CHAPTER-5

5.0 CLASSIFICATION OF INSECTICIDES ON THE BASIS OF CHEMISTRY

5.1 Organochlorins (OCs)

The insecticides which contain carbon, hydrogen and chlorine are known as organochlorins. These are chlorinated hydrocarbon, chlorinated cyclic and cyclodiene insecticides. These all organochlorine insecticides are banned in Pakistan due to long residual life which causes environmental hazard problems.

Examples of OCs

The typical examples of this class are DDT and their analogs, benzene hexachloride (BHC), lindane, dieldrin, endrin, heptachlor, toxaphene and endosulfon.

5.2 Organophosphates (OPs)

Organophosphates are byproduct of nerve gases (e.g. sarin, soman and tabun), developed during World War II in Germany. These are highly toxic and large class of insecticides. All organophosphate insecticides are derivatives of phosphoric acid. When H atoms of phosphoric acid are changed with organic radicals such as ethyl, methyl, or phenyl, the resulting compounds are named as organophosphates. Oxygen atom can be replaced with carbon, sulfur or nitrogen to produce different derivatives. Organophosphates inhibit acetylcholinesterase in the nervous system of pests and are divided into six subclasses such as:

1. Phosphates
2. Phosphorothioates
3. Phosphorodithioates
4. Phosphorothiolates
5. Phosphonates
6. Phosphoramidates

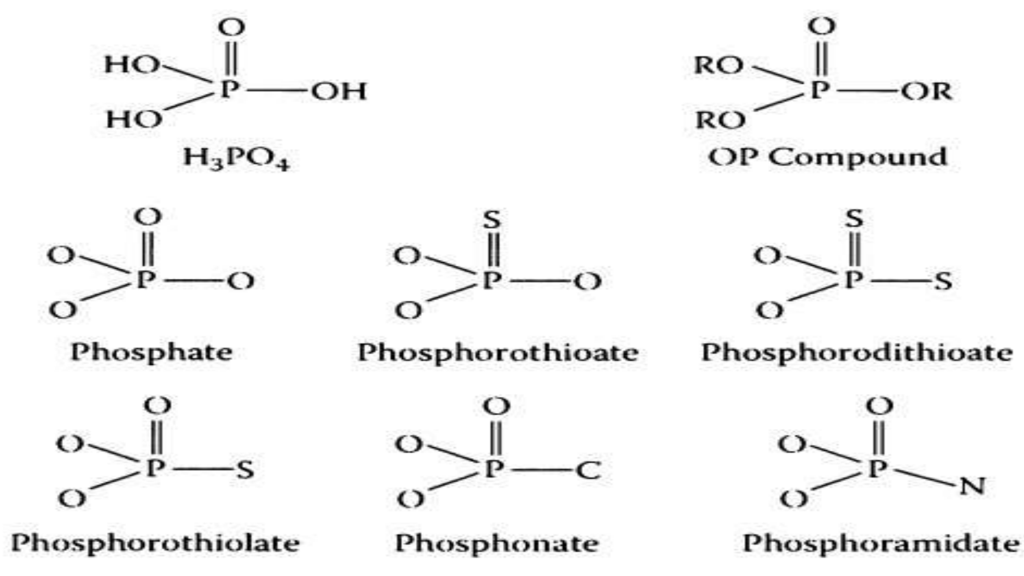

Figure 5.1 Chemical structures of Organophosphates

(Source: Simon, J. Y. (2014). The toxicology and biochemistry of insecticides: CRC press, Taylor & Francis Group, Boca Raton, London, New York)

5.2.1 Phosphates

This subclass of organophosphates has few insecticides such as mevinphos, monocrotophos and dicrotophos. These insecticides have been banned by Ministry of National Food Security and Research, Department of Plant Protection, Government of Punjab, Pakistan due to toxic effects on natural enemies and health hazards in human beings.

