management of insect pests and environemnt (Berenbaun, 1986).

Why plant natural products

Natural plant products when used show limited undesirable effects on the environment and non-target organisms (Grainge *et al*., 1986) than conventional insecticides due to its low toxicity. These are biodegradable in medium and impose low residue risks on food crops, drinking water, soil flora and fauna (Manasaray, 2000; Ottaway, 2001). If applied even in very low quantity these bio-chemicals efficiently cut down the pest population. There are so many plant products which are highly toxic to insects but less or moderately toxic to mammals with few exceptions. If used with natural diet or used by applying any control method, botanical insecticides primarily cause harmful effects in insect pests and do little harm to beneficial insects. Hence, naturally occurring insecticides are characterizaed favorably for low acute toxicity and ready dissipation in nature (Soloway, 1976). Such bioorganic chemicals can be used in poison baits to minimize human exposure and health risks. Only demerit of natural extracts/ products is that these are mixture of active and inactive components. Therefore, specific characterization has to play important role to make them more competitive in comparison to synthetic pesticides. Ingradients of plants can be used in low quantity to prepare combinatorial insecticidal formulations, for controlling pest menace. However, before use all herbal products should be evaluated for level of toxicity, effectiveness, environmental impact and costs. Herbal pesticides show some disadvantages as rapid break down, while less risky to health and environment, often creates a need for precise timing or more frequent applications. Several botanical insecticides are quite toxic and should be handled accordingly.

Plant extracts

Various solvent and aqueous extracts prepared from different plant species showed wider insecticidal activity against so many insect pests. Most of them have shown toxic, anti-feedant/ repellent and oviposition inhibitory activity. These phyto-chemicals generate irreversible growth inhibitory effects in insects and extend postembryonic development that delayed the formation of adults and reduce the F1 emergence. However, in a well-protected insect control operation plant extracts showed enormous toxicity against several stored product pests and provide prolonged protection to the seeds in treatments. However, closed chamber treatment causes high mortality in reproductive insects and successfully inhibits oviposition and egg hatching in susceptible insects. These also act as contact, stomach and systemic poisons that depend on operation method applied. Further, its dose-response relationship shows significant negative correlation between larval-pupal survival and adult emergence. These plant origin chemicals operate through molecular interactions or responses generated, which also act at cellular level and make organogenesis defaulted. It results in formation of abnormal pupae with weak texture, weight loss and structural deformities. However, generation of defaulted insects or non-reproductives failed to extend successive progenies in beetles, weevils, flies and moths in granaries. If such toxic and inhibitory phytochemicals are added in natural or artificial diets, they impose deleterious effects in insects.

However, in search of herbal pesticides number of plant species has been explored so far for their insecticidal potential against different insect pests. Many natural products such as plant extracts, latexes, essential oils, root and leaf powders, dust, wood extracts, tannins, oils, oil-resins, gums, soaps, waxes and microbes toxins have been used to control insects. These also have shown repellent (Tripathi *et al*., 2000), anti-feedent (Verma *et al*., 2000), growth (Matthews, 1993; Vale *et al*., 1999) and developmental inhibitory in nature against number of insect pests (Wango, 1998; Singh and Rao, 1999). However, plant extracts such as *Piper nigrum*(L) (Boff *et al.,* 2006), *Anethum graveoleons, Cuminum cyminum* (EL-Lakwah *et al.,* 2001), *Allium sativum* (Udo, 2005) , *Vitex negundo, Polygonum hydropiper* (Taleb and Salman 2005), *Myristica fragrans* (Haryadi and Rahayu, 2003) were found insecticidal to stored grain pests (Trakoontivakorn *et al*., 2006). Similarly, water extract of *Nigella sativa* was reported to show insecticidal and repellent activity against the Japanese beetle, *Papillia japonica* (McIneloo, 1982) while leaves of *Artimisia princepi* and seeds of *Cinnamomum camphora* (L) have shown repellent and insecticidal activity against *Sitophilus oryzae* and *Bruchus rugimanus* (Liu *et al*., 2006). Extracts of *Capparis deciduas* stem and flower shows insecticidal and oviposition inhibitory activities against *Bruchus chinensis* (Upadhyay *et al*., 2007) and *Tribolium castanaeum* (Upadhyay *et al*., 2007). Similarly, phenyl butanoid extracted from *Zingiber purpurem* act as oviposition inhibitor in Bruchids (Bandara *et al*., 2005). Moreover, root extracts of *Diospyros sylvatica* cause high mortality and impose significant repellent activity in subterranean termite, *Odontotermes obesus* in filter paper disc bioassay (Ganpaty *et al*., 2004). Similarly, leaf extracts of *Polygonum hydropiper* (L) and *Pogostemon paviflorus* (Benth) have shown high toxicity and mortality in tea termite *Odontotermes assamensis* (Holm) (Rahman *et al*., 2005). Thus, plant products provide prolonged protection to the seeds, by repelling insects, reducing oviposition and egg hatching and inhibition of embryonic development (Maheshwari, 1998).

Solvent and aqueous extracts of *Gloriosa superba* (Khan *et al*., 2007), *Paronia emodi* (Khan *et al*., 2005)*, Corydalis incise* (Dae, 2002)*, Cassia obtusifolia (*Dong *et al*., 2007), *Artemisia annua* (Shekari *et al*., 2008), *Teucrium royleanum* (Ahmad *et al*., 2007a), *Andrache cardifolia (*Ahmad *et al*., 2007b), *Angelica archangelica* and *Geranium sylvatica* significantly kill certain harmful insects by inhibiting enzyme activity (Sigurdsson, and Gudbjarnason, 2007). The extracts of leaf, root, stem and callus obtained from *Psehdarthria viscida* showed significant inhibitory activity against stored food grain pests (Deepa *et al*., 2004). Various extracts and pure compounds isolated *Capparis decidua* have shown significant toxic and repellent activity against *Odontotermes obesus* at a very low dose with an EC_{50} ranged between 0.008-0.017μg/gm (Table 2). Application of its pure extracts and compounds have significantly cut down the termite infestation in green saplings and damage done by workers termites (Upadhyay *et al*., 2011, 12). Further, treatment of infested saplings by both spray and tag binding has significantly reduced the number of termites (14.0%), % infestation (11.68) and tunneling activity (19.825) in garden saplings. Further, active ingredients of *Capparis decidua* repelled large number of termites in seasoning wood sticks that were planted in garden soil. It has protected the wood weight loss up to 3.25 % and no infestation was observed even after 6 month of digging (Upadhyay *et al*., 2011, 2012). *C decidua* also repelled large number of stored grain insect *Sitophylus oryzae*.

Plant latex

Plant latex is a natural polymer secreted as milky fluid by highly specialized cells known as laticifers (Hagel *et al*., 2008) found in root, stem, leaves and fruits of all flowering plants (Pickard, 2008). It is an emulsion like sticky material that exude from various plant parts upon a small tissue injury and squirts out as white glue from bark of plants. Normally, latex color is white, yellow, orange, or scarlet but it changes after an air exposure. Latex is stable dispersion of polymer micro-particles in an aqueous medium that coagulates on exposure to air. Latex is a complex mixture of diverse phytochemicals mostly secondary metabolites (Domsella and Melzig, 2008) (Table 1) such as flavaonoids (Seetharaman *et al*., 1986; Salunke 2005), alkaloids (Kotkar *et al*., 2002, Opel *et al*., 2009), triterpenes (Mazoir *et al*., 2008), acetogenins (Rupperchat *et al*., 1990; Castillo *et al*., 2010) , saponins, starch, sugars, oils, tannins, resins, gums, sterols, fatty acids and many enzymatic proteins such as thrombins, plasmins, papain, hevein, allergens toxins (Champagne *et al*., 1993; Carlini *et al*., 2002), lectins (Wititsuwan-nakul *et al*., 1998; Lam and Tzi, 2011), enzymes (Giordani *et al*., 1992) and enzyme inhibitors (Farias *et al*., 2007; Sadeghi *et al*., 2006; Freitas *et al*., 2007) (Table 2). Latexes from Persian poppy (*Papaver bracteatum*) and opium poppy (*Papaver somniferum)* contain glycosidase inhibitors 1, 4- dideoxy-1, 4-imino-d-arabinitol (d-AB1) and 1-deoxynojirimycin (DNJ) that showed insecticidal properties (Hirayama *et al*., 2007). *Ficus racemosa* latex contains Gluanol acetate, a tetracyclic tri-terpene that display larvicidal activity against mosquitoes *Culex quinquefasciatus* (Diptera: Culicidae) (Rahman *et al*., 2008).

Plant latex is highly toxic to insects and causes very high mortality in larvae, pupae and adults. Latex acts both as systemic and contact poison which depends on method and duration of treatment. Naturally, latex causes stomach poisoning in larvae, caterpillars, pupae and sap sucking adult insects. However, *Calotropis procera* latex shows larvicidal activity (Singh *et al*., 2005) against *Musca domestica, Anopheles stefensi*, *Culex quinquefasciatus* (Shahi 2010) and *Aedes aegypti* larvae at a topical dose of 3 μg/gm of latex (Ramos *et al*., 2006; Singh *et al*., 2004). Upon successful treatment, latex components inhibit feeding, oviposition, egg hatching, growth and reproductive cycle in many insect species (Singh and Jain, 1987; Champagne 1993; Carlini and Grossi-de Sa, 2002) mainly in mosquitoes *Aedes aegypti* (Singh *et al*., 2004). Its sub-lethal dose imposes deleterious effects in larvae and pupae, cause reduction in body weight and obstruct molting in larval stadia (Upadhyay *et al*., 2013). Latex generated toxicity also affects % pupation and prolong the pupal duration in treatments in comparison to corresponding control (Upadhyay *et al.*, 2013). Plant latex from *Calotripis procera* (Upadhyay *et al.*, 2013), *Annona squamosa* (Begum *et al.*, 2010), *Havea brassilensis* (Shaalan *et al.*, 2005), *Carica papaya*, *Goniothalamus macrophyllus* (Castillo *et al.*, 2010) and *Asclepias humistrata* (sandhill milkweed) showed strong insecticidal activity against larvae and caterpillars of herbivorous insects (Obregon *et al.*, 2009; Kitajima *et al.*, 2010) (Table 1). Similarly mulberry leaves latex showed very high toxicity (Hirayama *et al.*, 2007) and impose feeding inhibition in *Bombyx mori* (Konno *et al.*, 2006). It shows anti-feedant activity in herbivorous insects due to presence of unpalatable substances such as toxins, enzymes and immune allergens. In laboratory experiments toxicity remain intact in fractionated plant latex that shows very high lethal and deterrent effect in insects (Upadhyay *et al.*, 2013).

Table 1: Insecticidal activity latex bearing plant species with its common and scientific name.

Common name	**Scientific name**	**Family**	**Pesticidal activ ity reported**	**Effective against life stage**
Wild fig	*Ficus virgatalatex*	Moraceae	Insecticidal	Larvicidal and growth inhibitory
Sandhill milkweed	*Asclepias humistrata*	Asclepiadaceae	Insecticidal	Adulticidal and repellent
Aak / madar	*Calotropis procera*	Acslepidiaceae	Insecticidal	Insecticidal, growth inhibitory
Aak	*Calotropis gigantean*	Acslepidiaceae	Insecticidal	Insecticidal, gro wth inhibitory
Madar	*Calotopis procera*	Asclepiadaceae	Insecticidal	To xic, gro wth inhib itory and antifeedant
Milkweeds	*Asclepias angustifolia*	Asclepiadaceae	Insecticidal	Effect ive against herbivorous insects
Milkweeds	*A. barjoniifolia*	Asclepiadaceae	Insecticidal	Effective against herbivorous insects
Milkweeds	*A. fascicularis*	Asclepiadaceae	Insecticidal	Effective against herbivorous insects
Papaya	*Carica papaya*	Caricaceae	Insecticidal	Oviposition and development inhibitor
Tut	*Morus alba*	Moraceae	Insecticidal	To xic to larvae of lep idopteran insects
Rubber plant	*Ficus elasica*	Moraceae	Insecticidal	Inhibit egg hatching and larval development
Bargad	*Ficus bengalensis*	Moraceae	Insecticidal	Inhib it egg hatching and larval development
Chalate	*Ficus insipida*	Moraceae	Insecticidal	Inhib it egg hatching and larval development
Ficus	*Ficus racemosa*	Moraceae	Insecticidal	Inhibit egg hatching and larval develoment
Wild fig	*Ficus virgata*	Moraceae	Insecticidal	Inhibit egg hatching and larval develoment
Gazyu mmaria	*Ficus microcarpa*	Moraceae	Insecticidal	Inhib it egg hatching and larval development
Gu lar	*Ficus glomerata*	Moraceae	Insecticidal	Inhibit egg hatching and larval development
Pipal	*Ficus religiosa*	Moraceae	Insecticidal	Inhibit egg hatching and larval development
Anjir	*Ficus carica*	Moraceae	Insecticidal	Inhibit egg hatching and larval development
Pakar	*Ficus rumphi*	Moraceae	Insecticidal	To xic, antifeedant and antidote to snake bite

