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Differential Specification of Various Insecticides and their Environmental Degradation

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Abstract

Insecticides are tremendously applied to regulate insect pest population world widely. Various chemical categories of insecticide possess different mode of action and differential chemical interaction with various cellular biomolecules which ultimately results, in induction of species specific, sequential biochemical processes, within exposed organisms. The concerned biochemical processes occur through differential expression of various genetic elements which are eventually responsible for specificity of insecticides. Various insecticides affect cellular enzymes, ion channels, specific receptors, electron transport chain etc. which ultimately results in disruption of normal functionality of; nervous system, mitochondrial activity, exoskeleton integrity, midgut nutrient absorption ability, lipid bio-synthesis process, normal developmental pattern and mating behavior of insect pests. The purpose of this review is to provide comprehensive insight of different classes of insecticides, mode of action of concerned chemical categories, specific toxicity to target as well as non-target organisms and further, enzymatically degradation of concerned xenobiotics in living organisms and chemical degradation in environment.

Keywords: Degradation of Insecticides, Differential Specificity, Insecticides, Mode of Action

1. Introduction

Insecticides are generally synthetic chemicals or biochemicals, implemented to kill, harm, repel or mitigate various insect species. Depending upon specific activity on various pests, insecticides can be categorized into, selective and broad spectrum. Selective insecticides are effective for a limited insect species whereas broad spectruminsecticides are deleterious for categories of insects, although with variation in lethal dose. Specificity of concerned chemicals is due to differential interaction of insecticides with biochemical or physiological mechanisms in different insect pests (Figures 1–5). 2.

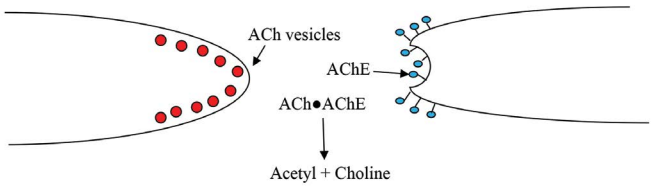


Figure 1. Diagrammatically depiction of ACh degradation of neurotransmitter by AChE.

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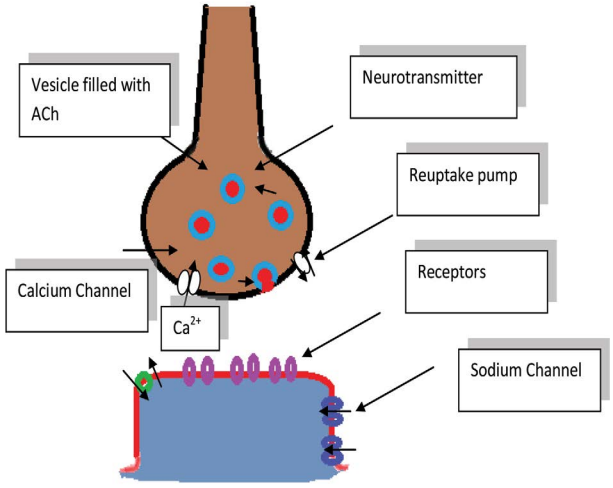


Figure 2. Diagrammatically depiction of ACh degradation of neurotransmitter by AChE.

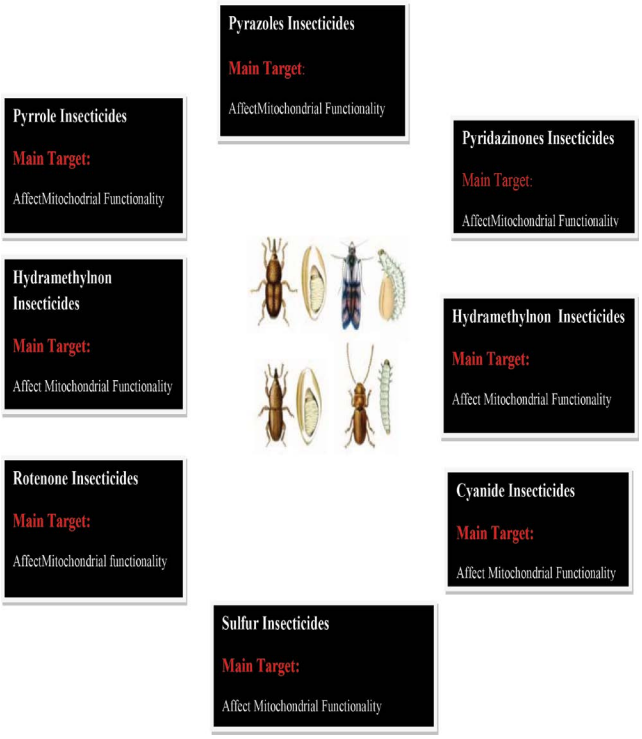


Figure 3. Mode of action of insecticides that affect energy production within cell.



Figure 4. Mode of action of insecticides that affect energy cell physiology.

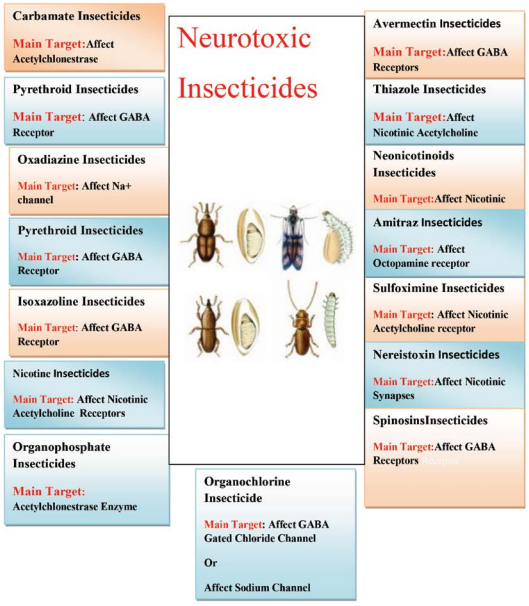


Figure 5. Mode of action of insecticides that affect nervous system of insects.

2. Classification on the Basis of Origin and Mode of Action

Depending upon origin of insecticides, predominant categories are inorganic insecticides and organic insecticides.

- **Inorganic Insecticides** category include natural substances or heavy metals including arsenates, copper and fluorine compounds etc. and furthermore types includes, systemic insecticide, contact insecticide and ingested insecticide.
- Systemic insecticides are generally absorbed by plant roots, and thereby to remaining parts of plants, including leaves, branches, fruits and twigs of plants. Insects are killed while chewing the plant parts.
- Contact insecticides, exhibit toxicity to insects, when come in direct contact with insect pests. Example include arsenates, copper and fluorine compounds.
- Ingested insecticides are effective when ingested by insects.
- **Organic insecticides** category includes, specific biochemicals that are derived from plant and animals, therefore are ecofriendly and impose less harm to crops. Examples include nicotine, pyrethrin, lime sulfur, sabadilla, garlic, onions, ryania, tomato leaves, tobacco water, snuff, retenone, oil etc.