5.2.2 Phosphorothioates

The sulfur atom is double bonded to the phosphorus atom in this subclass of organophosphates. Chlorpyrifos is a typical example of phosphorothioates. It is used as an acaricide and insecticide having contact and stomach poison activity against various insect pests on cotton, corn, sugarcane, fruits and vegetables. The trade name of chlorpyrifos is Lorsban® (40EC, Arysta Life Sciences, Pakistan). Chlorpyrifos has 95-270 $mgKg^{-1}$ oral LD_{50} and > 2000 $mgKg^{-1}$ dermal LD_{50} in rats.

Triazophos is another phosphorothioates having insecticide, acaricide and nematicide activity. It is used for the control of bollworms, beetles, soil insects, mealybugs and nematodes in cotton, fruits and vegetables (Afzal et al., 2015). Triazophos has 57-59 $mgKg^{-1}$ oral LD_{50} in rats (Simon, 2014).

5.2.3 Phosphorodithioates

The subclass containing two sulfur atoms in phosphoric acid molecule are known as phosphorodithioate insecticides. The examples of this class of insecticides are malathion and dimethoate. Malathion is a phosphorodithioate insecticide that is used for the control of household, greenhouse and garden pests (Selvi et al., 2010). Malathion has 5400 $mgkg^{-1}$ oral LD_{50} in male rats and 5700 $mgkg^{-1}$ in female rats, while dermal LD_{50} is > 2000 $mgkg^{-1}$.
Dimethoate is another phosphorodithioate insecticide. It has systemic, contact and stomach poison activity. It is used for the control of aphids, whiteflies, mites, thrips and leafhoppers on various crops. Dimethoate has 235 $mgkg^{-1}$ oral LD_{50} in rats (Simon, 2014).

5.2.4 Phosphorothiolates

The subclass which contains a single bond, sulfur to phosphorus atom is known as phosphorothiolate insecticides. Profenofos is a typical example of this class. It is used for the control of lepidopterans pests, mealybug and thrips on cotton and vegetables (Abbas et al., 2014b). The oral LD_{50} of profenofos is 358-1178 $mgkg^{-1}$ and dermal LD_{50} is > 2000 $mgkg^{-1}$ in rats.

5.2.5 Phosphonates

The subclass in which the phosphorus atom bonds directly to carbon atom is known as phosphonate. Trichlorfon is an example of this subclass. It is a contact and stomach poison and used for the control of fruit fly on fruits and vegetables. The trade name of trichlorfon is Diptrex® (80SP, Bayer Crop Sciences). The oral LD_{50} of trichlorfon is 450 $mgKg^{-1}$ and dermal LD_{50} is > 2000 $mgKg^{-1}$ in rats.

5.2.6 Phosphoramidates

The subclass in which the phosphorus atom bonds to nitrogen atom is known as phosphoramidates. Methamidophos and acephate are typical examples of phosphoramidates. **Methamidophos** is used as an insecticide and acaricide for the control of thrips, aphids, whiteflies, cutworms, armyworm and mites on cotton, fruits and vegetables. Methamidophos has 21 and 16 $mgkg^{-1}$ oral LD_{50} in male and female rats, respectively and 50 mgkg-1 dermal LD_{50}. It is banned in Pakistan due to effects on human and natural enemies.
Acephate is a systemic insecticide having stomach and contact poison activity. It is used for the control of aphids, jassid and thrips on cotton. The trade name of acephate is Commando® (75SP, FMC, Pakistan). The oral LD_{50} of acephate is 866$mgkg^{-1}$ and 945$mgkg^{-1}$ in female and male rats, respectively.

5.3 Carbamates

Carbamate insecticides are derivatives of carbamic acid (NH_2COOH). Three H atoms can be replaced with aromatic or aliphatic radicals to formulate the carbamate insecticides. However, second H atom on N atom cannot be replaced because the mono alkyl structure is more toxic compared to the N distributed molecule. Typical examples of carbamates are carbaryl, methomyl, carbofuron, carbosulfon, and thiodicarb.

