Inorganic Insecticides

Inorganic Insecticides are compounds that are not carbon based. They are stable chemicals which do not evaporate and are frequently soluble in water. Arsenical compounds such as calcium and lead arsenate were frequently used insecticides prior to the wide-scale development of synthetic-organic insecticides which began in the 1940s. Other examples of inorganic compounds with insecticidal properties are sodium fluoride, sodium silicofluoride and boric acid. These insecticides are not used in modern production agriculture.

Biological and Botanical Insecticides

Biological insecticides are bacteria, viruses, fungi and other microorganisms that attack insects. Naturally occurring pathogens are often very important in preventing the outbreak of pests. Some biological insecticides have been developed and marketed for the control of pests in field crops. These biological control agents generally have the advantage of being highly selective, and thus safe to the environment and non-target organisms. Common examples are nuclear polyhedrosis viruses (NPVs) and Bacillus thuringiensis (Bt insecticides), a bacteria. Some NPVs have activity of important pests such as bollworm, tobacco budworm and various armyworms species. However, they are not frequently used because of short persistence, slow activity and low efficacy relative to synthetic-organic insecticides. Bt products such as Dipel® and MPV® are still marketed and used widely by homeowners and organic producers. They were used extensively in cotton during the 1980s and 1990s, tank-mixed with other insecticides, to help control pyrethroid resistant tobacco budworms. Now, genetically modified crops such as Bt cotton and Bt corn have been adopted by many producers. Bt crops possess one or more genes from Bacillus thuringiensis, and plants produce their own insecticide. Depending upon the gene inserted into the plant genome, Bt crops provide control of very important pests such as tobacco budworm, bollworm, pink bollworm, armyworms, corn borers, and corn rootworms.

Botanical Insecticides are naturally-occurring, organic compounds which are produced by plants. Examples include nicotine (from tobacco) and pyrethrins (from Chrysanthemum). Derivatives of these natural compounds were used extensively for insect control prior to the development of synthetic insecticides. However, botanical insecticides are not currently used in the production of field crops because of their relatively low efficacy, short persistence, and high cost of production. Although most botanical insecticides are relatively safe to use, some plant-derived toxins are acutely toxin to humans.

Synthetic-organic Insecticides

Synthetic-organic insecticides were widely developed beginning in the 1940s. These compounds are the primary insecticides used for the control of insect pests. The first class of synthetic-organic insecticides used on a large scale were the organochlorines, followed by organophosphate and carbamate insecticides. Synthetic pyrethroid insecticides were first marketed in the late 1970's, and on a worldwide basis, and they are probably the most useful insecticides for the control of agricultural insect pests. Beginning in the mid-1990s, several new classes of insecticides were introduced for insect control in agriculture. These include neonicotinoid insecticides such as Centric®, Admire Pro® and Intruder® that are frequently used in the production of agricultural crops. Other new classes of insecticides used in field crops are represented by spinosad (e.g., Tracer®), emamectin benzoate (e.g., Denim®) and indoxacarb (e.g., Steward®). Also recently, new insect growth regulators have been developed and are being widely used for insect control in many agricultural systems. There are other new insecticide classes which are used to a limited extent in the production of cotton, corn, soybean and other field crops. With some exceptions, mostly with IGR insecticides, synthetic-organic insecticides affect nerve processes of insects. The toxicity to humans and other non-target organisms often varies widely among and within the various classes of synthetic-organic insecticides.

- **Organochlorine Insecticides:** Organochlorine Insecticides (OC or chlorinated hydrocarbons) were the first synthetically produced insecticides used on a large scale in production agriculture and in other areas of insect control. Representatives of this rather diverse chemical class include DDT, toxaphene, endosulfan, chlordane, mirex, lindane (BHC), and the cyclodienes (e.g., heptachlor, aldrin, dieldrin). OC insecticides are generally broad spectrum, affecting sodium channels within the nervous system of insects. The general public generally believes that DDT and other organochlorine insecticides are acutely toxic to humans and other non-target organisms, but in reality, the biggest problem with these compounds is their negative effects on the environment. OC insecticides are generally persistent and tend to bioaccumulate in the ecosystem, being stored and concentrated within food chains, and having chronic toxicological impacts on non-target organisms. Thus, most organochlorine pesticides have been banned from use. However, because they were the first highly-effective insecticides, they are an important component of insect control history.

  The evolution of insect resistance to organochlorine insecticides demonstrated the potential risks of relying solely on insecticides for pest control. However, the use of DDT and similar compounds for control of disease vectoring insects has saved countless lives. Worldwide, several of organochlorines are still important today. Chlordane is excellent for protecting wood from termites but is banned in the United States.