Other categories, include volatile chemicals, which comprise various natural or artificial pheromones, having species specific activity and therefore affect normal mating and feeding behavior of different insects.

Insecticides are further classified into various categories on the basic of chemical structure and major categories comprise: Organophosphorus insecticide, Carbamate insecticide, Organochlorine insecticide, Pyrethroid, Neonocotinoids, Pyrroles, Pyrazoles, Pyridazinones, Nicotine, Chloropicrin, Cryolite, Arsenical insecticides, Sulfuryl fluoride, Diafenthiuron, Chlorfenapyr, Benzoylureas, Buprofezin, Cyromazine, Diacylhydrazines, Azadirachtin, Amitraz, Hydramethylnon, Rotenone, Tetronic Acid Derivatives, Cyanide, Phosphine, Indoxacarb, Avermectins, Spinosins, Ryanoids, , nereistoxin analogue insecticide, Spinosad, isoxazoline insecticide, Flubendiamide, Flonicamid, Pymetrozine, *Bacillus thuringiensis.* , *Beauveria bassiana*, Horticultural Oil, Diatomaceous Earth, Elemental Sulfur, Kaolin, Soap, Israelensis, Oxadiazolone, Sulfoximine insecticides, Thiazole insecticides, Thiourea insecticides and Insect Growth Regulators.

2.1 Organophosphate Insecticide (OPs)

The concerned synthetic compounds organophosphate (OPs), are generally esters of phosphoric acid (Figure 1), generally used to control corn rootworms, cutworms, wireworms, seedcorn maggot, beetle, white grubs, corn rootworms, flea, piercing, sucking and chewing insects, mites on crops including *Brassica*, corn, dry bulb onions, legumes, and sweet potato. Organophosphate insecticides are generally non-persistent, systemic, cholinesterase inhibiting and broad spectrum in nature. Organophosphorus insecticides, include various further chemical categories including organothiophosphate, aliphatic organothiophosphate, alip hatic amide, oxime organothiophosphate, heterocyclic rgan othiophosphate, benzothiopyran organothiophosphate, benzot riazine organothiophosphate, isoindole organot hiophosphate, isoxazole organothiophosphate, pyrazolopyr imidine organothiophosphate, pyridine organothioph ospha te, pyrimidine organothiophosphate, quinoxali ne organot hiophosphate, thiadiazole organothioph osphate, triaz ole organothiophosphate, phenyl organothio phosphate, phosphonate, phosphonothioate, phenylethylphosphonothioa te, phenylphenylphosphonothioate, phosphoramidate, phosph oramidothioate and phosph orodiamide. Various examples include chlorpyrifos, diazinon, dichlorvos, ethion, fenthion malathionparathion etc., nerve gases comprising soman, sarin, tabun and VX, ophthalmic agents like echothiophate, isoflurophate, antihelmintics such as trichlorfon and herbicides like tribufos, merphos etc. Exposure of organophosphatescause various health problems including impaired memory, psychomotor speed, visual-spatial functioning coordination, disorientation, severe depressions, irritability, confusion, headache, speech difficulties, delayed reaction times, nightmares, sleepwalking, drowsiness, or insomnia, influenza-like condition with headache, nausea, weakness, loss of appetite, and malaise. General chemical structure of effective organophosphates, possesscharacteristic features including terminal ^{oxygen} connected to phosphorus by a double bond, whereas thiophosphoryl compounds, possess P=S functional group, and are comparatively, less toxic than related phosphoryl derivatives. Generally different classes of organophosphate insecticide possess anticholinesterase activity. Chemical structure of various nerve agents and gases including phosphonofluorides sarin, soman and cyclosarin, as well as phosphonothiote.

2.1.1 Mode of Action of Organophosphate

Generally, OPs that affect Cholinesterases including Acetylcholinesterase (AChE), Butyrylcholinesterase (BChE), Paraoxonase (PON) and Diisopropyl- FluoroPhosphatase (DFPase). Fundamental mechanism of organophosphate pesticide is, inhibition of carboxyl ester hydrolases, particularly acetylcholinesterase (AChE), that degrade neurotransmitter acetylcholine into choline and acetic acid. The concerned neurotransmitter is common in the central and peripheral nervous system, in neuromuscular junctions, and in red blood cells (RBCs). AChE enzyme is irreversibly inactivated by organophosphate. When OPs become associated with AChE, there is loss of leaving group and covalent bond formation take place between OPs and AChE, which ultimately facilitate phosphorylation of the serine hydroxyl group located at the active site of AChE. Subsequently, enzyme could undergo various modulations including endogenous hydrolysis of AChE by esterases or paraoxonases, or reactivation by a strong nucleophile or permanent inactivation due to irreversible binding of Ps.As a consequence, there is accumulation of acetylcholine neurotransmitter, at synaptic junctions, throughout the nervous system, which ultimately resulted in overstimulation of muscarinic and nicotinic receptors resulted in anxiety, headache, convulsions, ataxia, depression of respiration and circulation, tremor, general weakness, visual disturbances, tightness in chest, wheezing due to bronchoconstriction, increased bronchial secretions, increased salivation, lacrimation, sweating, peristalsis, and potentially coma. Under normal circumstances, for degradation of ACh, concerned neurotransmitter become associated with enzyme AChE. But if organophosphate react with AChE, the serine hydroxyl moiety in the active site of enzyme become phosphorylated, similarly to acetylation of AChE. Unlike that of acetylated enzyme, phosphorylated enzyme is highly stable, due to irreversibly attachment of organophosphorous. Therefore, phosphorylated enzyme can not do hydrolysis of ACh.

2.1.2 Different Enzyme Affected by Toxicity of OPs

Acetylcholinesterase: AChE is present in vertebrate and invertebrate animals including mammals, birds, fish, reptiles and insects. The concerned enzyme is responsible for hydrolysis of ACh into the inactive form choline and acetic acid. The activity of different esterase is inhibited, by OP and CM pesticides, by formation of organo-phosphate or carbamate ester. Thereafter, phosphorylated or carbamylated enzymes, cannot catalyze effective hydrolysis of ACh, which result in accumulation of neurotransmitter at synapse or neuro-muscular junction. In human, excessive involvement of AChE, is in central nervous system, along with organs and glands that are controlled by the parasympathetic autonomic nervous system. Even the presence of enzyme had been speculated in different tissues of various animals including fish electric organs, mammalian erythrocytes, brain of insects as well as mammals, and other tissue.

2.1.3 Detoxification of Organophosphate

Carboxylesterase enzyme help in degradation of OPs in two different ways, by hydrolysis of carboxyl ester side chain and irreversible binding of the OPs without hydrolysis. The products of hydrolysis are carboxylic acid derivatives, which are less toxic and more water soluble, therefore are more rapidly excreted in urine.