Carbaryl is a broad spectrum carbamate insecticide which is used for the control of aphids, leafhoppers, bollworms, boll weevils and armyworms on cotton, apple, pear and vegetables. The trade name of carbaryl is Sevin® (Bayer Crop Sciences). The oral LD_{50} of carbaryl is 250-850 $mgkg^{-1}$ and dermal LD_{50} is > 2000 $mgkg^{-1}$ in rats.

Methomyl is used for the control of aphid, fruit fly and armyworm on cotton, vegetables and ornamentals (Byrne & Toscano, 2001). The trade name of methomyl is Lannate® (40SP, Arysta Life Sciences). Methomyl has 17-26 $mgkg^{-1}$ oral LD_{50} and > 1000 $mgkg^{-1}$ dermal LD_{50} in rats (Simon, 2014).

Carbofuron is a systemic carbamate insecticide used for the control of borers on rice, sugarcane and maize. The trade name of carbofuron is Furadan® (3G, FMC). The oral LD_{50} of carbofuron is 5-13 $mgkg^{-1}$ in rats and > 1000 $mgkg^{-1}$ dermal LD_{50} in rabbits.

Carbosulfon is a carbamate insecticide that is used for the control of sucking pests and soil pests such as nematodes on various crops. This insecticide is marketed under the name of Advantage® (25DS, FMC). The oral LD_{50} of carbosulfon is 250 and 185 $mgkg^{-1}$ for male and female rats, respectively (Simon, 2014).

5.4 Pyrethroids

Pyrethroids are derivatives of pyrethrum which is extracted from a flower, *Chrysanthemum cinerariaefolium* and their active ingredients are pyrethrins. Pyrethrins contain four esters, two different alcohols and two different acids as follows:

1) Pyrethrins I (pyrethrolone + chrysanthemic acid)
2) Pyrethrins II (pyrethrolone + pyrethric acid)
3) Cinerins I (cinerolone + chrysanthemic acid)
4) Cinerins II (cinerolone + pyrethric acid)

Examples of pyrethroid insecticides are permethrin, bifenthrin, cypermethrin, fenvalerate, esfenvalerate, deltamethrin and lambda-cyhalothrin.

Permethrin is used for the control of mosquitoes, house flies, ticks and various pests on cotton, maize, wheat and alfalfa. The oral LD_{50} of permethrin ranges from 430-4000 $mgkg^{-1}$ in rats and dermal LD_{50} is > 2000 $mgkg^{-1}$ in rabbits.

Bifenthrin is a pyrethroid insecticide which is used for the control of sucking and chewing pests on cotton, mango and rice (Jan et al., 2015). It is also used for the control of household and livestock pests (Abbas et al., 2015a). The trade name of bifenthrin is Talstar® (10EC, FMC). The oral LD_{50} of bifenthrin ranges from 53.4-210.4 $mgkg^{-1}$ in rats (Tomlin, 2000). The dermal LD_{50} of this insecticide is >2000 $mgkg^{-1}$ in rats and rabbits (FAO, 2010).

Cypermethrin is used for the management of chewing pests of cotton such as spotted bollworms and American bollworms (Jan et al., 2015). The trade name of cypermethrin is Arrivo® (10EC, FMC). The oral LD_{50} of cypermethrin ranges from 187-326 $mgkg^{-1}$ in male rats and 150-500 $mgkg^{-1}$ in female rats. The dermal LD_{50} of cypermethrin is 1600 $mgkg^{-1}$ and > 2000 $mgkg^{-1}$ in rats and rabbits, respectively (Simon, 2014).

Esfenvalerate is a synthetic pyrethroid used for the control of lepidopteran pests such as spotted bollworms, American bollworms and armyworms on cotton, alfalfa and vegetables (Shad et al., 2012). The trade name of esfenvalerate is Sumi-Alpha® (110EC, Arysta Life Sciences). Esfenvalerate has 458 $mgkg^{-1}$ oral LD_{50} in rats and has 2000 $mgkg^{-1}$ dermal LD_{50} in rabbits.