Jackfruit	*Artocapus heterophyllus*	Moraceae	Insecticidal	Gro wth inhib itory and toxic
Opiu m poppy	*Papaver sommeniferum*	Euphorbiaceae	Insecticidal	Effective against eggs and larvae
Spurge	*Euphorbia lacteal*	Euphorbiaceae	Insecticidal	Effective against eggs and larvae
Sudha	*Euphorbia nerrifolia*	Euphorbiaceae	Insecticidal	Effective against eggs, larvae and pupae
Tridhara	*Euphorbia antiqunum*	Euphorbiaceae	Insecticidal	Effective against eggs and larvae
Splendens	*Euphorbia splendens*	Euphorbiaceae	Insecticidal	Post embryonic develop ment of *M. sclaris*
Badi Dudhi	*Euphorbia hirta*	Euphorbiaceae	Insecticidal	Inhibitor of egg hatching, embryonic development
Biodiesel plant	*Jatropha curcas*	Euphorbiaceae	Insecticidal	Effective against eggs, larvae and pupae
Hierba mala	*Euphorbia cotimfolia*	Euphorbiaceae	Insecticidal	Effective against eggs, larvae and pupae
Mohan	*Euphorbia rogleana*	Euphorbiaceae	Insecticidal	Effective against eggs, larvae and pupae
Hyaena-poison	*Hyaenanche globosa*	*Euphorbiaceae*	*Insecticidal*	Effect ive against eggs, larvae, pupae and adults
Persian poppy	*Papaver bracteatum*	Euphorbiaceae	Insecticidal	Mosquito and house fly larvae and eggs
Croton	*C roton sparciflorus*	Euphorbiaceae	Insecticidal	Mosquito and house fly larvae and eggs
Pili kaner	*Thivetia nerrifolia*	Euphorbiaceae	Larvicidal	Effective against eggs and larvae
Rubber tree	*Hevea brasiliensis*	Euphorbiaceae	Insecticidal	Effective against eggs and larvae
Persian poppy	*Papaver bracteatum*	Euphorbiaceae	Insecticidal	To xic and repellent
Safed Arand	*Jatropha curcas*	Euphorbiaceae	Insecticidal	Highly to xic to larvae, pupae and adults
Indian Spurge Tree	*Euphorbia. nivulia*	Euphorbiaceae	Insecticidal	To xic and repellent
Antique Euphorbia	*Euphorbia antiquorum*	Euphorbiaceae	Insecticidal	To xic and repellent
Goburchampa	*Plumeria rubra*	Apocynaceae	Inscticidal	Repellent and antifeedant
Oleander	*Nerium oleander*	Apocynaceae	Insecticidal	Effective against eggs and larvae
Sapthaparna	*Alstonia macrophylla*	Apocynaceae	Insecticidal	Effective against eggs and larvae
Pili Kaner	*Thevetia nerifolia*	Apocynaceae	Insecticidal	Effective against eggs, larvae, pupae and adults
Kaner	*Nerium indicum*	Apocynaceae	Insecticidal	To xic, antifedant and repellent
Dudhi	*Nerium tinctorum*	Apocynaceae	Insecticidal	To xic, antifedant and repellent
Sadabahar	*Vinca rosea*	Apocynaceae	Insecticidal	Effective against eggs, larvae, pupae and adults
Rubber vine	*Cryptostegia grandiflora,*	Apocynaceae	Insecticidal	To xic, antifedant and repellent
Plu meria	*Plumeria alba*	Apocynaceae	Insecticidal	Effective against eggs and larvae
Sharifa	*Annona squamosa,*	Annonaceae	Insecticidal	IV instar larvae of lep idopteran insects
Mexican Poppy	*Argemone ochroleuca*	Papaveraceae	Insecticidal	Adults and eggs of Cu lex sp.
Maulsari	*Mimusops elengi*	Sapotaceae	Insecticidal	Effective against eggs, larvae, pupae an

Plant latex is a rich source of enzymatic proteins mainly cysteine proteases, profilins and chitin-related proteins that act as catalytic enzymes (Wasano *et al*., 2009) and provide defense against phytopathogenic fungi, bacteria, vruses and insects. Latex also contains toxins, enzymes (Carlini CR, Grossi-de 2002), endogenous soluble proteins (Dubey and Jagannadham, 2007; Freitas 2010) and different types of proteases, which show proteolytic activity (Ramos *et al*.,, 2009; Freitas *et al*., 2010). These soluble proteins act at the cellular level and make organogenesis defaulted. It leads to the formation of abnormal pupae with weak texture, weight loss and structural deformities in various organs (Yagami *et al*., 1994; Yagami *et al*., 1998). All these effects generated are reported to be irreversible and growth and development inhibitory in nature. These soluble factors operate through molecular interactions or responses generated (Halitschke *et al*., 2001) between insects (herbivore) and its natural host plant (Winz *et al*., 2001). Such defensive interactions seems to be associated with insecticidal activity (Konno *et al*., 2004; Freitas *et al*., 2007) in plants against series of insect pests of crop plants (Konno *et al*., 2004; Freitas *et al*., 2007). Further, presence of enzyme inhibitors mainly α-amylase (Farias *et al*., 2007) and Kunitz-type trypsin inhibitors (Azarkan *et al*., 1997) obstruct feeding in caterpillars by disrupting peritrophic matrix (Pechan *et al*., 2002). It imposes long lasting hunger in insect larvae and adults that forcibly results in large number of deaths in insects. Amylase inhibitors isolated from common bean (*Phaseolus valgaris*) provide wider protection of crops from insect pests and are used to decrease insect pest population below the economic injury level. In addition, *N*-acetyl-β-d-glucosaminase (Giordani *et al*., 1992) II chitinase, calotropin and procerin isolated from *Calotropis procera* impose structural deformities in insects (Azarkan *et al*., 1997). Hence, due to presence of diverse chemical substances plant latex serves as defense material and prevents herbivorous insects from feeding (Ramos *et al*., 2011) (Table 2).

Latex is also an important natural source of immune allergens, which cause allergic reactions and induce immediate-type hypersensitivity in insects and other animals. It effectively deters crop pests from feeding on plants (Konno *et al*., 2004; Ramos, 2011) (Table 1). Though, no volatile has been isolated from plant latex so far that might show repellent action. However, major latex components are either proteins or enzymes which lack deterrent activity and act as non-restraint molecules (Freitas *et al*., 2007, 2010). Thus, deterrent activity may be a consequence of feeding deterrent cum repellent effect, which is possibly operated by some unknown volatile substance from latexes that might also play multi-defensive role in plants (Moursy, 1997; Markouk *et al*., 2000). Similarly, silver nano-particles synthesized using *Plumeria rubra* plant latex has shown larvicidal activity against *Aedes aegypti* and *Anopheles stephensi* (Patil *et al*., 2011). Fractionated plant latex also showed toxic and deterrent effect in *Spodoptera litura* (Ramos *et al*., 2011) (Table 2). This might be associated with carbohydrate-binding activity of proteins. Such type of interactions between laticifer fluids and insects would contribute to better understanding the toxic and repellent-like effects of certain bioorganic components in other harmful organisms. It will also help to design target specific insecticides based on functional interactions between insects and host plants.

Table 2: Insecticidal bio-organic constituents isolated from latex of different plant species

Latex plant	**Compound isolated**	**Biological activity**
1-deo xynojirimycin	*Papaver sominferum*	Insecticidal
Anabasine, luinine	*Anabasin aphylla*	Mosquitocidal
Nicotine, anabasine, lupinine	*Anabasis aphylla*	Mosqiutocidal
Opiu m alkalo ids	*Papaver sominiferum*	Anti-allergic, narcotic, insecticidal
Opiu m	*Papaver sominferum*	Glycosidase inhibition in insects
Profillins, Hevamine	*Heave brasilensis*	Insecticidal
Vinblastine, Vincristine	*Madagascar periwinkle*	Oviposition inhibitor
Anthrone (Aloin)	*Aloe harlana*	Larvicidal
Calotropinol	*Calotropis procera*	Larvicidal and repellent
Cysteine protease	*Calotropis procera*	Insecticidal, defensive
Procerin, Calotropin	*Calotropis procera*	Insecticidal
Methomyl and cardenolides	*Calotropis procera*	Pesticidal, acaricidal
Cardenolides	*Calotropis gigantiea*	Pesticidal, acaricidal
Triterpenoid saponins	*Calotropis procera*	Toxic, pesticidal
C-24 diep imer of stig mast-4-en-6β-o l-3-one.	*Calotropis procera*	Insecticidal
Quercetin-3-rutinoside	*Calotropis procera*	Toxic, poisonous
Tirucallo l a triperpene	*Euphorbia lacteal*	Insecticidal
DELTA 1-p iperidene alkaloids	*Carica papaya*	Insecticidal
Acetogenins	Annonaceous plants	Insecticidal
Pessoine and spinosine	*Annona spinescens*	Insecticidal
Annoglacins A and B	*Annona glabra*	Insecticidal
Pyrannocoumarins	*Calophyllum lanigerum*	Insecticidal
2-ep ihydroxy isojatrogrossidion	*Jatropha curcas*	Larvicidal
Chit inase	Mullberry	Defensive and insecticidal

Plant latex significantly inhibits molting in larval instars or transformation into next instar or larval stadia by slowing down the larval development. Latex generated toxicity significantly decreased the % pupation, pupal weight, survival and prolonged the pupal duration in treatments in comparison to corresponding control (Upadhyay *et al*., 2013). Latex treatment also affect gonadotrophic cycles in *Aedes aegypti* female insects (Ramos *et al*., 2006) and display inhibitory effects on egg hatching and larval development (Champagne *et al*.,1993). It increases the postembryonic development period of larvae and pupae, reduced the F1 emergence (Braga *et al.,* 2007; Ramos *et al*., 2011) and delayed the formation of adults. Similar effects were also noted in blowfly *Chrysomya megalocephala* (Diptera: Calliphoridae) post-embryonic development at 1.0% (w/v) dose of *Parahancornia amapa* latex (Apocynaceae) (Mendonça *et al*., 2011). It shortened the postembryonic development period of larvae, pupae and newly hatched larvae to adult whereas 3.0% latex provoked a prolongation of these periods (Mendonça *et al*., 2011). Similarly, crude latex from *Euphorbia splendens* var. *hislopii* (Euphorbiaceae) affects post-embryonic development time and viability of *Megaselia scalaris* under laboratory conditions at 5 μg/mL, 10μg/mL and 20 μg/mL concentration (Mello *et al.,* 2010). Rubber plant *Hevea brasiliensis* latex heavily deter beetle, *Luprops tristis* and inhibit development and reproductive efficiency of parental adults (Thomas *et al.,* 2009). Moreover, few fatty acid-amino acid conjugates occur in herbivore oral secretions also showed molecular interactions between insect and plant that signify herbivore-specific plant responses (Halitschke, *et al*.,. (2001). Due to massive lethality, reproductive and postreproductive inhibition shown by latex and its components these are considered as good insecticidal natural products which can be used for preparation of herbal pesticide formulations for safe control of insect pests (Upadhyay *et al*., 2011). Further, latex also has wider applications in the field of medical sciences. It is used for preparation of pharmaceuticals, adhesives, polymers, films, gloves, and other important diagnostic materials. Latex from few plants contains an elastic polymer related to rubber that form films without releasing potential organic solvent which is used for formation of various industrial products.

Essential oils

Essential oils are volatile substances, which are extracted from various plant parts by steam distillation. Essential oils and its components easily evaporate in the medium, deter insects from feeding, elicit negative responses, act as repellent and cause very high lethality in insects. Plant essential oils, contain volatile constituents that after evaporation in the medium act as repellent and deter large number of insects from feeding at low doses in stored grain insects. Due to very high repellent effect, insects start shifting towards peripheral areas or migrate from treatment site. These volatile compounds also impose negative orientation responses in insects and inhibit oviposition and egg deposition on the stored grain surfaces. However, post harvesting treatment of seeds with essential oils effectively cut down infestation in storehouses and helps to stop transmission of infestation from stores to field. Sub-lethal dose of these oils or oil constituents obstruct reproductive behavior mainly gonado-trophic cycle in adult females and show ovicidal activity (Table 3). These oviposition responses in insects are influenced by type of chemical, functional group and volatility generated. Thus, in storehouses volatile oils elicit negative responses in stored grain pests, forcibly disallow ovipoistion, and egg hatching, and significantly cut down progeny production. Toxic and inhibitory effects of volatile components also affect growth and development of larvae and pupae and delayed its generation time. A number of these essential oils, including the oils of cedar, cinnamon, citronella, citrus, clove, eugenol (a component of clove oil), garlic, mints, rosemary, and several others have been used to control stored grain insects. These oils and it components impose minimum risk to the users and work as contact or fumigant poisons.