- **Organophosphate Insecticides:** Organophosphorus Insecticides (OP) are a rather diverse group of chemicals that were derivatives of compounds developed for chemical warfare in WW II. OP insecticides were relied upon when insects developed resistance to the chlorinated hydrocarbons. These compounds may be classified into several chemical groups (phosphonates, phosphates, etc.). Examples include dicrotophos (Bidrin®), methyl parathion, chlorpyrifos (Lorsban®), acephate (Orthene®), and diazinon. Many agricultural uses of OP insecticides have been restricted in recent years, but OPs are still commonly used in many field crops and on a worldwide basis because they provide a broad spectrum of insect control. Organophosphorus insecticides are classical inhibitors of acetylcholinesterase, the enzyme which stimulates breakdown of acetylcholine at the post-synaptic nerve endings. In general, these insecticides are toxic to insects and mammals and should be handled with care. However, they are less persistent than organochlorine insecticides, and thus have less long-term environmental impacts.

- **Carbamate Insecticides:** Carbamate Insecticides were developed and used after insect populations had developed resistance to the chlorinated hydrocarbons and OP insecticides. Similar chemical compounds are used extensively in other areas of agriculture (herbicides, fungicides, etc.) and medicine. One of the members of this group is carbaryl, commonly sold as Sevin®. Carbaryl is widely used on many crops and is available to home gardeners and other applicators of non-restricted use insecticides because of its rather low mammalian toxicity. Conversely, methomyl (Lannate®), carbofuran (Furadan®) and aldicarb (Temik®), three carbamate insecticides that once were commonly used in row crop agriculture, are among the most toxic insecticides. The carbamates act similarly to the organophosphorus insecticides in that they inhibit acetylcholinesterase.

- **Synthetic Pyrethroid Insecticides:** Botanically-produced pyrethrins were seldom used for insect control purposes because of high production costs of and their instability in sunlight. When synthetic alternatives were developed, they were rapidly adopted for use in agriculture. Today, synthetic pyrethroids are used for many purposes because of their efficacy, low use rates, low cost, broad spectrum of control, and relatively low mammalian toxicity. The historical development of pyrethroids was a long process. The first widely-used pyrethroid insecticides were allethrin (Pynamin®), tetramethrin (Neo-Pynamin®), resmethrin, bioallethrin, fenvalerate (Pydrin®) and permethrin (Ambush®). The next generation of pyrethroids greatly influenced agriculture. They are still very important for insect control in commercial agriculture and include cypermethrin (Ammo®), bifenthrin (Brigade®), lambda-cyhalothrin (Warrior®), among others. The mode of action of pyrethroids is similar to that of DDT, affecting the function of sodium channels in nerve cells. Most entomologists consider the synthetic pyrethroids to be the most versatile and effective insect control materials ever developed. However, some important insect species have developed resistance to these chemicals, including the tobacco budworm.

- **Neonicotinoid Insecticides:** Neonicotinoid, or chloronicotinyl, compounds are a relatively new class of insecticides now used widely for insect control in field and vegetable crops. Examples include imidacloprid (Admire Pro® and Gaucho®), thiamethoxam (Centric® and Cruiser®) and acetamiprid (Intruder®). The class name originates from the mode of action. These compounds affect nicotinic receptors, similar to nicotine, essentially mimicking the function of acetylcholine within insect nerve cells. Neonicotinoids are characterized by more specialized activity and are most often used for the control of sucking insect pests such as aphids, plant bugs and whiteflies. They are also used extensively to control fleas on pets. This class of insecticides has relatively low toxicity to humans and other non-target organisms, but they are often criticized for their impact on pollinators.

- **Insect Growth Regulators:** These synthetic materials interfere with normal growth and development processes of insects which are regulated by hormones. In general, insect growth regulators are selective, having significant activity on a relatively small group of insects, and thus play a limited role in the protection of agricultural crops. The oldest examples are diflubenzuron and altosid. Diflubenzuron was used extensively in some early boll weevil eradication efforts. It has significant activity of some species of caterpillar and grasshopper pests and is commercially available as Dimilin®. Diflubenzuron blocks synthesis of chitin, an important component of insect cuticle. It is also used as a chemosterilant of boll weevil. Altosid, and the newer insecticide pyriproxyfen (Knack®), are juvenile hormone mimics (i.e., agonists). Juvenile hormone is a chemical that encourages or regulated the maturing process of insects. Methoxyfenozide (Intrepid®) and tebufenozide (Confirm®) are ecdysone agonists and are highly active on many species of armyworms and other foliage feeding caterpillars. Ecdysone is the hormone in insects which stimulates molting.

- **Other, Relatively New Insecticides:** There are many other, relatively new classes of insecticide chemistry that have recently been introduced and used in commercial agricultural. Representatives of these new classes include spinosad (BlackHawk®, class = Naturalytes), indoxacarb (Steward®, class Oxadiazine), emamectin benzoate (Denim®, class = Synthetic Avermectin), and chlorantraniliprole (Prevathon® and Besiege®, class Diamide). Like older insecticide classes, these newer insecticides are nerve poisons. However, they are more specific, having less impact on non-target organisms and a reduced risk of causing negative environmental impacts. The relatively narrow spectrum of activity of these compounds limits their use to the control of specific kinds of pests, but many are very useful in controlling populations of important insects that are resistant to older classes of insecticides.

More classes of insecticide and additional details can we found at the website for the Insecticide Resistance Action Committee.