Butyryl Cholinesterase (BChE) and PARAXONASE (PONs) are the concerned enzymes that help in removal of organophosphate compound. Enzyme BChE react with OPs, forming phosphylated esterases. PONs, help in functional removal of OPs. Both enzymes BChE and PONs, possess different isozymes, having different activities and specificities. Generally, some OPs inhibit AChE faster than BChE, but certain OPs compounds inhibit BChE faster. Additionally, unlike AChE, the BChE activities are affected, due to variation of physiological and pathological conditions[1-4].

2.1.4 Differential Response of Organophosphate or Carbamate Insecticides to Insects and Mammals

Some insecticides are preferentially toxic for insects, due to negative temperature coefficient in insect, furthermore, factors like selective uptake of these chemicals by insect epicuticle and enzymatically detoxification, also influence differential toxicity of concerned chemicals. Due to all these factors various insecticides possess differential toxicity to insects than mammals[5-7]. Furthermore, solubility of pesticides in water affects their impact on different organisms, example includes etofenprox and silafluofen[8]. Specificity of different insecticides for AChE of insect and mammals, also differentiate toxicity of selected chemical[9] for example 3-methyl substituted, methyl paraxon, exhibit differential inhibition of AChE of Musca domestica and

to bovine erythrocyte[10]. Similarly, diisopropyl paraoxon, is more toxic to house fly AChE than Apis mellifera[11]. Furthermore, sometime mutation provide resistance to certain pesticides[12].

Furthermore, thiophosphoryl compounds are less reactive with acetylcholinesterase in mammals and insects. During metabolism of thiophosphoryl chemical, lipophilic side group is removed in mammals, while inin sects it tends to ^{oxidize} P=S , by replacing ulphur with oxygen, which convert the compound to more effective inhibitor for acetylcholinesterase.

2.2 Carbamates (CM)

Carbamate compound was first extracted from Physostigma venenosum calabar bean, containing bio ingredients alkaloids physostigmine, a methylcarbamate ester. Different chemical categories of carbamate insecticides include, benzofuranyl methylcarbamate insecticides, dimethylcarbamate insecticides, oxime carbamate insecticides, phenyl methylcar bamate insecticides. Usually, carbamates are less persistent in the environment. Physostigmine are methylcarbamate as elucidated by Stedman and Barger, 1925. Carbamates, were first used as insecticide in 1950's. CM chemicals are esters of carbamic acid (NH2COOH), usually used as pesticides, as therapeutic drugs and as veterinary medicines. Carbamates are used to control pests, nematodes, aphids, caterpillars, beetles, stinkbug, diamondback moth, cabbage loopers on various crops including foliar spray on asparagus, brassicas, cucurbits, legumes, roots, tubers, fruiting and leafy vegetables, carrots, some cucurbits, eggplant, peppers, tomatoes, and sweet potatoes. Carbamates are generally non-persistent, broad-spectrum and cholinesterase-inhibiting. Additionally, certain thiocarbamates are also used herbicides. Like, organophosphates, carbamates also act as acetylcholinestrase inhibitors (AChEIs), with same primary mechanism of toxicity like OPs. Furthermore, carbamate inhibit AChE in reversible manner, but organophosphate in irreversible. The chemical classification of carbmates include two classes.

Class 1: First category includes AChE- inhibiting carbamates, comprising monomethylcarbamates and di-methylcarbamates. The chemical of specified category primarily possesses contact and systemic mode of action and are implemented as miticides, rodenticides, nematocides, anthelmintics, molluscides etc., and in various medical treatment including glaucoma and myasthenia gravis and in various neurodegenerative condition. Specification of carbamate compounds indicated that, some chemicals inhibit either AChE, true cholinesterase' or BuChE 'pseudocholinestrase' and some chemical categories inhibit both. Carbamate compounds are categorized as 'reversible-ChE inhibitor'. Concerned chemicals are covalently attached with enzyme and can be removed by hydrolysis similar to acetylcholine. Furthermore, CM attached ChE can also be bio-transformed by different other mechanisms, including N-demethylation aromatic ring hydroxylation, O-dealkylation, alkyl hydroxylation and sulfoxidation. Sometime, chemical produced after biotransformation, act as stronger inhibitor of ChE than parent compound.

Class II: This chemical category includes the dithiocarbamates, sulfur-containing carbamates, methyldithio- carbamates, dimethyldithiocarbamates, diethyldithiocarbamates, and ethyl-enebisdithiocarba mates that possess low ChE inhibition. Furthermore, chemical categories are grouped into following categories including: N, N-dimethyl arbamates of enols and hydroxy heterocycles, phosphocarbomates, and Oxinecarbomate.

2.2.1 Mode of Action Carbamate (CM)

Carbamate insecticides, chemically are complementary to the active site of acetylcholinestrase, therefore behaviourally are similar to neurohormones (Figure 5). Esteractic site , where ACh neurotransmitter attaches, contain a serine hydroxyl , that form covalent bond with electrophilic carbon atom of carbamate. Carmates inhibit AChE, identically to that of organophosphates, involving formation of enzyme–inhibitor complex through carbamylation of serine hydroxyl. Regeneration of acetylcholinestase from carbamylated enzyme is faster in carbamated enzymes than phosphorylated enzyme.

Structural carbamate insecticides are identical with that of neurotransmitter ACh, which is a neurotransmitter at synaptic junction in central nervous system of insects and in vertebrate parasympathetic nervous system. After attachment of carbamate insecticide with AChE, carbamylated enzyme is chemically more stable than acetylated enzyme. Therefore, resulting in accumulation of acetylcholine neurotransmitter, and eventually synaptic block, which cause lack of coordination, convolution, paralysis and ultimately death.

Different receptors affected by organochlorine insecticide toxicity includes $GABA_A$ receptors, Dieldrin antagonizes the $GABA_A$ receptor, producing convulsions after acute exposure in mammals.

2.2.2 Differential Selectivity of Carbmate Insecticides to Insects than Mammals

Due to structural similarly in carbamate and AChE, carbamylated enzyme formation take place, due to covalent attachment of CM to serine hydroxyl at active site. Carbamate insecticides are generally selective to insects incomparison to vertebrate, which include selective absorption through lipophilic insect cuticle, selective detoxification by vertebrate enzymes and are complementary resemblance with insect AChE than vertebrate enzyme.