Plant essential oils have shown very high insecticidal activity against field crop (Isman et *al.,* 2001), stored grain (Tripathi *et al.,* 2000 a b; Verma *et al.,* 2000) and household insect pests (Singh *et al.,* 2000). These potentially inhibit oviposition in stored grain insects at very low LC_{50} value (Tripathi *et al.,* 2000b; Jayasekhara *et al.*, 2005) and show good repellent action (Upadhyay *et al.,* 2007) against crop field and house hold insects (Malik and Naqvi, 1984). Volatile oils isolated from *Chenopodium ambrosoides* and *Thymus vulgaris* have shown larvicidal activity against *Lucilia sericala* (Morsy 1998) while, eucalyptus, margoram, pennyroyal and rosemary essential oils have shown insecticidal activity against *Pediculus humanus* (Yang *et al.,* 2004). Similarly, volatile oils isolated from leaves and flowers of *Lantana camphor* (L) have shown insecticidal activity against *Musca domestica* (Abdel-Hady *et al.,* 2005). Similarly, clove oil, cumin, black pepper, ajwain, dill oil and staranise oil have shown very low LC_{50} value that ranges between 1.05–1.2µl/mL. Foam sprayed with clove oil and placed between sacks caused the highest mortality of *Callosobruchus maculatus* (Abd El-Aziz and Shadia, 2001) (Table 3).

Essential oils isolated from mentha, carvacryl, citronella and eucalyptus have shown good repellent effects against *Aedes albopictus* (Yang and Ma, 2005). Cinnamaldehyde and cinnamyl acetate isolated from *Cinnamomum osmophloeum* have shown larvicidal and growth inhibitory effects in fourth instar larvae of *Aedes aegypti* at 29 ppm dose (Cheng *et al.,* 2004). Similarly, eugenol isolated from leaf buds of *Eugenia caryophyllata* essential oils showed significant toxic potential against *Pediculus capitis.* Volatile compound diallyl disulphide isolated from neem has shown potent toxic, fumigant and feeding deterrent activity against stored grain pests mainly *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst) (Koul, 2004). Similarly, methyl salycylate a volatile constituent isolated from *Securidacalonga pedunculata* exhibited repellent and toxic properties against *Sitophilus zeamais* and *Rhizopertha dominica*(Jayasekara *et al*., 2005) (Table 3). Similar toxic effects in insects were also observed in presence of different constituents of essential oils like d-limonene, linalool and terpenols (Weaver et *al.,* 1991, 1995). Thymol, a constituent of thyme essential oils binds GABA receptor of human and housefly to act as modulator (Priestley *et al.,* 2003).

Essential oils isolated from plants contain cyclic and monocyclic mono-terpenes that were found highly effective to repel insects. Filter paper strips treated with *Acorus calamus* oil significantly repelled more number of *Tribolium castaneum* adults (Jilani and Su, 1983). Similarly, the oils of Nigella, Frankincense and Pumpkin act as repellent, deterrent and protectant against the bean bruchids, *Bruchus incarnate* beetles (Abd El. Aziz and Ismail, 2000). Similar repellent and insecticidal activities of essential oils extracted from leaves of *Artemisia princeps* pamp and seeds of

Cinnamomum comphora have been shown against storage insect pests (Liu *et al*., 2006). 1, 8- Cineole from *Artemisia annua* shows toxicity and feeding deterrence activity against *Tribolium castaneum.* It also affects the progeny production in flour beetle (Tripathi *et al*., 2001). Moreover, combination of avidin and alpha AI did not show mortality, but cause a significant increase in developmental period of cowpea bruchids (Tarver *et al*., 2007). Legume seeds contain a wide range of allelochemicals that show toxic and deterrent effects against insect pests (Bell, 1978) (Table 3). Pea protein is repellent to several stored product insects (Bodnaryk *et al*., 1999).

Volatile oils of *Calendula micrantha* plant showed insecticidal activity and inhibited reproductive potential of Mediterranean fruit fly *Ceratitis capitata wied* (Hussein, 2005) while, volatile essential oils extracted from corn leaves have shown oviposition inhibition in *Sesamia nonagriodes* females (Konstantopoulou *et al*., 2002). The essential oils isolated from *Salvodora oleoides* and *Cedrus deodara* have shown significant oviposition deterrence against *Phthorimaea operculella* (Tare, 2000) while essential oils isolated from *Anethum sowa* and *Artemisia annua* have been reported for their repellent, toxic and developmental inhibitory activity against *Tribolium castaeneum* and *Callosobruchus maculates* (L.). *Artimisia annua* oil also affects viability of *Callosobruchus maculatus* eggs (Tripathi *et al*., 2000 a,b). However, 1% concentration of *Artimisia annua* essential oil significantly repelled Adult beetles of *T. castaneum*. Its dose-response relationship revealed a significant negative correlation between larval survival, pupal survival and adult emergence of *Tribolium castaneum* (Tripathi *et al*., 2000a). *Lippia alba* essential oil has shown toxic and developmental inhibitory activities against *Callosobruchus maculatus* and *Tribolium castaneum* (Verma *et al*.,. 2000). Sub-lethal doses of different essential oils such as cumin, ajwain, staranise and saunf effectively inhibit feeding and oviposition in *Bruchus chinensis* (Upadhyay *et al*., 2008). Essential oils isolated from few African plants have shown fumigant toxicity against *Anopheles gambiae* (Omolo *et al*., 2005), while *Ipomoea cairica* has shown larvicidal effect against *Culex tritaeniorhynchus* (100 ppm), *Aedes aegypti* (120 ppm), *Anopheles stephensi* (120 ppm) and *Culex quinquefasciatus* (170 ppm) (Thomas *et al*., 2004) (Table 3).

Volatile oils also impose negative orientation responses in insects and inhibit the egg deposition on the surface. Contrary to this, few chemicals such as n-alkenes isolated from *Ostrinia nubilalis* (Hubner) (Lupoli *et al*., 1990; Udayagiri and Mason, 1995) induce oviposition, but pentane extracts deter females from oviposition (Konstantopoulou *et al*., 2002). Besides crude oils, oil constituents like d-limonene, linalool and terpenols were also found active against many insect pests (Weaver *et al*., 1991, 1995; Rao and Singh, 1994). Moreover, few volatile constituent such as, di-n-propyl disulfide extracted from seeds of neem, *Azadirachta indica* has been found toxic to *Tribolium castaneum* adults and larvae, and *Sitophilus oryzae* adults when used as a fumigant. It significantly decreased the growth rate and dietary utilization with moderate inhibition of food consumption in both insects. It also acts as a strong feeding deterrent to stored grain pests (Koul, 2004). Similarly, fungal volatiles are also used to control stored grain insects (Steiner *et al*., 2007).

Besides plant extracts, essential oils have also shown very strong repellent and toxic activity against Formosan subterranean termite due to presence of volatile compounds (Kim *et al*., 2006) (Table 3). Among these monoterpenes were proved highly toxic to *Coptotermes formosanus* (Cornelius *et al*., 1997). Essential oils such

Calocedrus formosana (Cupressaceae) effectively work against *Coptotermes formosanus* at very low dose 27.6 mg/g (Cheng *et al*., 2004) while maca (*Lepidium meyenii)* essential oil effectively kill *Coptotermes formosanus* at 1% (w/w) concentration (Tellez *et al*., 2002). Similarly, clove bud oils kill Japanese termite *Reticulitermes speratus* at 7.6 ml/L air by fumigation (Park *et al*., 2005). Toxic, antifeedant and repellent activities are also reported in *Chamaecyparis nootkatensis*, *Sequoia sempervirens* and *Pseudotsuga menziesii* (Hennon *et al*., 2007) by using *Aleurits fordii* (Tung tree) extracts (Hutchins 1996) against *Reticuletermes flavipes* (Blaske and Hertel, 2001). 2'acetonaphthone also obstructed tunneling and feeding behavior in Formosan subterranean termite *Coptotermes formosanus,* Shiraki at 8.33 mg/kg concentration (Ibrahim *et al*., 2004). Besides this, natural amides such as nootkatone (Zhu *et al*., 2001) valencenoid derivatives (Zhu *et al*., 2003a), imidacloprid (Osbrink, and Lax, 2003) also deter feeding in termites and suppress adult survival (Upadhyay *et al*., 2010). Similarly flavanoids present in larch wood (Chen *et al*., 2004) and stilbene rich compounds such as piceid, isorhapontin and astringin also deter termites at a very low concentration -0.63 to 2.5 μmol/disc (Shibutani *et al*., 2004). Few natural products such as flavonoids (Boue *et al*., 2003), sesquiterpenes (Arihara *et al*., 2004) and thiophenes (Fokialakis *et al*., 2006) isolated from different plants species were found effective against (Kinunjai *et al*., 2000) (Table 3).

Essential oil extracted from the leaves of turmeric, *Curcuma longa* L., showed contact and fumigant toxicity. It repel large number of insects from feeding, reduce oviposition and egg hatching and progeny production in stored grain insects (Tripathi *et al*., 2002). The constituents of *Foeniculum valgare* fruit show contact and fumigant activity against coleopteran stored product insects (Kim and Ahn, 2001). *Citrus* oil is used as toxicant to kill several stored product insects (Su *et al*., 1972). The Japanese mint (*Mentha arvensis*) oil was found effective as fumigant against *Sitophilus oryzae* in sorghum *(Sorghum bicolor)* (Singh *et al*., 1995). Natural fungicides developed against aflatoxigenic fungi protect stored rice when mixed with lemon grass essential oil. Methyl salicylate as the principal volatile component in the methanol extract of root bark of *Securidaca longepedunculata* protected stored grains against insect pests (Jayasekara 2002). *Bauhinia monandra* leaf lectin (BmoLL) shows insecticidal action against *Anagasta kuehniella, Zabrotes subfasciatus* and *Callosobruchus maculatus* (Macedo 2007). N-acetylglucosamine-binding lactin obtained from *Koelreutaria paniculata* seeds affects the larval development of *Callosobruchus maculatus* and *Anagasta kuehnilla* larvae (Macedo *et al*., 2007). Beside this, volatile oils isolated from leaves and flowers of *Lantana camara* (L), *Callistemon lanceolatus*, *Cymbopogon winterianus*, *Eucalyptus sp*, *Nerium oleander*, *Ocimum bacillicum, Ocimum sanctum, Vitex negundo Satureja hortensis*, *Thymus serphyllum* and *Origanum*) have shown insecticidal, antifeedant and growth inhibitory activities against insect pests (Sharma *et al*., 2000; Isman *et al*., 2000b).

Plant essential oils have shown very high repellent and toxic action against stored grain insects at very low LC_{50} value (Jayasekhara *et al*., 2005). LC_{50} values of different essentials are presented in Table 3. Few important essential oils such as cumin, black pepper, ajwain, dill oil and staranise oil have shown very high toxicity and significantly suppressed the survival of larvae and pupae and reduced the F1 emergence (Upadhyay and Jaiswal, 2007). Different essential oils such cumin, ajwain, staranise and saunf have effectively inhibited the oviposition in *Bruchus* *chinensis* as their percent ODI noted at 20% of LC_{50} value was 45.45, 38.4, 37.61and 41.34, respectively. Black cumin and clove have shown moderate per cent ODI, i.e. 18.59 and 8.87 at 20% of LC_{50} value (Upadhyay and Jaiswal, 2007). Similarly, volatile oil of *Calendula micrantha* plant showed insecticidal activity and suppressed the reproductive potential of Mediterranean fruit fly *Ceratitis capitata wied* (Hussein, 2005). Essential oils isolated from *Anethum sowa* and *Artemisia annua* have been reported for their repellent, toxic and developmental inhibitory activity against *Tribolium castaeneum*. These also affect viability of *Callosobruchus maculatus* eggs (Tripathi *et al*., 2000 a,b). Similarly, *Lippa alba* oil has been reported toxic and developmental inhibitor against *Callosobruchus maculatus* and *Tribolium castaneum* (Verma *et al.,* 2000) ((Table 3).