Deltamethrin is a broad spectrum pyrethroid insecticide which is used for the control of lepidopteran pests, mites, weevils and beetles on various crops (Jan et al., 2015). The trade name of deltamethrin is Decis Super® (100EC, Bayer Crop Science). The oral LD_{50} of deltamethrin in rats ranges from 30-140 $mgkg^{-1}$. The dermal LD_{50} of deltamethrin is >2000 $mgkg^{-1}$ in rabbits (Rehman et al., 2014).

Lambda-cyhalothrin is used for the control of lepidopteran pests such as American bollworms, spotted bollworms, armyworms and leaf folders on cotton and rice (Shad et al., 2012). The trade name of lambda-cyhalothrin is Karate® (2.5EC, Syngenta). The oral LD_{50} of lambda-cyhalothrin is 79 $mgkg^{-1}$ and 56 mgkg-1 in male and female rats, respectively. The dermal LD_{50} of lambda-cyhalothrin is 632 $mgkg^{-1}$ and 696 $mgkg^{-1}$ in male and female rats, respectively (EPA, 2007).

5.5 Novel Chemistry Insecticides

5.5.1 Neonicotinoids

Neonicotinoids are new group of insecticides that are analogs of nicotine and also known as chloronicotinyls. Neonicotinoids affect the central nervous system of insects. These insecticides have low mammalian toxicity than nicotine. The examples of this group are imidacloprid, acetamiprid, thiamethoxam and nitenpyram.

Imidacloprid is a systemic insecticide used for the control of sucking insect pests on cotton, sugarcane and tobacco (Saeed et al., 2017). The trade name of imidacloprid is Confidor® (Bayer Crop Science, Pakistan). The oral LD_{50} of imidacloprid is 450 $mgKg^{-1}$ and dermal LD_{50} is >5000 $mgKg^{-1}$ in rats (Simon, 2014).

Acetamiprid is a systemic neonicotinoid insecticide used for the effective control of whitefly, jassid, thrips, mealy bug and leaf minor on cotton, tobacco and melon (Saeed et al., 2017). In Pakistan, acetamiprid is sold under different trade names such as Mospilan® (Arysta Life Sciences) and Acelan® (FMC). The oral LD_{50} of acetamiprid in male and female rat is 217 and 146 $mgKg^{-1}$, respectively. The dermal LD_{50} of acetamiprid is >2000 $mgKg^{-1}$ in rats (Paranjape et al., 2015).

Thiamethoxam is a systemic neonicotinoid insecticide having broad spectrum activity against various pests. It is used for the control of whitefly, aphid, jassid and others on various crops such as cotton, rice, potato, vegetables and ornamentals (Saeed et al., 2017). The trade name of thiamethoxam is Actara® (Syngenta, Pakistan). The oral LD_{50} of thiamethoxam is > 5000 $mgKg^{-1}$ and dermal LD_{50} is 2000 $mgKg^{-1}$ in rats (Simon, 2014).

Nitenpyram is used for the control of whiteflies, thrips, jassid, and aphids on various crops. The trade name of nitenpyram is Paranol® (10EC, Kanzo Agrochemicals). The oral LD_{50} of nitenpyram is 1575 $mgKg^{-1}$ in female rats and 1680 $mgkg^{-1}$ in male rats (Simon, 2014). The dermal LD_{50} of nitenpyram is > 2000 $mgKg^{-1}$ in rats.

5.5.2 Insect growth regulators (IGRs)

IGRs are novel chemistry insecticides that disrupt growth and development of insects, resulting eventually death. IGRs are divided into five types, namely juvenile hormone mimics, benzoylphenylureas, diacylhydrazines, triazines, and thiadiazines. These insecticides have very low mammalian toxicity.