2.3 Organochlorine

Organochlorides are of two different types, DDTtype compounds and chlorinated alicyclics which include cyclodienes, bornanes and the cyclohexanes. Furthermore, organochlorine is a large group of chlorinated hydrocarbons that include chlorinated derivatives of diphenyl ethane, hexachlorobenzene HCB, hexachlorocyclohexane or lindane, cyclodiene including aldrin, dieldrin, endrin, chlordane, nonachlor, heptachlor and heptachlor epoxide, and chlorinated hydrocarbons. The specific chlorinated compounds exhibit special characteristics including longer persistibity, broad spectrum nature, therefore excessively implemented in agriculture. Due to tremendous use, persistivity, lipophilic nature, narrow spectrum ativity, such compounds have become bioaccumulated in nature. Organochlorine chemicals affect soil by impacting soil fertility, crop productivity, ecological imbalance and human health. In organochlorine pesticides, dichlorodiphenyltrichloroethane (DDT), was first synthetic compounds formulated by Ziedler, in 1873, and its insecticidal properties were discovered by Paul Muller, 1939. Earlier, the specific compound was excessive implemented due to its broad –spectrum activity, persistence, insolubility, inexpensive and easy applicability, but later on, its uses had become restricted. Generally, organochlorine compounds are endocrine disruptors, neurotoxicants and carcinogens, additionally concerned chemicals can cause thyroid inactivity, diabetes, cancer, renal problem and reproductive diseases[13]. Organochlorine, which are structurally similar to DDT, act primarily, on the peripheral nervous system. Organochlorine chemicals create disturbance in glutathione homeostasis and induce alteration in cyt P450 monooxygenase enzymes, which ultimately causes neurotoxicity. The chemical groups including alkyl, alkylthio, halogen, hydroxyl and amino, are suitably lipophilic whereas, carboxy, sulfonyl and nitro groups are polar. The insecticide in category of chlorinated cyclodienes include aldrin, dieldrin, heptachlor, endrin, chlordane, and endosulfan. Organochlorine are used to control bugs, mosquito, soil dwelling insects. Long-term exposure can cause headaches, confusion, and dizziness; digestive problems, loss of muscle control and tremors etc.

2.3.1 Mode of Action

Concerned organochlorine, induce toxic effects, by preventing closing of sodium channel, after depolarization, which results in creation of a destabilizating negative potential, therefore repetitive discharges in neurons, whereas, certain other organochlorine insecticides, act antagonists to y-aminobutyric acid (GABA)gated chloride channel. Thus, normal transmission of nerve impulses is affected, resulting in uncontrolled neuronal excitation[14-28].

2.3.2 Differential Response of Organochlorine Compounds to Insects than Mammals

Organochlorine insecticide possess toxicity to insects and other living organisms including mammals but few reports support that certain organochlorine chemicals possess differential toxicity to insects in comparison to mammals. Dieldrin is known to inhibit GABA receptors in both mammals and insects but at the same time, insect GABA receptors are more sensitive than mammalian GABAA receptors to fipronil and dieldrin[29].

2.4 Synthetic Pyrethroid Insecticides

The specific synthetic pyrethroids are neurotoxic chemicals, broad spectrum, which are structural analog of natural insecticide pyrethrum, an extract of *Chrysanthemum cinerariaefolium* mostly are implimented in agriculture, public health and forestry. Earlier, processed powder, prepared from *Chrysanthemum* roseum and *Chrysanthemum corneum*, was commercialized in Europe. Those insecticidal preparations were subsequently,

introduced in USA, Japan, Africa and South America. Currently, *Chrysanthemum cinerpriaefolium* is cultivated in the USA, Japan, Kenya, Brazil, the Democratic Republic of the Congo, Uganda and India. Pyrethrins are generally formulated from *Chrysanthemum cinerariaefolium* and C. cineum flowers. The specific botanical extracts are viscous liquid with high boiling point, contain active insecticide esters, and are sensitive to oxidation and are photoliable, therefore storage is difficult. Thereafter, synthetic derivatives of pyrethrins, pyrethroids were developed. Majority of pyrethroids were synthesized through chemical modification of *Chrysanthemic* acid moiety of pyrethrin I and esterification of the alcohols. Synthetic pyrethroids possess improve specificity, activity and comparatively less toxicity to vertebrates. In 1949, first commercial pyrethroid, allethrin was introduced, thereafter, synthesis of resmethrin was carried out, by modification of alcohol component of pyrethrin I. Resemethrin, is not photochemically stable and lack persistence, the properties required for agricultural commercialization. Thereafter, derivatives including cyano substitute at the benzylic carbon of the 3-phenoxybenzyl group was synthesized. Pyrethroids are classified into two categories depending upon their chemical structure and toxicity.

Type I: Those lacking the ct-cyano group on the phenoxybenzyl moiety.

Type II: Those with a ct-cyano group on the phenoxybenzyl moiety.

Due to mode of action similarity of pyrethroids and DDT analogs, researchers have developed hybrid pyrethroids. In 1973, permethrin was synthesized and was the first compound that exhibited sufficient photostability for agricultural use. Permethrin revolutionized pyrethroids as a class, subsequently leading to their widespread use to control pests. Pyrethrins and pyrethroids are nonpolar chemicals that undergo rapid degradation including major mechanism of degradation; ester cleavage, oxidation and hydroxylation.

Pyrethrin and pyrethroid enter in body by different means including penetration through epidermis, thereafter, carried by blood or hemolymph, subsequently distribution to body. From epidermis or through sensory organs, concerned chemicals enter to central nervous system. Additionally, pyrethroids can also enter the body through the airway or orally. Pyrethroid of type I, induce excessive muscular activity, as are associated with tremors, salivation, choreoathetosis, and terminal chronic seizures, whereas pyrethroids of type II, decrease core body temperature, with enhanced salivation.

Furthermore, examples of synthetic pyrethroids like allethrin, resemethrin, phenothrin, permethrin, cyfluthrin, cyhalothrin, fenvalerate and tralocythrin. Pyrethroids are used to control aphids, worms, ants, gnats, moths, beetles, earwigs, grasshoppers, mites, midges, spiders, ticks, yellow jackets, maggots, thrips, caterpillars, flies, fleas, and termites, ants, cockroaches, spiders, stinging insects, pantry pests, bed bugs. Exposure to concerned compounds in air, food or water may cause giddiness, headache, vomiting, muscle twitching, low energy, convulsions and loss of consciousness[29].

2.4.1 Mode of Action of Synthetic Pyrethroid Insecticides

Generally, pyrethrins, pyrethroids, DDT and DDT analogs, are neurotoxic, and possess similar mode of action. Exposure of pyrethrins and pyrethroids create hindrance in coordination and paralysis, known as knockdown effect, along with repetitive activation in sense organs and in myelinated nerve fibers. Pyrethroids of type I and Pyrethrin, slightly prolongate the open time of channel, which results in multiple long action potentials, whereas type II pyrethroids, significantly prolong channel open time, resulting in an increased resting potential and ofteninducing a depolarization. Furthermore, pyrethroids of type I induce multiple spike discharge whereas type II causes a stimulus-depolarization of membrane potential. Furthermore, primary mechanism of toxic action of pyrethroids is to create interference with sodium gate in the nerve membrane. The hyperexictation that results from prolongation of the open phase of sodium gate functions in neurotoxic effects such as tremors and convulsion[30,31].