Himachalenes and atlantones isolated from oil from wood chips of Himalayan Cedar, *Cedrus deodara* (Roxburgh) Don (Pinales: Pinaceae), showed promising larvicidal activity against larvae of *Plutella xylostella* (Chaudhary *et al*.,, 2011). The himachalenes enriched fraction was more toxic (LC_{50} = 362 μg/ml) than the atlantones enriched fraction (LC_{50} = 365 μg/ml). LC_{50} of crude oil was 425 μg/ml and of acetonitrile fraction was 815 μg/ml. Similarly essential oils derived from the wood of *Juniperus drupacea* contains non-oxygenated monoterpenes and diterpenes (myrcene) which have shown high larvicidal activity against the West Nile virus vector *Culex pipiens* (Vourlioti-Arapi *et al*., 2012). Moreover, hinokitiol-related compounds (hinokitiol (beta-thujaplicin), beta-dolabrin, gamma-thujaplicin, 4-acetyltropolone and alpha -thujaplicin) isolated from the acid oil of *Aomori hiba* (*Thujopsis dolabrata* Sieb. et Zucc. var hondai MAKINO) showed very high insecticidal activity against termites and acaricidal activity against mites (Inamori *et al*., 2006). Essential oil obtained by hydro distillation of female cones (FC) of *Carolina sapphire* [(*Cupressus Arizonica* var glbra (Sudw.) Little)] was found highly toxic against *Aedes aegypti* larvae as LD50 of 33.7 ppm was obtained at 24-h post treatment (Ali *et al*., 2013). The essential oils isolated from *Salvodora oleoides* and *Cedrus deodara* have shown significant oviposition deterrence against *Phthorimea operculella* (Tare, 2000) (Table 3).

Essential oils isolated from *Chenopodium ambrosioides* L., *Eucalyptus globulus Labill*, *Eucalyptus smithii* RT Baker, horseradish, anise and garlic were found toxic to larvae of *Lycoriella ingénue* (Dufour) at 10 and 5 μL/L air. Similarly, allyl isothiocyanate, trans-anethole, diallyl disulfide and p-anisaldehyde isolated from above plant species were found highly toxic as LC_{50} values obtained were very low i.e. 0.15, 0.20, 0.87 and 1.47 μL/L respectively (Park *et al*., 2006). Similar, acaricidal activities are reported in major constituents isolated from the oil of *Juniperus chinensis* (var. globosa) leaves against *Dermatophagoides* spp. and *Tyrophagus putrescentiae*. The 50% lethal doses (LD_{50}) of *Juniperus chinensis* oil against *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus,* and *Tyrophagus putrescentiae* were 21.60, 19.89, and 38.10 microg/cm^2, respectively. The main acaricidal component was identified as bomyl acetate with LD50 of 2.94 microg/cm^2) against *Dermatophagoides farinae* which was found significantly lower than those of DEET (37.13 microg/cm2) and alpha-eudesmol (29.72 microg/cm^2). It was also found active against house dust and stored food mites, even though it constitutes only 19.5% of *Juniperus chinensis* oil (Lee *et al*., 2009) (Table 3).

Table 3. Insecticidal activity of certain essential oils and its constituents isolated from different plant species.

Essential oils	**Component/s**	**Quantity**	**Insect**	**Activity**	**References**
Mentha piperata oil	Carvacryl	7%w/v	*Ades albopictus*	Repellent, toxic	Yang & Ma 2005
Eucalyptus oil	Terpenol	15%w/v	*Ades albopictus*	Repellent, toxic	Yang & Ma, 2005
Daucus carrota sativus	Methyl jasmonate	1.2 %	*Carrot psyllid*	Antifeedent, toxic	Nissinen 2005
Artemisia princeps oil	eucalyptol, or α-terpineol	250-1000 μg/gm	*S. oryzae* and *B. rugimanus*	Repellent, Insecticidal	Liu et al, 2006
Mentha longifolia	3-octanol	0.1% dose	Bark beetle	Antifeedant	Faccoli et al, 2005
Rutaceae plants	Limonene	0.3-1.0% ED_{50}	Bark bettles	Antifedeent	Faccoli et al, 2005
Lanatana Camara oil	Zingiberene, gamma-curcumene	0.0125-0.2%	*Musca domestica*	Insecticidal & Repellent	Abdel Hady et al, 2005
Calandula micrantha	calenduladiol	0.020-0.5%	*Ceratitis capitata*	Suppress reproduction	Hussein 2005
Neem seed oil	Nimbin	12-28.5μg	*S. oryzae* *T. castaneum*	Insecticidal & Repellent	Koul 2004
Chenopodium oil	ascaridole, carvacrol and caryophyllene oxide	5.0 g m/ l		Toxic	Bostanian et al, 2005
Securidaca longependaculata	Methyl salicylate	34 & 36 μl	*S. zeamain* & *R. dominica*	Repellent and toxic	Jayaekara et al, 2005
Eugenia melanadenia	sesquiterpenes	0.0085%	*Aedes egypti*	Larvicidal	Aguilera 2003
Psidium rotundatum	a-pinene, 1,8-cineole	0.0063%	*Aedes egypti*	Larvicidal	Aguilera 2003
Conyza mevii	Z)-nerolidol, β-farnesene	1.05X 10^{-4} mg/cm^3	*Anopheles gambiae*	Insecticidal	Omolo et al, 2005
Plectranthus marriboides	α-thujene, germacrene	2.52X10^{-4}	*Anopheles gambiae sensu stricto*	Insecticidal	Omolo et al, 2005
Corn leaf essential oil	(Z)-3-hexenol, neophytadiene	2.4 to 3.1 %	*Sesamia nonagrioides*	Oviposition inhibitor	Konstantopoulou 2004
Ipomea carica (Linn)	Pentasaccharide resin glycosides	100-170ppm	*Culex triteeniorynachus and other mosquito species*	Larvicidal and insecticidal	Thomas et al, 2004
Eucalyptus marjoram	calyptol	0.0625 mg/cm^2	*Pediculus humanus capititis*	Insecticidal	Yang et al, 2004
Allium sativum	Allyl isothiocyanate	5-10 μl	*Lycoriella ingénua* (Dufour)	Insecticidal	Park et al, 2006
Pimpinella anisum	m-anisaldehyde	1.25 μl	*Lycoriella ingénua*	Insecticidal	Park et al, 2006
Armoracia rusticana	p-anisaldehyde	1.25 μl	*Lycoriella ingénua*	Insecticidal	Park et al, 2006
Chenopodium ambrosoides	Thyme	70-130 ppm	*Lucilia sericala.*	Larvicidal	Morsy et al, 1998
Thymus vulgaris	Thyme	25-380 ppm	*Lucilia sericala.*	Larvicidal	Morsy et al, 1998
Eucalyptus globulus Labill	Thyme	20-120 ppm		Larvicidal	Park et al, 2006
Carolina sapphire	alpha-pinene	37.5ppm	*Aedes aegypti*	Larvicidal	Ali et al, 2013
Salvodora oleoides	trachelogenin	7.25 μl	*Phthorimea operculella*	Oviposition inhibitor	Tare 2000
Cedrus deodara		20-80μl	*Phthorimea operculella*	Oviposition inhibitor	Chaudhary et al, 2011
Cumin, ajwain, staranise and saunf	Terpenes, flavonoids	10-42 μl	*Bruchus chinensis*	Insecticidal	Upadhyay et al, 2007
Capparis decidua	Tricontanol and 2-carboxy-1,1-dimethylpyrrolidine	1-80μl	*Bruchus chinensis*	Insecticidal	Upadhyay et al, 2006
Piper nigrum	phenolic amides	1-20μl	*Tribolium castaneum*	Insecticidal	Upadhyay and Jaiswal 2007
Pelargonium spp	geraniol	48.5-58.5ppm	*Aeded. aegypti*	Insecticidal	Ali et al, 2013
Lippia alba	linalool, 1,8-cineole	25-150ppm	*Tribolium castaeneum*	Insecticidal	Verma et al, 2000
Curcuma longa L.,	turmerone, atlantone, and zingiberene.	36.71 ppm	*Callosobruchus maculates, R.dominica*	Insecticidal	Tripathi et al, 2002

Plant natural products

Eugenol is an essential oil component that occurs mainly in clove, *Eugenia caryophyllata*, *Artemisia giraldi*, *Artemisia subdigitara, Citrus sinensis* and *Citrus aurantium.* It shows insecticidal activity against *Sitophilus zeamais* (Chu *et al*., 2012), *Bemisia tabaci* (Ribeiro *et al*., 2012) and *Spodoptera litura* (Bhardwaj *et al*., 2010). More specifically methyl eugenol, trans-anethole, estragole, linalool and basil oil are used to trap dipteran insects (Vargas *et al*., 2009; Vargas *et al*., 2012) such as *Ceratitis capitata, Bactrocera dorsalis* and *Bactrocera cucurbitae* (Chang *et al*., 2009) for monitoring purposes (Vargas *et al*., 2010) (Table 4). It is a fast acting contact insecticide which was found effective against a wide variety of household pests such as cockroaches, ants, mites, flies, wasps, spiders, crickets and fleas. It is also used to control pests of ornamental plants such as armyworms, thrips, aphids and mites. Eugenol also occurs in *Cinnamomum cassia* and *Allium sativum* shows strong fumigant action against beetles and termites (Park *et al*., 2000; Park and Shin, 2005). It is reported that eugenol application shows no or little residual activity afterapplication. There are eugenol based commercial formulations i.e. Bioganic Brand's Flying Insect Killer and Bioganic Lawn and Garden Spray Products, which are less noxious and are available for common use.

Table 4. Insecticidal activities of important natural plant products

Plant product	**Plant species**	**Target insects**	**Biological activity**	**References**
Tannins	*Lippia origanoides*	*Tetranychus cinnabarinus*	Antifeedant	Sivira *et al*., 2011
Gu ms	*Anacardium ocudantale*	*Callosobruchus maculates*	Antifeedant	Maria *et al*., 2012.
Nicotine	*Nicotiana tobaccum*	Soft bodied sucking insects	Toxic and Antifeedant	
Nicotinoids	*Nicotianna tobaccum*	Moths	Inhibitory to AchE receptors	Dederer *et al*., 2011
Neonicotenoid analogues		Lepidopterans	Insecticidal	
Rotenone	*Cacalia tanguitica*	Complex I inhibitor	Insecticidal	Lu mmen, 1998
Rotenone	*Derris, Lonchocarpus*	Aphids, cattle grubs, fleas, lice	Insecticidal	
Capasciacin	Hot pepper	*Trichoplusia ni*	Insecticidal	Annontois *et al*., 2007
Capasciacin	Hot pepper	*Tetranychus urticae*	Insecticidal	Edelson *et al*., 2002
Resin	*Croton urucurana*	*Dysderdercus maurus*	Larv icidal	Siliva *et al*., 2012
Oil resin	*Copaifera reticulata*	*Aedes aegypti*	Larv icidal	Silva *et al*., 2007
Oil resin	*Copaifera multijuga*	*Anopheles darling*	Insecticidal	Trindade *et al*., 2013
Oleo-gu m-resin Myrrh	*Comminphora molmol*	*Aedes aegypti*	Larvicidal	Massoud and Labib, 2000
Sabadilla	*Diaprepes abbreviatus*	*Schistocerca Americana*	Antifeedant	Sandoval-Capinara, 2011
Sabadilla	*Sabadilla officinale*	Hemipteran insects	Antifeedant	
Deguelin	*Muellera fruitiscens*	*Aedes aegypti*	Insecticidal	Nirmal *et al*., 2012.
Triterp inic saponins	*Diploknema butyracea*	*Spodoptera litura*	Insect growth regulator	Saha *et al*., 2010

Phenolics	*Eichhornia crassipes*	-	Insect growth regulator	Yi *et al*., 2006
Sterols	*Myrtillocactus geometrizans*	*Spodoptera frugiperda*	Insect growth regulator	Cespedes *et al*., 2005
Sugar esters	*Nicotiana glutinosa*	*Bemesia argentifolia*	Insecticidal	Tong *et al*., 1996.
Ph\\enyl propanoids	Semisynthetic	*Spodoptera litura*	Insecticidal	Bhardwaj *et al*., 2010
Ryania	*Ryania speciosa*	Corn borer	Insecticidal	
Quassia	*Quassia amara*	Aphids Sawflies	Insecticidal	
Acorus	*Acorus calamus*	Aphids and caterpillar	Larvicidal	
Quessin and neoquesin	Quessin amara	Moths	Insecticidal	
Pyerethrum	*Chrysanthemuc cineriaefolium*	Aphids	Insecticidal	
Allicin	*Allium sativum*	Termites and stored grains insects	Insecticidal	Yang *et al*., 2009
Capparin	*Cappris decidua*	Termites and stored grains insects	Insecticidal	Upadhyay *et al*., 2007, 2011, 2012
Acetogenins	Plants of Annonaceae	Lepidopterans	Pesticidal	Ruprrecht *et al*., 1990
Azadirachtin	*Azadirachta indica*	All insects	Pesticidal	
Saponins	*Trigonella foenum-graecum*	Stored grain insects	Insecticidal	
Pinene	*Hedychium* essential oils	Mosquito	Repellent	
Plant toxins	*Taxus cuspidate*	Nearly all insects	Toxic	
Plant toxins	*Senecio jacobeae*	Nearly all insects	Toxic	
Non Sugar amino acids	Albizia sp, Lathyrus sp	Beetles	Insecticidal and enzyme inhibitor	
Nephthoquinone	*Calceolaria andiana*	White flies, aphids and mites	Insecticidal and enzyme inhibitor	