5.5.2.1 Juvenile hormone mimics

Pyriproxyfen, a juvenile hormone mimic insecticide, have been used for the control of house fly, whitefly, boll weevil, mosquito and cockroach (Crowder et al., 2007; Abbas et al., 2015b). The trade name of pyriproxyfen is Admiral® (FMC, Pakistan). Pyriproxyfen is highly toxic to target pests and low toxic to mammals. It is used in integrated management strategies for the control of different pests due to reduced risks. The oral LD_{50} of pyriproxyfen is > 5000 $mgkg^{-1}$ and dermal LD_{50} is > 2000 $mgkg^{-1}$ in rats (Simon, 2014).

5.5.2.2 Benzoylphenylureas

Benzoylphenylurea insecticides are derivatives of urea (H_2NCONH_2). Lufenuron is a benzoylurea insecticide that inhibits the production of chitin in insects. Due to inhibition of chitin synthesis, insects never develop a hard exoskeleton, and ultimately die after hatching or molting. Lufenuron have been effectively used against different insect pests such as lepidopteran and coleopteran pests (Abbas et al., 2015b; Nascimento et al., 2015). It is also used for the control of citrus leafminer and mites on citrus. The trade name of lufenuron is Match® (Syngenta, Pakistan). Its oral and dermal LD_{50} in rats is >2000 and >4000 $mgKg^{-1}$, respectively (Simon, 2014).

Diafenthiuron is a thiourea insecticide. It is used for the control of whiteflies, aphids, jassids and mites on cotton and vegetables. It kills both nymph and adult stages of pests by contact and stomach poison activity. Trade name of diafenthiuron is Polo® (Syngenta, Pakistan). The oral LD_{50} of diafenthiuron is 2068 $mgKg^{-1}$ and dermal LD_{50} is >2000 $mgKg^{-1}$ in rats (Simon, 2014).

5.5.2.3 Diacylhydrazines

Diacylhydrazine insecticides are derivatives of hydrazine (H_2N-NH_2). These insecticides mimic the action of molting harmone, ecdysone in larvae of lepidopteran pests. The examples of this group are tebufenozide and methoxyfenozide.

Tebufenozide is used for the control of lepidopteran pests on vegetables. The trade name of tebufenozide is Topgun® (Jaffer Brothers, Pakistan). Its oral and dermal LD_{50} is > 5000 $mgKg^{-1}$ in rats (Simon, 2014).

Methoxyfenozide is a highly selective insecticide for the control of armyworm on cotton, vegetables and fruit trees. The trade name of methoxyfenozide is Runner® (Arysta Life Sciences, Pakistan). The oral LD_{50} of methoxyfenozide is >5000 $mgKg^{-1}$ and dermal LD_{50} is >2000 $mgKg^{-1}$ in rats (Simon, 2014).

5.5.2.4 Triazines

Triazine insecticides are derivatives of triazine. Currently, only example of this group is cyromazine which is a cyclopropyl derivative of melamine. It affects the nervous system of immature larval stages of certain insects. It is used for the control of dipterous pests, including leaf-miners on ornamental and vegetable crops. The trade name of cyromazine is Trigard® (Syngenta, Pakistan). The oral LD_{50} of cyromazine is 3387 $mgKg^{-1}$ and dermal LD_{50} is > 3100 $mgKg^{-1}$ in rats (Simon, 2014).

5.5.2.5 Thiadiazines

Thiadiazine insecticides are derivatives of thiadiazine. Buprofezin is the only present example of thiadiazines. It is used for the control of whiteflies, aphids, jassids and thrips on cotton and vegetables (Basit et al., 2012). The oral LD_{50} of buprofezin is 2198 $mgKg^{-1}$ and dermal LD_{50} is > 5000 $mgKg^{-1}$ in rats (Simon, 2014).

5.5.3 Avermectins

Avermectins are macrocyclic lactones and extracted from soil microorganism, *Sepreptomyces avermitilis* Kim and Goodfellow (actinomycete). The typical examples of avermectins are abamectin and emamectin benzoate.

Abamectin is derived from naturally occurring avermectins and contains a combination of avermectins B1a and avermectins B1b as active ingredients. It is used as insecticide and acaricide for the control of insect and mite pests on various field crops, fruits, vegetables and ornamentals (Simon, 2014). The trade name of abamectin is Alarm® (1.8EC, DJC, Pakistan). The oral LD_{50} of abamectin is 300 $mgkg^{-1}$ in rats and dermal LD_{50} is >2000 $mgkg^{-1}$ in rabbits (Simon, 2014).