2.4.2 Differential Toxicity of Pyrethroid Insecticides to Insects

Pyrethroids exhibit differential toxicity to different animals, as it had been reported that, the specific chemicals were more potent on cockroach sodium channels than rat sodium channels, furthermore, it had been concluded that concerned chemicals are less toxic to mammals. Fipronil, possessing, mode of action to influence γ-aminobutyric acid receptor to block the chloride channel and it act against certain species of insects than mammals.

2.5 Neonicotinoids

Neonicotinoids are synthetic derivative of natural occuring insecticides nicotine, broad spectrum[32], developed in 1980s. Different chemical categories of neonicotinoid insecticides include nitroguanidine neonicotinoid insecticides, nitromethylene neonicotinoid insecticides and pyridylmethylamine neonicotinoid insecticides. Such chemicals which are effectively used against sucking insects, chewing insects and for Lepidoptera. Acetamiprid is used against sucking insects, including aphids and whiteflies, on ornamentals, cotton, leafy vegetables, citrus etc. Imidacloprid was first commercized in 1992, and it is systemic insecticide that act effectively against sucking insects, soil insects, whiteflies, termites, turf insects, Colorado potato beetle and on plants including cotton, rice, cereals, peanuts, potatoes, vegetables, pome fruits, pecans, and turf. Acute expose induces respiratory problems, problem in coordination of muscles. Active ingredients include imidicloprids, clothianidin, cetamiprid, thiacloprid, thiamethoxam, dinotefuran and nitenpyram.

2.5.1 Mode of Action

Neonicotinoids specifically acts directly on Nicotinic Acetylcholine Receptor (nAChR) and possess similar mode of action as natural insecticide, nicotine, which influence the functionality of central nervous system, by binding to postsynaptic nicotinic acetylcholine receptors irreversibly, ultimately resulting in paralysis and finally death.

2.5.2 Differential Toxicity of Neonicotinoids

The specific chemicals are more selective to insects than mammals as mode of action of neonicotinoids include blocking of a specific neuron pathway, more abundant in insects than mammals. Neonicotinoids bind with their electronegative tip, consisting of nitro or cyano group, and interact with cationic subsite on insect's receptor. The specific target specificity is a predominant property of neonicotinoids. Predominant neonicotinoids include, imdidacloprid as systemic insecticide, possess low toxicity to most animals, but toxic to insects, because of specific nicotinic acetylcholine receptors. The specific insecticide is absorbed by plant root, subsequently through xylem, move to other parts of plants[33].

2.6 Pyrroles

With implementation of fermentation technogoly, a insecticidal chemical dioxapyrrolomycin was synthesized in 1985 form *Streptomyces fumanus*. The specific isolated compound possess broad spectrum insecticidal properties and had been categorized in new class of insecticide pyrroles. The specific insecticides are effective against mosquitoes, termites and agricultural pests. Chlorfenapyr is an pro- insecticides, which is derived from a class of microbially produced compound known as halogenated pyrroles. Mode of action of chlorfenapyr include conversion to a active compound after entering into body of host and the concerned chemical disrupt the production of adenosine triphosphate.

2.6.1 Mode of Action

Generally pyrrole insecticides are broad spectrum, contact or systemic insecticides, which require activation by oxidase enzymes to produce active compounds. Pyrrole insecticides target, is not nervous system of insects but such chemicals act at cellular level and disturbe respiratory pathways, along with proton gradient. It works by targeting the oxidative pathways in the insect's mitochondria thus disrupting ATP production[34-41].

2.6.2 Differential toxicity of Pyrrole

Pyrrole like chlorfenapyr need enzymatic activation for conversion to active form, which possess insecticidal properties, but mammals lack the concerned enzymes. Therefore, the concerned chemicals inhibit energy production more specifically in insects.

2.7 Pyrazoles

The specific category consists of nonsystemic, contact and stomach insecticides. Derivatives of pyrole possess broad spectrum insecticidal, fungicidal and antimicrobial properties. Examples include bixafen, fluxapyroxad, penflufen, penthiopyrad, sedaxane, furamethpyr, tebufenpyrad and fenpyroximate and isopyrazam. Concerned enzymes act as succinate dehydrogenase inhibitors[42-48]. Among various derivatives, phenylpyrazole insecticides are a class of chemically-related broad-spectrum insecticides, possessing the chemical structures characterized by a central pyrazole ring with a phenyl group attached to one of the nitrogen atoms of the pyrazole. Phenylpyrazoles are used to control

lepidopteran and orthopteran pests, cockroaches, ants and wasps[48].

2.7.1 Mode of Action of Pyrazoles

The specific compounds inhibit mitochondrial electron transport at NADH-CoQ reductase site resulting in inhibition of ATP formation, whereas phenypyrazoles interfere in normal functionality of gamma-aminobutyric acid- (GABA) which regulated the chloride channel in neurons, therefore, concerned chemical interfere in normal nerve conduction.

2.7.2 Differential Response to Pyrazole Insecticide to Insects than Mammals

Fibronil, a phenylpyrazole insecticide, block glutama teactivated chloride channels, in case of insects, as the specific channels are absent in mammals, therefore fibronil possess toxicity to insects[49].

2.8 Pyridazinones

Pyridazinones insecticides are generally broad spectrum, derivative of pyridazinone, example include Pyridaben, which is used to control mites, leafhoppers, thrips, aphids and whiteflies on vegetables, ornamental and on other fruit crops. This category includes contact insecticides and miticides, exhibit toxicity to aquatic arthropods and fishes.

2.8.1 Mode of Action of Pyridazinones

Mode of action of pyridazinones includes, the concerned chemicals interfere in mitochondrial electron transport at the NADH-CoQ reductase site, therefore disturbing adenosine triphosphate (ATP) formation, ultimately resulting in cell destruction and eventually death of organism. Furthermore, concerned chemicals reduce carotene and chlorophyll content in plants, by blocking biosynthesis pathway of carotene formation, photodestruction of chlorophylls and other cell components[50-52].

2.9 Oxadiazine Insecticide

Predominant example Indoxacarb insecticide, contact and stomach poison, non-systemic, used to control sucking insects. Indoxacarb insecticide influence insects from direct exposure and through ingestion of insecticide exposed plant part. Indoxacarb, after entering into insect body, kill insect by binding to a site on sodium channels and blocking the flow of sodium ions and ultimately resulted in impaired nerve function, feeding cessation, paralysis, and death. The concerned insecticide is generally used on fruits, vegetables, soybeans, alfalfa and peanuts. It is used to control many insects, including beet armyworm, cabbage looper, corn earworm, diamondback moth, fall armyworm, imported cabbageworm, southern armyworm, tomato pinworm, and the tomato fruit worm.

2.9.1 Mode of Action

Indoxacarb is converted to more toxic form in insect by involvement of enzymes esterase/amidase and finally active products block Na+ channel of neuron irreversibly, in nerve cells, resulting in paralysis and death.

2.9.2 Differential Toxicity of Insects

Differential sensitivity to indoxacarb to insect is due to amino acid changes and channel sensitivity that influence voltage dependence of slow and fast inactivation, in insects[52].