Limonenes

Limonenes (d-Limonene) are active components which occur in essential oils of many plant species such as *Mentha longifolia*, *Pulicaria gnaphalodes*, *Achillea wilhelmsii* (Khani and Asghari, 2012), *Saussurea nivea* (Chu *et al*., 2012), *Euclyptus globules* (Kumar *et al*., 2012), *Liicium pachphyllum* fruits (Liu *et al*., 2012), *Zanthoxylum shinofolium* (Wang *et al*., 2011, *Schizonpeta multifida* (Liu *et al*.,2011), *Carum carvi* fruits (Fang *et al*., 2012), *Zanthoxylum beecheyanum*, Cheng *et al*., 2009), *Schizonepeta tenuifolia* (Park *et al*., 2006) *Crithium maritimum* (Tsoukatou *et al*., 2001). It also found in Mentha, Salvia, Melissa, oranges and other citrus fruit peels and showed insecticidal activity against number of insect pests such as Flour beetle, *Tribolium castaneum;* cowpea weevil *Callosobruchus maculatus*; *Musca domestica; Rhodinus prolix;, Lycoriella ingenua* and different species of mosquitoes i.e. *Culex pipiens, Aedes aegypti* and *Aedes albopictus.* Limonene showed low oral and dermal toxicity to mammals; hence it is used as a contact insecticide to kill ants, roaches, palmetto bugs, fleas, silverfish and ticks of pets. Its mild insecticide spray is used to kill mosquito larvae. Limonene cause skin irritation or sensitization in pets and repel oudoor dogs and cats. Many products containing limonene are formulated and available in the market with different trade names such as Ortho Home Defense Indoor Insect Killer, Concern Citrus Home Pest Control, Orange Guard. Safer Fire Ant Killer, and Citrex Fire Ant Killer.

Capsaicin is used to control insects such as aphids, spider mites, thrips, whitefly, lace bugs, leafhoppers, and other pests. Moreover, capsaicin-containing products are primarily used to repel insects, rather than to kill existing infestations. The growing hot pepper (Capsaicin) was found effective against cabbage looper *Trichoplusia ni* (Hubner), spidermite, *Tetranychus urticae* (Koch) (Antonious *et al*., 2007), green peach aphid *Myzus persicae* (Sulzer) (Edelson *et al*., 2002) and beetles (Baumler and Potter, 2007). Both capsaicin and its formed products were found effective as repellents to animal pests such as rabbits, deer and squirrels. Few marketed products of capsaicin include Hot Pepper Wax Insect Repellent and Bonide Hot Pepper Wax and are available in the market to kill soft bodied insects (Table 4).

Nicotine

Nicotine showed insecticidal activity to house hold (Tan *et al*., 2007; Tong *et al*., 2013) and field crop insects (Rosey and Janger 2008). Both nicotinoids and neonicotenoids bind to acetylcholine receptors of housefly and impose insecticidal activity (Tomizawa and Casida 2009; Dederer *et al*., 2011). Topical nicotine treatment sucessfully kill *Pediculus humanus capitis* (Burkart and Burkart 2000). Neonicotenoid insecticide (imadocloprid) shows acute poisoning (Wu *et al*., 2001; Tomizawa and Casida, 2009) and finds active against *Aphis craccivora*, *Myzus persicae* and *Locusta migratora* (Weisner and Kayser, 2000) (Table 4). Nicotine derived from tobacco, is one of the most toxic botanicals. It is a fast-acting nerve toxin and is highly toxic to mammals. It is easily absorbed through the eyes, skin, and mucous membranes. Because of its high toxicity, it is no longer registered for use as a pesticide. Home brewed nicotine preparations are tested toxic and are prohibited from indoor use.

Pyrethrins

Pyrethrins are effective as broad-spectrum insecticides to control pests such as aphids, whiteflies, stinkbugs, stored grain insects (Anthanassiou *et al*., 2013), mosquitoes (Anthrey *et al*., 2012, Ahoua *et al*., 2012) and mites, *Cimex lectularius* (Anderson and Cowles, 2012). Pyrethrum and pyrethrins are often formulated with another insecticide to ensure that paralyzed insects do not recover. However, different insect species mainly mosquotes have developed resistance against pyrethoids and its derivatives (Temu *et al*., 2012, Ahouan *et al*., 2012). Pyrethrum is a botanical insecticide made from the finely powdered flowers of *Chrysanthemum* (Table 4). It is prepared from crude flower dusts or dried flower heads of *Chrysanthemum*. However, pyrethrins are insecticidal compounds that are extracted from pyrethrum (Table 4). Pyrethrum is a contact insecticide that affects insect nervous system, which eventually results in convulsions and death. Its low doses often cause temporary paralysis to insects. Pyrethrins are slightly toxic to man and not hazardous to birds and other wildlife. They have almost no residual activity, breaking down rapidly from exposure to sunlight, air or moisture. Because the pyrethrum mammalian toxicity is very low, it can be applied to food crops close to harvest. But it also shows high contact toxicity to common beneficial insects. Pyrethrum and pyrethrins are marketed under a wide variety of trade names, including Concern Multi-Purpose Insect Killer and Natural Guard Natural Insect Spray.

Sabadilla, Ryania and Rotenone

Sabadilla, azadirachtin and rhynodone were found deterrent to *Schistocerca americana* where rotenone, sabadilla and rhynodine reduced the feeding activity of *Diaprepes abbriviatus* (Sandova-Mojica and Capinera, 2011). However, sabadilla is the only compound, which was found effective in field conditions and its anti-feedant activity, remain intact against insects for a longer period. Rotenone is one of the most toxic compounds and is commonly used botanical insecticide. Rotenone is less toxic to mammals, entering through inhalation, and may cause skin irritation. It also acts as a nervous system poison. It is highly toxic to fish and other aquatic life and is commonly used as a fish poison. It is also harful to many beneficial insects and should not be used to control severe insect infestations. *Muellera frutescens* shows presence of rotenone, rotenolone and deguelin. Both rotenone and deguenin showed larvicidal activity against *Aedes agegypti* (Nirma *et al*., 2012). Similarly aerial constituents from *Derris elliptica* showed cytotoxic activity against *Spodoptera litura* and *Trichplusi ni* (Wu *et al*., 2012). Chloroform extract of *Cnidium officinale* rhizomes and its constituents neocnidilide showed larvicidal and adulticidal activity against *Drosophila melanogaster* (Tsukamoto *et al*., 2005). Friedelin isolated from *Cacalia tangutica* and rotenone shwoed 16-18% mortality in *Musca domestica* and *Aedes albipictus* (Huang *et al*., 2009). Biopesticides from *Chenopodium* have shown toxic effect against *Orius insidosius* (Say) and *Aphidius colemni* (Bostanian *et al*., 2005) (Table 4).

Neem oil

Neem oil (*Azadirachta indica*) possesses very high insecticidal activity that kills various categories of insects and mites. Neem oil possesses very high toxicity to mosquito larvae. Neem oil is an effective repellent for wide variety of common garden bugs, including caterpillars, nematodes, locusts, aphids, Japanese beetles and mites (Gomez *et al*., 2010). In homemade formulations, neem oil is used to combat ants, cockroachs, flies, termites, mosquitoes and bedbug and leafminer infestations (McKenna *et al*., 2013). Neem oil also acts as an anti-feedant. It is used as a repllent in India more that 4000 years back. It is also used to make neem toothe paste which is highly recommended toothpaste in India. Neem oil is used for safer control of insect pests without harming most beneficial insects. It deters insects from feeding, enters in the body system and blocks the real hormones from working properly. Therefore, it is also tested as an effective anti-feedant, repellent and oviposition inhibitor to insects (Scudeler *et al*., 2013). These also inhibit egg hatching and development of larvae and pupae and stop molting. Both Neemazal powder and neem cake were found active against different pest insects mainly mosquiotoes (Nicoletti *et al*., 2012) and stored grain insects such as *Tribolium castaneum, Rhyzopertha dominica* (F) and *Sitophilus oryzae* (L.) (Athanassiou *et al*., 2005) (Table 4).

Oil-Resins

Resins are oxidation product of various essential oils and vary in their chemical composition. These are mostly found in stem of the trees having resin canals. Oil resins have been identified in the plants of family Anacardiacae, Guttiferae, Leguiminosae, Liliaceae, Pinaceae, Styracaceae and Umbelliferae. These are solid components yellowish in color and souble in alcohol or its derivatives. Resins show complexity and contains ingradients like resin acids, volatile oils, gums, cinnamic and benzoic acid, cellulose and tannins. However, oil resin from *Camellia reticulata* showed larvicidal activity against *Aedes aegypti* (Silva *et al*., 2007; Kanis *et al*., 2011) and *Culex quinquefasciatus* Say (Diptera: Culicidae) (Silva *et al*., 2003). Similarly, oil-resins and its derivatives isolated *from Copaifera multijuga*, display larvicidal activity against *Anopheles darling* and *Aedes aegypti*

(Diptera: Culicidae) (Silva *et al*., 2013). Myrrh (oleo-gum-resin) obtained from the stem of *Commiphora molmol* showed toxicity to 2nd, 3rd and 4th instar larvae of *C. pipiens* (Massoud and Labib, 2000) (Table 4).

Gums

Gum is plant exudate which contains resins, sticky in nature, soluble in alcohol or other organic solvents except water. It swells in water easily and form an emulsion like slurry or a viscous mass. True gums are formed after disintegration of internal tissues and are secreted as exudates (Maria *et al*., 1992). However, gum exudate of the cashew tree (*Anacardium occidentale*) prevented oviposition and reduced the number of surviving adults of *Callosobruchus maculatus.* The feeding of larvae of *Crimissa cruralis* was also strongly affected by the gum. Neem Gum is a clear, bright and brown-coloured gum which is a by-product obtained after lignocellulose breakdown (Table 4). Its components interrupt the life cycle of parasites by inhibiting the ability of reproduction. The more important gum yielding plant species are *Acacia catechu, Acacia modesta, Acacia. nilotica, Acacia senegal, Anogeissus latifolia, Bauhinia retusa, Cochlospermum religiosum, Albizia chinensis, Albizia lebbeck, Azadirachta indica, Bauhinia purpurea, Barringtonia racemosa, Feronia limonia, Mangifera indica, Pithecolbium dulce,* and *Tilia tomentosa.*

Tannins

Tannins occur in the leaves, seeds, unripe fruits, root and vascular tissues such as xylem, phloem and the periderm of plant stems (Table 4). It is found in cell sap, cell wall and in woody tissues of plants, testa of seeds and in pathological growths such as galls. These are heterogenous group of complex compounds glucosidal in nature, show-coloring activity due to presence of tannic acid or a complex glucoside of gallic acid (Berbehenn and Martin, 1994. Chemically tannins are poly-phenols, proanthocyanidins, cranberries procyanidins, prodelphinidins, gallotaninns and hydrolysable tannins. Polyphenolics present in tannins affect the nutritional ecology of herbivores (Mole, 1989) and deter them from feeding (Coley *et al*., 1985). Tannic acid imposes histopathogical effects in aquatic dipteral larvae (Rey *et al*., 1999).