Emamectin benzoate is a semisynthetic bio-insecticide derived from a naturally occurring avermectin compound and contains B1a and B1b as active ingredients. Emamectin benzoate is used for the control of lepidopteran pests on various crops at low rates (Shad et al., 2012). It is a chloride channel activator causing prevention of muscle contraction, cessation of feeding and finally death. The trade name of emamectin benzoate is Proclaim® (019EC, Syngenta). The oral LD_{50} of emamectin benzoate is 1516 $mgkg^{-1}$ in rats and dermal LD_{50} is > 2000 $mgkg^{-1}$ in rabbits (Simon, 2014).

5.5.4 Spinosyns

Spinosyns are derived from the soil microbe, *Saccharopolyspora spinosa* Mertz & Yao. Spinosyns affect the gamma aminobutyric acid and acetylcholine transmission by depolarizing neurons in the insect nervous system. These are reduced risk insecticides for example, less toxic to mammals, birds, fish and human beings and highly effective against targeted pests. The typical examples of Spinosyns are spinosad and spinetoram.

Spinosad is derived from Spinosyns and contains spinosyn A and spinosyn D as active ingredients. It is used for the control of armyworms, American bollworms, diamondback moths, thrips, leaf miners, fruit flies, house flies and mosquitoes (Zhao et al., 2006; Shad et al., 2012). The trade name of spinosad is Tracer® (240SC, Arysta Life Sciences). The oral and dermal LD_{50} of spinosad is > 5000 $mgkg^{-1}$ and > 2800 $mgkg^{-1}$ in rats (Simon, 2014).

Spinetoram has mixture of spinetoram J and spinetoram L as active ingredients. It is used for the control of lepidopteran pests, leafminers, thrips and certain psyllids on various crops (Li et al., 2015). The trade name of spinetoram is Radiant® (120SC, Arysta Life Sciences). The oral and dermal LD_{50} of spinetoram is more than 5000 $mgkg^{-1}$ in rats (Kagaku, 2012).

5.5.5 Phenylpyrazoles

Phenylpyrazole insecticides are derivatives of phenylpyrazole that disrupt GABA-gated and glutamate-gated chloride channels in the insect central nervous system. Fipronil is the only member of this class that is marketed in Pakistan. The trade name of fipronil is Regent® (Bayer Crop Science, Pakistan). Fipronil is a systemic insecticide and is used for the control of rice and sugarcane borers and house flies (Abbas et al., 2014a). The oral and dermal LD_{50} of fipronil is 97 $mgKg^{-1}$ and > 2000 $mgKg^{-1}$, respectively in rats (Simon, 2014).

5.5.6 Pyrroles

Pyrrole insecticides are derived from pyrrole. Chlorfenapyr is the only example of this class. It is metabolized into an active insecticide after entering into host. Chlorfenapyr is used for the control of whiteflies, bugs, thrips, jassid, armyworm and mites on cotton, vegetables and ornamentals (Ullah et al., 2016). Its oral LD_{50} in rats is 441 $mgKg^{-1}$ (Simon, 2014).

5.5.7 Oxadiazines

Oxadiazine insecticides are derivatives of oxadiazine. These insecticides are voltage dependent sodium channel blockers. Indoxacarb is the only example of this class. It is used for the management of lepidopteran pests on corn, vegetables and fruits (Sayyed et al., 2008). The trade name of indoxacarb is Steward® (DuPont, Pakistan). The oral and dermal LD_{50} of indoxacarb in rats is 1732 $mgKg^{-1}$ and > 5000 $mgKg_{1}$, respectively (Simon, 2014).