2.10 Ryanoids

The concerned insecticides are specific chemicals that are synthetic analogues of ryanodine, an insecticide extracted from Ryania speciosa. Specific chemicals are used to control mosquitoes, several fly species, and fleas.

2.10.1 Mode of Action

Concerned chemical bind with calcium channels in cardiac and skeletal muscle, therefore affect the normal muscle contraction.

2.11 Tetronic Acid Derivatives

Tetronic acid derivatives are broad spectrum insecticide effective against whiteflies. Specific mode of action includes interference with lipid biosynthesis[53].

2.12 Cyanide Insecticides

Cyanide insecticides are broad spectrum insecticide used to control ants are associated with various acute and chronic symptoms including seizure, slow heart rate, low blood pressure, cardiac arrest, headache, dizziness.

2.12.1 Mode of Action

The mode of action includes creation of hindrance in ATP synthesis in cell, by inducing inhibition of mitochondrial enzymes cytochrome c oxidase.

2.13 Sulfuryl Fluoride

Sulfuryl Fluoride is an inorganic compound with insecticide properties, implemented to control *termites, wood infesting beetles, bedbugs, carpet beetles, clothes moths, cockroaches,* and *rodents*. It is a neurotoxic easily condensed gas, which is widely used as a fumigant insecticide.

2.13.1 Mode of Action

Mode of action of specific chemical includes inhibition of lipoprotein lipase, an enzyme responsible for hydrolysis of triacylglycerols of lipoproteins.

2.14 Rotenone

Rotenone is a naturally occurring insecticide in *Derris, Lonchocarpus, Tephrosia,* and *Mundulea* species. Rotenone, is a broad spectrum, non-specific insecticide with some acaricidal properties. Rotenone is used in home gardens for insect control, for lice and tick control. The specific chemical works by creating interference with electron transport chain in mitochondria. It creates inhibition in transfer of electrons from iron-sulfur centers in complex I to ubiquinone and ultimately in formation of ATP. The concerned chemical also causes formation of reactive oxygen species, which damage DNA and other mitochondrial component. Rotenone exposure can produce vomiting, incoordination, muscle tremors, chronic convulsions, cardiovascular effects, and Parkinson's disease-like neuropathology in experimental lab animals.

2.14.1 Mode of Action

In insects, rotenone act as both a contact and a systemic insecticide. Rotenone inhibits the transfer of electrons from Fe-S centers in complex I to ubiquinone in the electron transport chain, ultimately interfere in ATP synthesis. Rotenone causes inhibition of mitochondrial respiratory chain complex I, nitrosative stress, increased nitric oxide and malondialdehyde levels, aggregation of α-synuclein and polyubiquitin, activation of astrocytes and microglial cells etc.

2.15 Diafenthiuron

Diafenthiuron is a broad-spectrum insecticide, effective on various pests including whiteflies, aphids, jassids, thrips, mites, diamond black moth on cotton, cabbage, chilli and brinjal. Specific chemical is used to control pyrethroids resistant pest.

2.15.1 Mode of Action

Mode of action of concerned chemical is not known[54–55].

2.16 Benzoylureas

Benzoylureas is prototype insecticides that can be applied by fumigation or spraying, which act against a wide range of insect species, that act as insect growth regulators, as specific chemical create hindrance in chitin synthesis in the insect's body.

2.17 Thiazole insecticides

Thiazole insecticides are used to control black vine weevil and diamondblack moth.

2.17.1 Mode of Action

The specific chemicals are manufactured from Piper nigrum extract and act as potent agonists on insect nicotinic acetylcholine receptors of pesticide[56–58].

2.18 Buprofezin

Buprofezin is insecticide used to control pests such as mealybugs, leafhoppers, whitefly on vegetable crops. The concerned chemical is effective against early instars and crawlers.

2.18.1 Mode of Action

Mode of action of specific chemical include, inhibition in chitin synthesis.

2.19 Pymetrozine

Pymetrozine is a new insecticide belongs to chemical family pyridine azomethines. The specific chemicals are highly effective against sucking insect pests, for control of aphids and whiteflies in field crops, vegetables, ornamentals, cotton, hop, deciduous fruit, and citrus, and of the brown planthopper, Nilaparvata lugens in rice[59,60].

2.20 Thiourea

Thiourea is a category of insecticide with unknown mechanism[61,62].

2.21 Hydramethylnon

Hydramethylnon, trifluoromethyl aminohydrazone, is an organic chemical compound, with insecticidal properties and used to controlled control ants, cockroaches, termites, crickets, and silverfish. The specific chemical, act as metabolic inhibitor, it inhibiting complex III in the mitochondrial inner membrane and create disturbance in oxidative phosphorylation. Examples include maxforce, combat, siege, amdro, sensible.

2.22 Chloropicrin or Nitrochloroform

Chloropicrin or nitrochloroform, is a synthetic chemical with broad spectrum insecticidal properties. The specific chemical had been used as poison gas in World War. Chlorpicrin is injected into soil, for fumigation purposes,as specific chemical is effective for fungi, microbes and insects. Concerned chemical can be absorbed through inhalation, ingestion and by dermal route.

2.22.1 Mode of Action

Mode of action of specific chemical is unknown, that could be related to its metabolic dechlorination on reaction with thiols biomolecules.

Sulfur act effectively on various garden pests including insects, thrips, spider mites, psyllids, fungi and rodent. The mode of action of sulphur include, it disrupts of electron transport in the mitochondria[63,64].

2.23 Flubendiamide

Flubendiamide, is insecticide effective against *Helicoverpa* spp., *Heliothis* spp., *Spodoptera* spp., *Plutella* spp., *Pseudoplusia* spp., *Trichoplusia* spp., and *Agrotis* spp.

2.23.1 Mode of Action

The mode of action of specific chemical include disruption in normal balance of Ca2+ ions, resulting in cessation of feeding in target pest.

2.24 Flonicamid

Flonicamid is a pyridinecarboxamide compound, that act selectively against hemipterous pests, such as aphids, whiteflies, planthoppers, plant bugs, mealybugs and thysanopterous pests on cereals, rice, potatoes, cotton, vegetables and ornamental. Flonicamid influence the normal feeding behaviour of aphids.

2.25 Arsenical

Arsenical derivatives possess insecticidal properties and are used to control gypsy moth and ants, Paris green, lead arsenate and chromated copper arsenate had been extensively used as insecticides[65-67]. Thereafter, use of organic arsenical pesticides began in 1950s.

2.25.1 Mode of Action

Arsenic combine with reduced lipoic acid, and make it unavailable for various biochemical process which occur during degredation of sugar in cell.

2.26 Sulfoximine Insecticide

Sulfoximine insecticide broad spectrum are used to control aphids, plant hoppers, possess sulfoximine functional group and concerned insecticides are used to control sap feeding insects.