Tannins present in medicinal herb *Ajuga parviflora* (Benth) showed insecticidal activities against red flour beetle (*Tribolium castanaeum*), wheat weevil (*Sitohilus granaries*) and their larvae (Rahman *et al*., 2013) at 321.42 microgram/mL concentration. Similar activity is also reported in tannins present in *Vitex polygama* and *Siphoneugena densiflora* (Myrtaceae) against *Spodoptera frugiperda* (Gallo *et al*., 2006). Similarly, gymnenmagenol isolated from *Gymnema sylvester* (Retz) Schult was found active against larvae of malaria and filariasis vectors (Khanna *et al*., 2011). Ethanolic extract of *Lippia origanoides* and *Gliricidia sepium* showed acaricidal activity against *Tetranychus cinnabarinnus* (Sivira *et al*., 2011). Moreover, tannins present in *Mellingtonia hortensis* influence the efficacy of neem and *Bacillus thurigenesis* against teak defoliator (*Hyblaea puera cramer* (Lepidoptera: Hyblaeidae). Gallotannin also occur in plants that are hydrolyzed with gallic acid and give colour reactions (Inoue and Hagerman, 1988). However, insects treated on artificial diets containing tannins from non-host plant may seek high sequestration of tannins, which may increase the susceptibility level in larval instars. However, low level of tannins in host plants is tolerable to insects and they easily feed on host plant. If tannin concentration is increased in the diet, it generates adverse effects in insects. It helps to increase the bioefficacy and lethal action of biopesticides and help to manage the forest insects. Intolerance to high concentration of tannins acts as feeding barriers for phytophagous insects. Soon after feeding tannins leaves salivary proteins of insects bind with high affinity and insects remove them out at an earliar stage of digestion. Dietary tannins occur in natural diet inhibit the growth of Aphid *Aphis cracciora* which is pest of groundnut. Thus, tannins prohibit feeding in insect larvae, oxidize food substances in peritrophic enevelop and midgut, and cause indigestion of food in the gut (Sivira *et al*., 2011).

Waxes

Plant tissues also secrete waxes which are long-chain apolar lipids forming a protective coating (cutin in the cuticle) on plant leaves and fruits. Waxes are water-resistant materials made up of various substances including hydrocarbons such as normal or branched alkanes and alkenes, ketones, diketones, primary and secondary alcohols, aldehydes, sterol esters, alkanoic acids, terpenes and monoesters (wax esters). These possess very long carbon chains of carbon atoms from 12 to 38 carbon atoms. More commonly, waxes are esters of an alcohol other than glycerol. Few important waxes mainly Carnuba wax which is obtained from leaves of a Brasilian palm tree (*Copernicia prunifera cerifera*), Ouricouri wax from ouricouri palm (*Syagrus coronata, Cocos coronata*), Jojoba from seeds of the jojoba tree (*Simmondsia chinensis* Euphorbiacae*)*, Candelilla wax from small shrubs, *Euphorbia cerifera* and *Euphorbia antisyphilitica* (*Euphorbiaceae*) while Esparto wax is a by-product in the artisanal preparation of paper in northwest Africa and southern Spain as "Halfah grass", *Stipa tenacissima.* All plant waxes show melting point between 61-85^{o}C*.* Naturally, wax coatings of ripe fruits and seeds and hard coat of cutin protect plants from insect attack. Leaf hairs also contain terpenoids and phenolics. More exceptionally plant stem contains outer covering known as cutin made up of hydroxy fatty acid polymer, while underground stem and root contain suberin. These substances are frequently mixed with other lipids and form a complex mixture called epicuticular wax. Cutin is a lipidic polymer containing C16 and C18 families of acids. Sugar esters are used as commercial insecticides that affect feeding in insects and are used for control of whitefly *Bemisia argentifolii*. Hydrocarbons, esterified fatty dialcohols and cinnamic acid present in wax may have toxic effects against variety of insects.

Horticultural Oil

Vegetable oils and oil products are used to control soft-bodied insects and mites. Few vegetable oils such as Rice bran oil, Cottonseed oil, Mustard oil, Palm oil, olive oil and Soybean oil are used to control flies. These also protect chickpea food grains in stores from beetle attack and show repellent action and decrease the adult emergence (Yokoyama and Miller, 2004). Moreover, few other vegetable oils such as coconut, maize or groundnut oil have been recognized as toxicants or growth inhibitors due to presence of large amount of various fatty acids. However, vegetable oils and its constituents impose risks to insects and beneficial natural enemies of insect pests. Essentially all commercially available horticultural oils are refined petroleum products and contain aromatic compounds containing sulfur, nitrogen or oxygen.These can be removed by filtration, distillation and dewaxing of base oil. Oil forumaltions are made by using either summer or dormant oils, which is toxic to overwintering insects such as scales, aphids, mites of fruit and shade trees and woody ornamental plants. Summer oils are lighter and are used to actively growing plants. Several oil formulations have been developed which are found to be useful to protect flowers, vegetables and other herbaceous plants from insect attack and invasion. These oils act upon respiratory system of insects and block the spiracles; insects breathe and cause death by asphyxiation. In some cases, oils also may act as poisons, interacting with the fatty acids of the insect and interfering with normal metabolism. Oils also are easy to apply as spray and a ready formulation can be prepared by mixing other natural products, which work as pesticides to extend their performance.These are temperature sensitive, at higher temeperature they loss insecticidal poetential due to evaporation and compositional changes. However, a mask or respirator should be worn when applying horticultural oils bacuase they quickly dissipate through evaporation, leaving little residue.

Insecticidal Soaps

Plant natural products are also used to prepare soaps which are non-toxic to humans and other animals. Herbal soaps are used to control soft-bodied arthropods such as aphids, mealybugs, scale insects, mosquitoes, psyllids and spider mites. These act as contact insecticides showing no residual effect in medium as well as on the non-target organisms. These impose minimal adverse effects on other organisms and can be easily applied by spraying directly on the insect infested sites. Soaps are also made by using inorganic components and these are not considered botanical insecticides. Mostly these are made by using salts of fatty acids which are the principal components of the fats and oils found in animals and plants. More often soaps cause disruption of the cell membranes of the insects and remove the protective waxe layer found on the integument of insect. It causes excess loss of water due to dehydration, which impose more severe adverse effects in insects in comparison to toxicants. Few insects such as Lady beetles, green lacewings, pollinating bees and other beneficial insects are non-susceptible to soap sprays, Soaps are emulsified soilds and contains simple ingradients, and hence it is difficult for pests to develop resistance. Nevertheless, use of soap-detergent sprays generate phytotoxicity, therefore, homemade formulations are to be avoided. Repeated exposure of soaps allows its accumulation in the leaves and causes an injury. In the field treatments, soaps and oils can be coated on both upper and lower surfaces of leaves as well as stems provide wider protection against adults and caterpillars. Heavy dose of soaps cause foliage burn. These are readily available and inexpensive. Few oil based complete formulations of herbal soaps are available in the market i.e. Sunspray, Ortho oil spray, Green Lingh oil, Ultra Fine Oil for routine use to control insects.

Root Powder

Root powder is also found active against caterpillars and larvae of insects. However, *Periploca sepium* root powder contains periplocoside X, oligasaccharide A, periplocoside A, periplocoside E, and periplocoside N which possess insecticidal activities against the red imported fire ant. Among all the compounds, periplocoside X showed significant activity with LD(50) values of 748.99, 116.62, 2169.58, and 3079.33mg/L against soldiers, workers, males, and alate females of red imported fire ant (Li *et al*., 2012). Similarly, 2-isopropyl-5-methylphenol from *Stellera chamaejasme* found active against *Aphis craccivora* and *Pieris rapae* (Tang and Hou 2011). However, carvacrol isolated from the root of *Stellera chamaejasme* shows insecticidal activity

(Tang *et al*., 2011) while Anthraquinone aldehyde found in *Galium aparine* L showed insecticidal activity against *Spodoptera litura* (Morimoto *et al*., 2002). Similarly, *Tephrosia candida* was found active against larvae and adults of diaprepes root weevil (Lapointe *et al*., 2003) while *Rhinacanthus naustus* against *Aedes aegypti* and *Culex quinquefasciatus* larvae (Rongsriyam *et al*., 2006) and *Dahlstedia pentaphylla* against *Boophilus microplus* (Pereira and Famadas, 2006). Moreover, *Securidaca longe pedunculata* root powder exhibited repellent and toxic properties against *Sitophilus zeamais, Sitophilus oryzae, Rhizopertha dominica* and *Protepharus truncate* which are highly destructive pests of stored grain (Jayasekara *et al.,* 2005). Some insecticides from *Chenopodium* have shown toxic effect against *Orius insidosius* (Say) and *Aphidius colemni* (Bostanian 2005) while *Melia dubia* has shown growth inhibitory and anti-feedant activity against *Spodoptera litura* and *Helicoverpa armigera* larvae (Koul *et al.,* 2000) while chemicals present in the corn plant affect host selection and oviposition behavior of *Sesamia nonagioides* (Konstantopoulou 2002). Similarly, 7-hydroxycoumarin shows anti-insect property against *Aphis creccivora* and *Culex pipens pallens* (Xiaorong and Taiping 2008).

Wood extracts, dusts and chemicals

Sextonia rubra contains ethyl-acetate-soluble termiticidal metabolite, rubrynolide, which protects wood from termite infestation and degradation (Rodrigues *et al*., 2011). Similarly, both heartwood and sapwood of *Taiwania cryptomerioides* were found effective against *Coptotermes formosanus* at 10 mg/g concentration (Chang *et al*., 2001). Azadirachtin (neem) used as systemic insecticide in trees control emerald ash borer and invasive wood-boring beetle at a dose of 0.2 azadirachtin cm^1 tree diameter (Kreutzweiser *et al*., 2011). Extracts from black heartwood of *Cryptomeria japonica* (Gu *et al*., 2009) showed larvicidal activity in mosquitoes while Ficus and Persea Litchi wood volatile chemicals control Mediterranean fly *Ceratitis capitata wied* (Niogret *et al*., 2011) and protect biodegradation of hardwood lignocellulosics by the western poplar clearwing borer, *Paranthrene robiniae* (Hy. Edwards) (Ke *et al*., 2011). Similarlay, stilbenes from bark of *Picea glehni* (Shibutani *et al*., 2004), sesquiterpenes from black heartwood of *Cryptomeria japonica* (Fokialakis *et al*., 2004) and larch wood constituents deterred termites from feeding (Chen *et al*., 2004). Besides this, combining microbial and chemical insecticides showed enhance mortality in insects manifold (Shapiro-Ilan *et al*., 2011). Wood and leaf dust inert silica dust based insecticides are also used on plant surfaces for control of insect pests (Ulcichs *et al*., 2006).

Garlic

Allium sativum (Garlic) contains so many sulphur compounds which were found active against number of insect pests and showed antimicrobial and antioxidant activities (Meriga *et al*., 2012). Garlic contains lectins which showed strong insecticidal activity (Upadhyay and Singh, 2012) against coleopteran (Yang *et al*., 2009), hemipteran (Saha *et al*., 2007), homopterna (Roy *et al*., 2002) and lepidopteran insects (Sadeghi *et al*., 2008; Meriga *et al*., 2012). Garlic oil was found active against *Lycoriella ingénue* (Park *et al*., 2006) and show fumigant action against Japanese termite (*Reticulitermes speratus* Kolbe). Several garlic products are available in the market which is intended for use to repel insects from feeding. Garlic and its constituents not only repel a wide variety of pests but also repel beneficial insects. Products containing garlic or garlic oil are used as garlic barrier and mosquito barrier.

Allium sativum leaf contains agglutinin that shows allergeinicty and can be used to develop sap sucking resistant food crop cultivars (Mondal *et al*., 2011). Recombinant garlic lectins were also found active against aphids (Fitches *et al*., 2008). However, garlic constituents are also used as natural insecticides to control stored product pests mainly stored grain beetles (Hubert *et al*., 2008; Zhao *et al*., 2013).

Neem

Neem plant is a depository of green pesticides, its active ingradients show enormous insecticidal activity against more than 350 pest insects. Neem products are also used to manage pests on vegetables, fruit, ornamentals, and lawns and can be found at many home garden centers. One of the most desirable properties of Neem is its low degree of toxicity, and almost nontoxic to humans and animals. Neem products are completely biodegradable and do not persist in the environment after rains. It is used as an ingredient in toothpaste, cosmetics, pharmaceuticals and other products. Effectiveness against different insects is variable and test results have been inconclusive in many cases. Because of low toxicity in neem products, these effectively control, chewing insects more than sucking insects. Neem often works more slowly than other pesticides, and effectiveness is reduced in cooler climates. It shows little effect when applied directly on insects, except in the oil formulations; most insects are affected only after consuming foliage that has been treated. Neem is most effective as a foliar spray applied periodically to new flushes of growth. Neem products exhibit inhibition of metamorphosis in insects. It also affects insects which do not undergo metamorphosis. Neem extracts and its constituent's works as a systemic pesticide absorbed into the plant and carried throughout the tissues. This may make them effective against certain foliage-feeders that cannot be reached with spray applications, such as leafminers and thrips. Neem derived insecticides obtained from a semi-solid neem wax fraction were found highly toxic to insects (US patenet no. 5372817).