5.5.8 Pyridinecarboxamide

Pyridinecarboxamide insecticides are modulators of chordotonal organs. Flonicamid is the only example of this class. It is a novel systemic insecticide and used against aphids, whiteflies, thrips, leafhoppers and plant bugs on wheat, cotton, potatoes, pome fruit and vegetables. Flonicamid has an excellent safe profile against beneficial insects and will provide a new option in integrated pest management programs. It is highly effective for the control of all aphid species on various crops and fruits. It inhibits the aphid feeding by inhibition of stylet penetration to plant tissues, resulting death due to neurological effects (Morita et al., 2007). Flonicamid had 884 $mgkg^{-1}$ and 1768 $mgKg^{-1}$ oral LD_{50} in male and female rats, respectively (Simon, 2014). The dermal LD_{50} of Flonicamid is >5000 $mgKg^{-1}$ in rats.

5.5.9 Diamides

Diamides are a new group of insecticides that have been classified as ryanodine receptor modulators. Ryanodine receptors are calcium channels located in the sarcoplasmic reticulum. Diamides cause continuous opening of calcium channels and uncoordinated muscle contraction, subsequently resulting death of insects. Diamide insecticides are particularly active against lepidopteran pests at lower dose rates and have an excellent safety profile. Diamide insecticides comprise 7 % of the global insecticide market after eight years of market launch, which highlights the importance of this chemistry. To date, two representatives of the diamide insecticides are registered on the basis of chemistry as shown follows:

5.5.9.1 Phthalic Diamides

Phthalic diamides are also known as benzenedicarboxamides. Flubendiamide is an only example of this class, registered with the trade name of Belt® (Bayer Crop Science, Pakistan). It is effectively used for the control of lepidopteran pests (Tohnishi et al., 2005). The oral and dermal LD_{50} of flubendiamide is >2000 mg/Kg, respectively in rats (Singh & Mandal, 2013).

5.5.9.2 Anthranilic Diamides

Anthranilic diamide insecticides are derivatives of anthranil. Chlorantraniliprole is a first generation of anthranilic insecticides. This insecticide is currently registered under the trade name of Coragen® (DuPont). It is effectively used for the control of lepidopteran hemipteran and coleopteran pests on various crops (Sial & Brunner, 2012; Su et al., 2012). The oral and dermal LD_{50} of chlorantraniliprole is >5000 $mgKg^{-1}$ in rats (Simon, 2014).

Cyantraniliprole is a second generation anthranilic diamide insecticide, currently registered under the trade name of Cyazypyr® (DuPont). It has very low toxicity to natural enemies and vertebrates. It has systemic and translaminar activity against various sucking and lepidopteran insect pests. The oral and dermal LD_{50} of cyantraniliprole is > 5000 $mgKg^{-1}$ in rats (Simon, 2014).

5.5.10 Tetronic acids

These insecticides are derivatives of spirocyclic tetronic acids that inhibit the lipid metabolism enzyme, acetyl-CoA-carboxylase. The trade name of spiromesifen is Oberon® (Bayer Crop Science). It is a novel insecticide/acaricide, used effectively against whiteflies and mites on cotton, fruits, vegetables and ornamentals. Its oral and dermal LD_{50} is > 2500- and > 4000 $mgKg^{-1}$, respectively (Simon, 2014).

5.5.11 Tetramic acids

Tetramic acid insecticides are derivatives of tetramic acid. The example of this class is spirotetramat, registered under the trade name of Movento® (240SC, Bayer Crop Science). It is used for the control of whiteflies, aphids, thrips and scale insects (Peng et al., 2017). The oral and dermal LD_{50} of spirotetramat is > 2000 $mgKg^{-1}$ in rats (Shimokawatoko et al., 2012).

5.5.12 Nereistoxin analogs

The insecticides of this class are analogs of nereistoxin, a natural toxin of marine worm. Cartap hydrochloride is the member of this class that is marketed under the trade name of Padan® (FMC). It is systemic insecticide and effectively used for the control of rice and sugarcane borers. The oral LD_{50} of cartap is 345 $mgKg^{-1}$ in rats (Simon, 2014).

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