2.26.1 Mode of Action

Sulfoximines insecticide, also possess nAChR agonists activity[68,69].

2.27 Amitraz

Amitraz insecticide is a non-systemic, narrow spectrum in nature, which is quite effective against insect, including red spider mites, leaf miners, scale insects, and aphids than mammal.

2.27.1 Mode of Action

Mode of action of specific insecticide includes its effectiveness on alpha-adrenergic agonist activity, interaction with octopamine receptors of the central nervous system and inhibition of monoamine oxidases and prostaglandin synthesis. Therefore, it causes overexcitation of nervous system, therefore, paralysis and death in insects.

2.28 Nereistoxin Analogue Insecticides

Nereistoxin analogue insecticides are broad spectrum, systemic insecticide used against chewing and sucking

insects. Nereistoxin analogues specifically are used on pests of rice, potatoes, soybeans, groundnuts, sunflower, maize, sugarcane.

2.28.1 Mode of Action

Nereistoxin (NTX) is derived from *Lumbriconereis heteropoda* and is potently toxic to insects as it causes blockage of nicotinic synapses.

2.29 Isoxazolines Insecticides

Isoxazolines Insecticides The specific category of synthetic insecticide had been commercialized in 2013, for control of veterinary and agricultural pests. The insecticides are broad spectrum against variety of pests including Lepidoptera, Hemiptera, Coleoptera, thrips, and mites.

2.29.1 Mode of Action

After ingestion, isoxazolines are absorbed into blood and are distributed throughout the whole body of the host. Isoxazolines insecticide act as non-competitive GABA receptor antagonists, specific for GABA receptors in insects. Ultimately, binding to chloride channels in nerves and muscle cells, resulted in blockage of normal nerve transmission.

2.29.2 Differential Mode of Action of Isoxazolines

Differential mode of action of isoxazolines Concerned chemicals are specific for GABA receptor for insects than mammals.

2.30 Insecticidal Soap

Insecticidal soap is narrow spectrum, mainly based on potassium fatty acid and specific used to control plant pests, in organic farming. Insecticidal soap is used to control aphids, adelgids, mealybugs, spider mites, thrips, jumping plant lice, scale insects, whiteflies, and sawfly larvae.

2.30.1 Mode of Action

Insecticidal soap affect, direct entry through trachea, which disrupt cell membrane, and block breathing opening or trachea. Insecticidal soap interferes with growth hormone and affect metabolism. Furthermore, insecticidal soap dissolve wax layer on the cuticle, which leads to water loss by evaporation.

2.31 Avermectins

It is fermentation product isolated from Streptomyces avermitilis possessing insecticidal, acaricidal and antihelminthic properties, narrow spectrum. Avermectin act like insect growth regulator, preventing the production of viable eggs.

2.31.1 Mode of Action of Avermectins

Avermectin affects GABA and /or glutamate receptors and stimulate an influx of chloride into nerve cells. Avermectin binds to Cl- channel, which resulting in loss of cell function and nerve impulse, and ultimately death of insect[70–72].

2.32 Cryolite

Cryolite an uncommon mineral also possesses insecticide properties, additionally, the specific chemical is used as solvent for extraction of aluminium. The specific chemical destroys midgut tissue in caterpillars, therefore quite specific for, a certain category of Lepidoptera insects only.

2.33 Kaolin Spray

Kaolin spray, are used to control grasshoppers, leafrollers, mites, thrips, some moth varieties, psylla, flea beetles and Japanese beetles. The specific chemical possess nsecticidal properties and kaolinite is main ingredient in such formulation. Kaolin sprays are used for specific nsect pests in apple, pear, citrus, pomegranates and vegetable. Kaolinite is a clay mineral mainly composed of silicate mineral. Kaolin– based sprays form particle film on plant surface, which increase photosynthetic activity in plant and reduce heat stress on plant surface.

2.33.1 Mode of Action

Kaolin interferes with feeding behavior, egg-laying,increasing mortality of target pest.

2.34 Spinosins

Spinosins are specific bioinsecticides which are produced by a soil bacterium Saccropolyspora spinosa. The concerned chemical belongs to Spinosyn family[73]. Spinosad is extracted from Saccharopolyspora spinosa by fermentation which is toxic to thrips, spiders, mites, mosquitoes, ants, fruit flies etc.[74–76].

2.34.1 Mode of Action

Spinosad is a neurotoxic bioinsecticide which target nicotinic acetylcholine receptors and Gamma-Aminobutyric acid (GABA).

2.35 Diatomaceous Earth (DE)

Diatomaceous Earth (DE) possesses insecticidal properties, fleas, ants and bed bugs, because such product help in killing, repelling of pests. DE is used to control bed bugs, slugs, cockroaches, beetles and cutworms. Generally, insect possesses thin covering of wax on their body that helps to prevent water loss from the cuticular surface. Diatomaceous earth is quite effective in absorbing oils. DE on coming in contact with insect body, absorb protective waxy covering of the insects.

2.36 Nicotine as Insecticide

Nicotine as insecticide, narrow spectrum, are used to control aphids, thrips and spider mites. Consequently, nicotine was widely used as an insecticide in the past. Different nicotine compounds with insecticidal properties include nicotine sulphate, nicotine acetate, nicotine lactate, nicotine nitrate, nicotine trichloroacatate, nicotine resinate, nicotine oleate, nicotine palmitate, nicotine stearate, nicotine tartrate, nicotine resinate, nicotine oleate, nicotine salicylate, nicotine caseinate, nicotine tannate, nicotine alginate, nicotine bentonite.

2.36.1 Mode of Action

Nicotine acts as an agonist at most nicotinic acetylcholine receptors (nAChRs).

2.37 Bacillus thuringiensis,

Bacillus thuringiensis a naturally occurring soil bacteria, able to produce certain chemical with insecticidal properties quite effective against mosquitoes, blackflies and some midges and nontoxic to wildlife, humans, and other organisms not closely related to the target pest.

2.37.1 Mode of Action

Specific microbial insecticide induce activation by alkaline and enzyme activity in the insect gut and interact with specific receptors sites present on cell membrane of gut wall. Thereafter, in target species, paralysis and destruction of gut wall and subsequently, poison enter into body of insect cavity and haemolymph. Eventually, results in killing of target pest[78].

2.38 *Bacillus thuringiensis israelensis* (Bti)

Bacillus thuringiensis israelensis (Bti), act as biological control agents for various pest including various species of mosquitoes, fungus gnats and blackflies. Bti strains, encodes numerous Cry and Cyt toxins, including Cry4, Cry10, Cry11, Cyt1, and Cyt2.

2.38.1 Mode of Action

The specific bacteria subspecies secrete pore-forming toxins, which cause lysis of midgut epithelial cells of target pests.

2.39 Beauveria bassiana

Beauveria bassiana is a fungus that act as biological insecticide and is used to control pests such as termites, thrips, whiteflies, aphids and different beetles. The fungal spore, on coming in contact with insect cuticle, germinate and grow, and through spiracle enter into the inner body of the host. Fungus deplete all nutrient from insect body and thereby cause mortality of insect.