Neem exudates showed antifeedant and ovipositional deterrent effects in insects (Murugan *et al*., 1995) while neem kernel extract and neem oil effect nutritive and reproductive physiology of *Helicoverpa armigera* (Murugan *et al*., 1996a). It also contains azadirachtin (Schmutterer, 1990; Mordue and Blackwell, 1993) that show effective control against teak defoliator *Hyblaea puera* (Murugan *et al*., 1999a). It also shows synergistic effect on *Spodoptera litura* Fab (Murugan *et al*., 1999b). Neem plant is multipurpose plant that contains potential anti-insect ingradients which can be developed as a good quality biopesticides. Azadirachtin shows low mammalian toxicity and acts as an insect feeding deterrent and growth regulator. Neem and neem products do not cause lethal action on insects but mostly inhibit feeding in them. These also inhibit insect metabolism and insect dies with out reproducing. Several neem based commercial products are available in the market which is Azatin XL, Neemix, Neem oil, Bioneem, SouthAg Tiple action, Neem azal etc. These are suitable to control over wintering insects of foliage, ornamental, and food crop plants. Neem works as potential natural insecticide to control teak pests, *Hyblaea puera* and *Eutectona machaeralis* (Murugen 1997). More exceptionally leaf dust, bark and root powder and seed kernel of neem also possess multitude of pesticidal active ingradients such as triterpene and limnoids. Among liminoids Azadirachtin, Salannin, Meliantriol, and Nimbin are identified as toxicant and repellent.

Neem plant also contains azadirachtin, a major insecticidal constituent that shows selective toxicity to inscet pests, and do not harm the useful pest- predator relationship. It shows toxic and repellent effect against more than 300 harmful insects. Azadirachtin (C35H44O16) contains complex structure and represent a group of compounds such as Azadirachtin A, B, C, D, E, F and G. Among which azadirachtin-A (Aza A) shows repellent, antifeedent and insecticidal activity against a number of insect pests. Azadirachtin is a relatively new and promising botanical insecticide made from extracts of Neem seeds. It is used to control a wide variety of insects including leafminers, whiteflies, thrips, caterpillars, aphids, mealybugs, spider mites, scale crawlers, and beetles. Neem is most effective against actively growing immature insects. Azadirachtin has a very low mammalian toxicity. It acts as an insect feeding deterrent and growth regulator. The treated insect usually cannot molt into its next life stage and dies without reproducing. Neem also contains salanin, which shows potent pest controlling activity far greater than the chemical synthetic chemical pesticides. Neem plant parts also contain few minor compounds such as chloriphyle, calcium, phosphorus, iron, thiamine, riboflasium, nicocin, vitamin C, carotene, and oxalic acid and salts. Other bioactive compounds which have been identified are Nimbin, Nimbidin, Ninbidol, Gedunin, Sodium nimbinate and Quercetin, which act a insect repellent, anti-feedant, anti-hormonal. Neem plant also contains Coumarins like scopoletin, dihydrosocoumarins, hydrocarbons like docosane, pentacosane, hectacosane, octacosane sulphur compounds, Tannins, phenolics, flavonoglycosides, Limonoids, Terpenoids and steroids,. Tetranorterpenoids, Fatty acid derivatives like margosinone and margosinolone. Due to presence of many active chemotypes, neem is considered as a green depository of nature. These products are labeled for use on ornamentals, foliage plants, trees, shrubs and food crops. Many neem products and formulations are also effective as a fungicide against powdery mildew.

Neem dust is also used to control insect pests. It affects longevity, fecundity and ovarian development in many insect species of lepidopteran, dipteran and coleopteran insects. However, different combinations of neem leaf dust mixed in adult rearing diet significantly reduce the longevity and fertility in insects. Neem leaf dust contains nimbicidine, which affect pupation and subsequent adult emergence of late-instar larvae. It blocks ovarian development in developing pupae. It is effectively used as a safe alternative of synthetic insecticide for the control of *Bactrocera* species (Khan *et al*., 2007).

Insect growth regulators

Insect growth regulators are analogs and antagonists of endogenous hormones, i.e. analogs of molting and juvenile hormone and the antagonist for juvenile hormone. These are structurally similar or identical to the insect molting hormones found in many plants mainly in ferns and yews. These show complexity in structure, possess steroid nucleus, and show weak insecticidal effect when applied topically or orally to most insects. However, molting hormone analogs are used in sericultural industry for programming the synchronization of cocoon spinning of silkworm colonies (Nakanishi, 1977), while juvenile hormones analogs inhibit larval transformation and oocyte aturation. These are recognized by different names as juvocimenes isolated from *Ocimum basilicum*, juvabione from *Abies balsamea*, and farnesol from many plant oils. Few other juvenile hormone analogs such as methoprene and kinoprene are used for the control of mosquitoes, flies, fleas, and some stored-products pests (Staal, 1975). Chromenes, the juvenile hormone antagonists isolated from *Ageratum houstonianum* as juvenile hormone antagonists (Bowers, 1976) found effective against few species of insects. Similarly, insect growth regulatory activities are also observed in *Blechrum chilenese* (Hincapie *et al*., 2011), *Diploknema butyracea, Sapindus mukorossi* (Saha *et al*., 2010), *Lantana camera* (Yi *et al*., 2006), *Cestrum parqui* (Iqbal *et al*., 2006) and *Myrtillocactus geometrizens* (Cespedes *et al*., 2005), *Haplophyllum tuberculatum* (Acheuk *et al*., 2012). These were found active against orthopteran and lepidopteran insect pests (Kihampa *et al*., 2009).

Plant toxins

Many plants possess phyotoxins, which impose toxic effects in insects and kill them. Toxins mixed in food irritate the midgut epithelim of insects after assimilation, from where it transferred to heamocoleomic system, poison it and causes death of insects. Insects avoid eating on toxin bearing plant tissues, cell sap and exudates secreted. Insects mostly beetles (*Dendroctonus brevicornis*) are choosey to feed on pine trees having alpha and beta pinene, myrcene and 3 cerene but avoid feeding on trees which possess high concentration of limonene. Several diterpenoids act as good quality antifeedants and triterpenoids such as azadirachtin has been proved as potent insecticidal agent. Mushroos *Amanita*, *Claviceps purpurea* contain alkaloids, which show lethal action. Algae such as *Anabena*, *Aphoni zomerion, Microcystis, Nostoc* and *Gloeotrichia* also relase toxins. Similarly, seed coat of *Taxus cuspidate* and *Taxus buccata* contains alkaloids, which are highly toxic in nature. Most of the terpenoids such as lactucin, pasthenin, limonene, pulegons, carvene, caryophyllene, zingiberene, camphor, acids mainly kavrenioc and payriferic inhibit feeding in insects. Monoterpenoids are also found toxic to lepidopteran, coleopteran and dipteran insects and are generally toxic to unadpated insects. Terpenoids such as Camphor, limonene (bark of *Oinus ponderosa*), pulegone and carvone from *Satureja douglesii,* parthenin (*Parthenium* leaf) found toxic and feeding deterrent to flour beetle *Tribolium confusum.* Phytotoxins from bacteria are more selective and generate pathogenic effects in number of insect species. Aflotoxins isolated from fungi sporidesmin, citvinin, patulin, phomazin, cyperine target soft-bodied insects and show anti-reproductive effects. Besides this, certain toxins also found on leaf surface and naturally inhibit insects from feeding. Leaf surface toxin slareol and eprsclareol occur in the wax of *Nicotiana glutinosa* which show antifeedant effect in insects. Similarly, kavrenioc isolated from *Helianthus annus* was found toxic to moth *Homesoma electellum*. Zingiberene occur in leaf trichome of *Lycopersicum hirsutum* is toxic to Colarado beetle. Latucin was found antifeedant to locust *Schistocerca gregaria* Bt toxins, its spores effect insect integumentary and respiratory system (Table 4).

Microbial insecticides

Microorganisms such as viruses, bacteria, fungi and protozoa are used as insecticides to kill field crop insects. These are much valuable due to its low toxicity to nontarget animals and humans after application and are highly specific to insect species, which kill only single species of insects. There are microorganisms which are active against a wide variety of insects or group of related insects (such as caterpillars). However, few microbial strains target only one or a few species. They kill narrow range of insects, and spare the beneficial insects almost entirely. Moreover, pathogenic bacteria secrete many toxins, which show deleterious effects in insects. Bacteria secrete both exotoxins and endotoxins. Exotoxins are heat labile proteins inactivated at 60-80^{0}C. Bacteria mainly sporeformer form endospores, which show wider resistance to environmental changes, temperature and humidity and remain in dormant stage for longer period of time. When incubated naturally or artificially they show very high lethal specificity against insects. These also form toxic crystals which are proteinaceous in nature. *Bacillus thuringeinsis* found effective gainst Cabbageworm *Pieris brassicae* mainly caterpillars. These crystals are highly toxic to majority of lepidopteran insects. There are endotoxins crystals, which enters in the gut and generate bacterial cell, which migrate into the hoemocoel and multiply and causing septicaemia. It shows the formation of sporangium full of spores, which after death of insect relseased into the soil.

Endotoxins travel from the site of entry to other body tissues or mainly towords target cells. Contrary to this most of the gram-negative bacteria have lipopolysaccharide, which is called endotoxin. *Escherichia coli* secrete hemolysin and *Pneumococci, Sptreptococci*, and *Staphylococci* secrete leucocidins. *Bacillus thuringiensis* products are the most widely used microbial insecticides. These are commonly known as Bt toxins. Different subspecies of Bt are effecetive against differen groups of insects or their larvae. *Bacillus thuringiensis* products and its different subspecies were found effective against different groups of insects or their larvae mainly young larval stages. Application of *Bt* insecticides is normally done in late afternoon or in evening, or on a cloudy day because *Bt* breaks down in sunlight. Though *Bt* does not kill insects immediately, but poisoned insects stop feeding almost immediately and show symptoms of skin lysis on next day morning and death. Similarly, the bacterium *Lysinibacillus sphaericus* is an insect pathogen which cause many diseases in them and show vast lethality (Berry, 2012). Similarly, milky **s**pore products contain the bacteria *Bacillus popillae* and *Bacillus lentimorbus* which are applied to turf and watered into the soil to control the larval (grub) stage of the Japanese beetle. These are used to control grub beneath undisturbed sod for a period of 15 to 20 years lawn applications. Various *Bacillus thuringiensis* strains (Osman *et al*., 2013) posess vegetative insecticidal proteins such as Vip3Aa7 (Dong *et al*., 2013; Li *et al*., 2012), Vip 3c (Palma *et al*., 2012), Vip 3A (Gulzar *et al*., 2012) which show strong action against *Plutella xylostella, Helicoverpa armigera* (Downes and Mahon 2012), *Spodoptera frugiperda* (Chakroun *et al*., 2012) and *Heliothis virescens* (Gulzar *et al*., 2012) larvae. Microbial toxins are also produced and are killer of insects. *Bacillus thuringiensis* produces both exo and endotoxins. These are proteinaceous in nature cause disruption of the gut epithelium of insects.

Bt products are highly toxic to different types of larvae of insects. However, insecticidal products of *Bacillus thuringiensis* var. *kurstaki* (*Btk*) found toxic to leaf-feeding caterpillars, of vegetables pests, bagworms and sap sucking insects (Sattar *et al*., 2011).. These also effectively control European corn borer larvae but some caterpillars remain scare off from the controlling action of *Bt*, especially those larvae which live in the soil or bore into plant tissues without consuming a significant amount of the *Bt* applied to plant surfaces. Important commercial formulations of *Bacillus thuringiensis* var. *kurstaki* products available in market are Dipel, Javelin, Thuricide, Safer Caterpillar Killer. Contrary to this, *Bacillus thuringiensis* var. *israelensis* (*Bti*) formulations found insecticidal to mosquito, black fly, and fungus gnat larvae. *Bti* is most effective for mosquito or black fly control when it is used on a community-wide basis. For most homeowners, eliminating standing water sources is more effective than applying *Bti* or other insecticides. Floating products sold as dunks or pellets can eliminate mosquito larvae in ornamental ponds and other areas that cannot be drained. *Bti* products that are available commercially include Mosquito Dunks, Vectobac, Teknar, and Bactimos. Similarly, *Bacillus thuringiensis var. tenebrionis* (*Btt*) products which insecticidal to certain beetles mainly to control Colorado potato beetle and elm leaf beetle adults and larvae, but are not pathogenic or toxic to some other key beetle pests. Bonide Colorado Potato Beetle Beater, and Novodor are products containing *Btt*. Micro-organisms related to genus *Clostridium* grow in the gut, multplicated and kill the insect. Bacterial crystals are non-toxic to mammals as the enzyme pepsin degrades it easily. However, Bt toxins and its new variants show wider insecticidal against insects belonging to coleopteran, hymenoptera and lepidoptera (Sellami *et al*., 2013; Sauka *et al*., 2012).

Spinosad is an insect toxin derived from a soil-dwelling bacterium. It kills insects primarily by ingestion and is used against fire ants, caterpillars, thrips, whitefies, aphids, leaf miners, scales and plant bugs. It is also used against borers of fruit trees, bees, but never applied to plants in flowering stage. When applied at recommended rates, it poses less risk than most insecticides to mammals, birds, fish, and beneficial insects. It functions as stomach poison and affected pest stop feeding within minutes, but may remain on the plant for up to two days. There are some commercial formulations of spinosad which are available in the market in the brand name of Ferti-lome Borer, Bagworm, Leafminer and Tent Caterpillar Spray. Fire ant baits formulated with spinosad include Conserve Fire Ant Bait, Justice, Payback Spinosad Fire Ant Bait and Eliminator Fire Ant Killer Bait.

Beauvaria bassiana is a fungus that attacks and kills a variety of immature and adult insects. It is used to control various insect species such as whiteflies, aphids, mites, caterpillars, leaf hoppers, grasshoppers, Colorado potato beetles, Mexican bean beetles, Japanese beetles, boll weevils, cutworms, sod webworms, bark beetles, chinch bugs, fire ants, European corn borers, and codling moths. Beneficial insects, such as lady beetles, are also found susceptible to *Beauvaria bassiana***.** It takes three to seven days after application for spores to germinate, penetrate, and grow inside the insect, thus killing them. Thorough spray coverage is essential because fungal spores must contact the insect for infection to occur. Few commercial products such as Naturalis H and G and Botanigard contain spores that germinate after application.

Fungal toxins mostly produced by entomogenous fungi are aflatoxins, and destruxins. Aflatoxins suppress the metabolic activity by suppressing the activity of DNA and RNA. These cause chemosterility in insects. Contrary to this, destruxins cause paralysis and death in insects. Besides bacteria, viruses also found promising insect control agents. These are of two types-inclusion and non-inclusion viruses. Inclusion viruses are further subdivided into polyhedron virus (PV) and granulosis virus (GV) which produces granular bodies. Inclusion viruses are considered as best insect controlling agents. Upon ingestion polyhedron of PV virus dissolved in the gut, releasing virus particle. Now these virus particles penetrate the gut epithelium and infect the hemocytes, tracheal matrix and epidermal cells. Inside hemocytes virus enters in to the nucleus, multiply and associate its genome with the host genome. Further due to rapid multiplication of virus rod insect stops feeding, become motionless and pale or yellowish in color. Polyhedra disintegrate into body tissues such as integument, hemocoel get ruptured prior to death. On the hsot plant, usually after 24-48 hrs of NPV application most of the insect larvae found dead and become dark brown in color. NPV is found active against Bombyx mori, Lymantria monacha and gypsy moth Portheria dispar. Nuclear polyhedrosis is a disease on insects.

Mode of action of botanicals

Various natural plant products show different mode of action. Plant extracts contain so many components which act differently, some are contact posion, stomach posion and few of them possess systemic activity if used in the soil or injected in the plant or assimilated from food items by the organisms. Moreover, there are three important categories of natural products mixtures, pure compounds and formed products having different physical forms such as liquid, crystalline chemicals, non-volatiles and volatile substances. Volatile substances show wider control in insect pests in godwons or in close chambers or in food grains bags. These are employed as fumigants, which generate toxic fumes or mix in air due to their high volatility and irradiate insect populations (Kim *et al*., 2012). Volatility of active components is increased by increasing or maintaining the temperature of fumigation chamber above 45 ^{0}C. Further, toxic air or fumes generated from oil constituents hit the respiratory system and cause high lethality in different stages of stored grain insects. The gaseous active component enters the insect body through the tracheal system and destroys the tissues in a number of ways. The mortality rate depends on type of essential oil component used, area treated, exposure time and type of operation done. Further, commercial fumigants such as slow releasing tablets or cellulose-coated discs are also being made by combining different natural products in certain proportion. Few natural products such as nicotine, rotenone, pyrethrum, Sabadilla, Ryanodine, flavonoids, alcohols and terpenes show very high fumigant properties and kill large number of insects (Cornelius *et al*., 1997). Respiratory poisons bind to respiratory enzymes phosphoglucomutase, enolase, succinic dehdrygenase and cytochrome oxidase that occur in mitochondria and inhibit their activity. They act on electron transport chain inside mitochondria where it inhibits the oxidation of FAD. Morevover, poison induced toxicity occurs due to inhibition of key respiratory enzymes or glucose catabolic enzymes such as phosphates, peroxidase, and catalases. These poisons also interfere in substrate level phosphorylation and uncouplers of oxidative phosphorylation, inhibit pyruvate dehydrogenase system, and induce accumulation of ketoacids and ketoglutarate in cells. Natural products such as essential oils should apply only in controlled conditions or confined spaces to kill insects by fumigation or by blocking the respiration in insect larvae and adults. However, essential oils act as respiraitory poisons, they form film covers in aqueous medium that checks respiration in larvae of different mosquito species. Besides this, volatile oil constituents are used to kill termites in underground tunnels, due to high evaporation and assimilation. Nevertheless, fumigation has great advantage to kill insects in cracks and crevices and in other places where both spray and dust cannot possibly operated.

Most of the neuroactive poisons bind to nicotine receptors of insects, paralyze neurons and show nerve impairmeint. These also check efflux of K^+ ion permeability and show negative action potential of K^+ ions, hence these do not move out, and effect sensory nerves. Further, nerve poisons slow down ionic flow in nerve exons by interfering the movement of N^+ and K^+ ions. This rapid in and out of ion produces repeatitive discharge in the nerves resulting in tremors, exhaustion and death. Nerve poisons also inhibit muscular contractility; CNS and somatomotor function, and induce autonomic salivation. Neuroactive compounds bind to acetylcholine esterase and attached to the esteric site of the enzyme forming a phosphorylated or carbamylated enzyme. It results in nerve excitability. Pyrethroids are nerve poisons, which inhibit activity of acetylcholine esterase, and sodium postassium ATPase occur in nerve membranes. Rotenone showed no specific effect on insect nervous system.

Natural products, which act as contact poisons, are employed for control of insects with piercing-sucking and chewing mouth parts. These are used as dust or in form of spray to kill insects. These poisons produce desirable result only after exposing insects or coming in contact with the body of insects. Contact poisons penetrate through the integument or through capillary action, attacking and dissolving the internal living tissues. Contary to this, so many natural plant products also act as stomach poison for insects. These are applied through food, or with insects natural diet. Stomach poisons are found effective against insect pests having chewing and biting types of mouth parts in orthopteran, coleopteran, dipreran and lepidopetran insects.

In addition, many natural products are used in poison baits due to their low toxicity and slow action (Cornelius and Lax, 2005). These act as synergists in conjunction to other pesticides and remarkably increase the toxicity of the mixture over the sum of the toxicities of the components. Many pure compounds isolated from plants act as slow acting toxic chemicals which are used in wood baits or cellulose matrix. Mostly young instars, larvae, and worker insects are exposed to lethal dose of desirable food. For poisoning bait, stations are made into soil at intervals around insect habitat, mainly tunnels, crevices, holes and nests (Cornelius *et al*., 2000). Insects prefer palatable food and young insects, which are attracted easily toward baits, feed upon, and transfer it to the companions by either grooming or by trophallaxis to other colony members, thereby reducing or eliminating the entire colony. Mostly slow acting chemicals are eaten up by instars. Success of baits depends on design, chemical used, pest number and abiotic factors in the ecological area concerned. Successful insect baiting required proper maintenance of stations. Poison baits are used to exploit feeding, tunneling and reproductive behavior in termites (Osbrink *et al*., 293). Similarly application of Summon disks and filter paper disks coated with few chitin synthesis inhibitors are also used to control the aggregation, feeding and recruitment behavior in *Coptotermes formosanus* termites (Cornelius and Lax, 2000). Howver, use of poison baits is environmentally safe method for control of insect pests.

Future prospects

Biodiversity of plant exists in different geographical areas of the world, which represent millions of botanicals of biomedical, agricultural and industrial use. However, thousands of botanicals have been identified from large number of plant species belonging to many families, but it is true that very few plant species have been investigated for screening its insecticidal activities. Over 50 years of time (1960 - 2010) approximately 45,000 species have been investigated so far for its insecticidal activities. There are few additional reports on anti-cancer, antitumor, antiviral, antiparasitic and antimicrobial activities of natural plant products. Still thousands of new drugs/compounds are un-noticed, unregistered or are in cue for its biological testing. More than this there are so many active ingredients, which have never been tested for their actual and most appropriate biological activity. These are undoubtedly overlooked from its proper use. Although, synthetic pesticides show long term residual effects in soil, water, foods, flora and fauna but they have been used massively. These have imposed high risks to man and his environment with millions of deaths of non-target organisms. Pesticide industries are developing broad-spectrum highly toxic pesticides with high killer potential. In fact condition is more critical due to uncontrolled use of highly toxic pesticides. It is regularly causing poisoning of food chain, bioaccumulation, species vulnerability, extinction, diseases and pest resurgence. Diversity loss has massively increased manifold. Still few highly toxic pesticides are banned in developed countries but these are still used for pest control in some of the developing and under developed countries. There should be a complete ban on highly toxic killer poisons worldwide. There exists no uniform policy to the date which can prohibit production and use of killer chemicals in non toxic soils. Why policy makers are silent on the usage of synthetic pesticides which affects drinking water used in bottles, milk and other food items. Why not green chemical compounds or active ingredients with low toxicity have been favored to upgrade them to have good pesticide formulations? There are so many secondary metabolites, which represent many families of tropical flora, if screened for over all biological activities; they might show broad-spectrum insecticidal potential against different insect pests. Unfortunately, most of them remain undiscovered, undeveloped and unused for integrated pest management. Moreover, secondary metabolites are of potential use as commercial insecticides.

Conclusion

From various researches it has been established that plant natural products possess multiple biological activities. Most of the subtropical countries possess enormous biological-chemical diversity that can be screened for finding more appropriate insect controlling agents. There are thousands of plant species which have never been evaluated for its insecticidal and antimicrobial potential. These might possess very high toxic potential against insects and disease pathogens. It is true that most of the world' plant species belong to tropics and half of them are still un-known and have never been screened for their chemistry. What is the reason that green chemicals are not developed and prepared according to the type of pest population living in the nature? This single negligence is causing massive environmental damage and mass killing of non-target organisms. Hence, due attention should be paid to generate good quality plant origin pesticides. For usage, regulation and development of international standards a pesticide development and control authority must be established to minimize the risks of synthetic chemicals used in any form for any purpose. Such authorities should ensure monitoring of use and postuse adverse effects on non-target organisms. They should develop a strong mind set in public use and support non-pesticidal methods to control insect population and to limit environment damage. Further, reducing the health hazards natural products such as organic compounds, extracts and oils must be catalogued about source of insect controlling agents. Its activity such as repellent, attractant, toxic, and growth regulator and inhibitory and its biological effects should be known in mammalian models. More specifically, a complete list of active phytocheimcals that inhibit the food preference; food selection and food digestion in insects must be prepared to reduce health hazards. All such compounds of pesticidal use must be licensed; for its proper use, farmers and workers must be trained to achieve good success. Further, to implement the major objectives, training and awareness programs should be started for safe control of insects. There should be environmental conservation groups and pesticide industries should reduce the burden of pesticide resistance and must favor use of combinatorial green pesticides. However, fumigation based control is also applied for reduction in residual toxicity. It will help to improve the performance of natural biological agents in cropland ecosystem. Besides this, male and female insect sterlizaing agents should be known, so that sub- lethal exposure of these botanicals may effectively target over population of the polyphagous pests without killing non-target organisms. High mortality in insect pest population also be achieved by systemic action of bio-pesticides if used in soil or any other medium. However, plant based natural pesticides can effectively control soil dwelling and foliar feeding insects by systemic action. Thus, a 50% cut in synthetic pesticide use will reduce the risk of environment pollution, mortality and morbidity. Use of plant toxins, microbial toxins and resistant plant varaities also effectively reduces the risk of biomagnifications, bioacculmation and pest resurgence, infestation and damage done by the phytophagous insects. Thus, less toxic and biodegradable herbal pesticide formulations should be preferred for use against insects with out causing no harm to the environment. It will solve the problem of compaign for environmental protection by minimizing addition of new harmful chemical into the food chains in future. No doubt, adoption of non-chemical methods will minimize poisoning of soil and water. It will not only ensure protection to environment but also cut down expenditure incurred on pesticides. However, for replacement the synthetic pesticides, natural products that show moderate toxicity, high repellency and oviposition, growth and development inhibitory activities must be formulated for insect control of all categories. Further, various pesticide resistance, pest resurgence and environmental damage. There must be composite formulations of new safer insecticides from plants based on natural chemical defense mechanisms of plants. For obtaining newer and active broad-spectrum bioinsecticides bioorganic, farming of plant species must be practiced.

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