2.40 Horticultural Oils or Narrow Range Oils

Horticultural Oils or Narrow Range Oils, possess insecticidalproperties and are generally derived from petroleum or vegetable based. Concerned oils are generally mixed with surfactant. Such insecticides are generally ecofriendlyand are based on cotton seed oil and soybean oil.Horticulture oils are used to control Adelgids, aphids, caterpillar,leafhoppers, mealybug, mites, scale, spider mites, thrips and whiteflies.

2.41 Insect Growth Regulators (IGR)

Insect Growth Regulators (IGR), interfere, either in normal development of insects, by affecting related hormones or by chitin synthesis interference. IGR category include Juvenile Hormone mimics (JH) and chitin synthesisinhibitors, Insect growth regulators, benzoylphenylurea, moulting hormone agonists, moulting hormones, moulting inhibitors.

2.41.1 Mode of Action

Fundamental mechanism of such chemicals includes creating interference in normal process of insect development, insect exoskeleton and various hormones involved in the normal process, as explained in the following text.

2.42 JH Mimics

JH mimics, structurally resembles with Juvenile hormone, therefore create hindrance in normal metamorphosis. In holometabolous insects, for ecdysis of mature larvae to imago, declined concentration of juvenile hormone is required, and at this stage, exposure of JH or JH mimics can kill insects.

2.42.1 Mode of Action

JH mimics influence the hormonal balance in insects and furthermore affect embryogenesis and metamorphosis.

2.43 Azadirachtin Insecticide

Azadirachtin insecticide is chemically a secondary metabolite belong to limonoid group. Initially, it had been observed effective against Schistocerca gregaria. The specific chemical had been found to be effective against 200 species of insects.

2.43.1 Mode of Action

Azadirachtin induce peristalsis inhibition, create molting defect by creating alternation in ecdysteroid and JH release, create hindrance in normal cell division, blockage of digestive enzyme production in gut[79].

2.44 Ecdysone Agonists

Ecdysone hormone is required for ecdysis. Ecdysone agonists, therefore, disrupt the normal process of moulting, by mimicking with 20-hydroxyecdysone. Examples of ecdysone agonists include, diacylhydrazines, Tebufenozide, halofenozide, chromafenozide[80,81].

At the time of ecdysis, there is differential secretion of Ecdysone hormone that regulate complete transition period.

2.44.1 Mode of Action

Ecdysone is converted into 20-hydroxyecdysone (20E) at cellular level and regulate the dramatic changes that happen, at specific phase. Certain chemicals which act as IGR and interfere in normal development of insects. Example include Benzoyl hydrazine analogs of 20E act like the Ecdysone hormone and induce expression of genetic elements responsible for ecdysis. Furthermore, resulting in abnormal development of larva. Examples of IGR include, tebufenozide and methoxyfenozide, specific for lepidopteran, halofenozide, specific for coleopteran larvae.

2.45 Cyromazine Insecticide

Cyromazine insecticide, is classified as an insect growth regulator, which inhibits the growth and development of Diptera. The precise mode of cyromazine action remains unknown[82].

2.46 Diacylhydrazine

This insecticide is effective against Lepidopteron insects and it induce precocious molting.

2.46.1 Mode of Action

The concerned chemical is nonsteroidal ecdysone agonists and therefore induce hindrance in normal molting process in insect.

2.47 Chitin Synthesis Inhibitors

Chitin synthesis inhibitors, the specific class of insecticide, inhibit chitin synthesis in insects and therefore influence the normal pattern of development in insects, particularly during moulting, chitin deficiency, result in procuticle disruption and therefore insect cannot molt. Example include diflubenzuron and hexaflumuron[83], spirodiclofin.

2.47.1 Mode of Action

Such inhibitor disturbs the process of chitin formation during preimaginal stages, metamorphosis and reproductive development of insects. CSI are generally natural or synthetic chemicals, and possess ovicidal effect. Additionally, such chemicals possess sterilizing effects, because concerned chemical get incorporated into ovary and interfere in gametogenesis[84].

3. Natural Removal of Insecticides

Under natural condition, degradation of synthetic pesticides occur which include oxidative reaction,

reduction reaction, hydrolysis reaction and photodegredation.

Oxidative degradation of insecticides: Under this process, free oxygen molecules, singlet oxygen, ozone, hydrogen, peroxide, other hydroxyl radicals, or certain enzymes including oxidase react with pesticides and help in degradation of pesticides. Free radicles may be formed after oxidation process or from other biomolecules. Degradation of DDT occur by oxidation and reduction reaction, in presence of UV radiation.

Reductive degradation of insecticide: Under this process, pesticide undergo degradation by reduction reactions, generally, by involvement of H+ help in reduction. DDT and malathion undergo degradation by the specific mechanism.

Hydrolysis degradation of insecticides: Under this process, degradation of pesticide occurs due to reaction with water. Generally, organophosphate and carbamate insecticideundergo degradation by the specific process.

Photodegradation of insecticides: Under this process, degradation of insecticides occurs, due to breakage of chemical bonds under the effect of sunlight. Organic molecules undergo this type of degradation, due to absorption and excitation of electrons. Generally, pyrethroids undergo degradation by this mechanism.

Microbial degradation of insecticides: Under this process, micro-organisms present in water or soil help in degradation of insecticide. The factors influence this type of degradation include amount of insecticide, microbial population, and other abiotic factors including temperature, pH, soil moisture and aeration. Usually, insecticide degradation is carried out by fungi, bacteria and other micro-organisms. Insecticide that undergo, degradation through this process include pyrethroids, organophosphate, organochlorines and carbamate.

4. Conclusion

Generally insecticides possess natural origin or are derivative from plants and animals, further chemical categories include organophosphate; esters of phosphoric acid, carbamate; esters of carbamic acid, Organochlorine; chlorinated hydrocarbon, synthetic pyrethroid; structural analog of natural insecticide pyrethrum, Neonicotinoid; synthetic derivative of nicotine, Pyrroles; synthetic derivatives of Streptomyces fumanus, Pyrazole; derivatives of pyrole, Pyridazinones; derivative of pyridazinone, Ryanoids: derivatives of Ryanoids, Spinosin; ferment from Saccharopolyspora spinosa. Various chemical categories of insecticide, possess different mode of action which include disruption; in normal functionality of nervous system, by impacting action potential generation or transmission, in normal mitochondrial activity and energy production process, in normal exoskeletons integrity and formation processes, in normal development patterns, in midgut functioning, in lipid bio-synthesis, in normal mating behavioral pattern of insect pests. Different ins ecticide possesses differential effect on mammals and insect pest specially exoskeleton of insects and developmental phase of insects. Present review provides comprehensive insight of various chemicals used as insecticide, with specific mode of action and differential effect on target and non-target organisms.

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