Understanding Pests, Pest Control and Pesticides

Chemical pest controls are a relatively recent invention, but the practice of pest management is the product of evolution and biological relationships. The first acts of pest control were simple techniques but, as agriculture has come into existence, techniques increased from personal protection to include protection and expansion of crops.

All of the variations of interactions of species can be simplified into three basic scenarios:

- Mutualism in which the organisms involved benefit one another (i.e. co-dependence of plants on nitrogen fixing bacteria in their roots).
- Commensalism is when one species benefits and the other species neither benefits nor is harmed (epiphytes such as orchids growing on trees). The trees do not benefit from the orchid but are not harmed.
- Parasitism or predation is when one species benefits but the other species is either harmed or killed. It is these interactions which started the need for pest management.

History of Pest Management

The early chemical weapons where elemental compounds of sulfur, heavy metals and salts. Some of these compounds were in use up through the present day. The list of these compounds include:

- Elemental sulfur - deter lice and other pests
- Arsenic compounds - kill insects, bacteria and fungi by binding with important thiols and interrupting enzymatic processes such as ATP production
- Mercury compounds - affinity for thiols and disrupt biological processes
- Lead compounds - act as a calcium analog and block calcium driven such as heme synthesis

These inorganic compounds lasted a long time and were not easily degraded. Unfortunately, they often leached into the ecosystem, wreaking havoc on local wildlife and posing a health threat to its human inhabitants.

At first, chemicals were extracted and purified from their botanical sources. It was at this time that nicotine compounds were purified from tobacco, pyrethrums were extracted from flowers, and rotenone isolated from roots. Compounds were blended and produced for the purpose of pest control. In 1814, an inorganic compound of copper (II) acetoarsenite called “Paris Green” was introduced as a pigment. By 1867, Paris Green was widely sold as an insecticide and rodenticide which was produced up until the 1960s.

During the Victorian era, traditional pest controls were investigated and their chemicals identified and isolated. As a result, all of the chemical compounds that were historically available in their botanical forms (e.g. rotenone in roots and pyrethrums in chrysanthemums) were purified for commercial and home use, and elemental compounds were blended to create more efficient pesticides.

Modern Pest Management

Modern pest management and control is an increasingly diverse science with thousands of different management strategies. The management strategies are developed around three goals:

1. Repel pests or prevent predation
2. Control the life cycle of the pest and stop damage or predation
3. Eliminate or kill the pest

These three goals depend upon three basic types of pest control groups: physical controls, biological controls and chemical controls. Physical control mechanisms are strategies which create barriers to limit contact between predator and prey. Biological controls use other organisms to control target pests (i.e. companion planting and use of predator insects such as lady bugs or praying mantis). A final method of implementing biological control is conservation or increasing of predator habit or conditions to increase predator growth.

The most popular strategy of modern pest control is chemical controls which are poisonous substances that control organisms harmful to human or animal health (biocides and pesticides). Pesticides are substances intended to prevent, destroy, repel or mitigate any pest. They also are plant regulators, defoliants or desiccants. The classes of pesticides include all the target groups of biota from bacteria (bactericides) to large predators (predacides). In agriculture, we are most familiar with insecticides, fungicides and herbicides with herbicides being the most widely used type of pesticide. (1)

All pesticides are either broad spectrum (non-selective) able to kill or incapacitate a wide range of species, or narrow spectrum (selective) in their target species.

Pesticide Application and Mode of Action

Most pesticide compounds are not applied as pure materials but are often combined to facilitate application, delivery and efficiency of the pesticide. Additional chemicals, such as solvents or substrates are added to aid in the final form of the applied pesticide (liquid, solid, gas/aerosol) or in application (dispersants, carriers and stabilizers). The active ingredients are either natural or synthetic substances which will kill or disable the targeted pest.

Modes of action in pesticides define the systems, processes or organs which are targeted by the pesticide. Biological systems such as growth, respiratory, circulation, or digestive systems are the target of some pesticides. Other agents target specific biological pathways or processes to stop, limit or control those processes such as reproduction. Finally, there are agents which target specific cellular locations to control or limit cellular functions such as controlling ATP production or blocking neurotransmitters.

The most common modes of action are agonists (activators) which bind to a receptor to illicit a response, antagonists (disruptors, inhibitors or blockers) which bind to a receptor to stop a response or modulators which control reaction rates. The ways in which these actions are accomplished are most often by either mimicking natural process chemicals or by creating barriers which block channels and processes.

The IRAC (Insecticide Resistance Action Committee) grouped pesticides according to target process and mode of action. The targets include nervous and muscular system pesticides, growth inhibitors, respiratory pesticides, midgut pesticides, and non-specified action (see Table 1).

Table 1. IRAC pesticide groups by action and type (2)

Action	Group #	Type	Pesticide Groups
Nerve and Muscle	1	Acetylcholinesterase (AChE) Inhibitors	1A: Carbamates 1B: Organophosphates
	2	GABA-gated Chlorine Channel Blockers	2A: Cyclodiene Organochlorines 2B: Fiproles
	3	Sodium Channel Modulators	3A: Pyrethroids, Pyrethrins 3B: DDT, Methoxychlor
	4	Nicotinic Acetylcholine Receptor (nAChR) Competitive Modulators	4A: Neonicotinoids 4B: Nicotine 4C: Sulfoximines 4D: Butenolides 4E: Mesoionics
	5	Nicotinic Acetylcholine Receptor (nAChR) Allosteric Modulators	Spinosyns
	6	Glutamate-gated Chloride Channel (GluCl) Allosteric Modulators	Avermectins, Milbemycins
	9	Chordotonal Organ TRPV Channel Modulators	9B: Pyridine Azomethine Derivatives 9D: Pyropenes
	14	Nicotinic Acetylcholine Receptor (nAChR) Channel Blockers	Nereistoxin Analogues
	19	Octopamine Receptor Agonists	Amitraz
	22	Voltage-dependent Sodium Channel Blockers	22A: Oxadiazines 22B: Semicarbazones
	28	Ryanodine Receptor Modulators	Diamides
	29	Chordotonal Organ Modulators - Undefined Target Site	Flonicamid
	30	GABA-gated Chloride Channel Allosteric Modulators	Meta-dimides, Isoxazolines
	32	Nicotinic Acetylcholine Receptor (nAChR) Allosteric Modulators - Site II	GS-Omega/Kappa HXTXHv1a Peptide
Growth	7	Juvenile Hormone Mimics	7A: Juvenile Hormone Analogues 7B: Fenoxycarb 7C: Pyriproxyfen
	10	Mite Growth Inhibitors	10A: Clofentezine, Diflovidazin, Hexythiazox 10B: Etoxazole
	15	Inhibitors of Chitin Biosynthesis Affecting CHS1	Benzoylureas
	16	Inhibitors of Chitin Biosynthesis, Type 1	Buprofezin
	17	Molting Disruptor, Dipteran	Cyromazine
	18	Ecdysone Receptor Agonists	Diacyl Hydrazines
	23	Inhibitors of Acetyl CoA Carboxylase	Tetronic and Tetramic Acid Derivatives

Respiration	12	Inhibitors of Mitochondrial ATP Synthase	12A: Diafenthiuron 12B: Organotin 12C: Propargite 12D: Tetradifon
	13	Uncouplers of Oxidative Phosphorylation via Disruption of the Proton Gradient	Pyrroles, Dinitrophenols, Sulfluramid
	20	Mitochondrial Complex III Electron Transport Inhibitors	20A: Hydramethylnon 20B: Acequinocyl 20C: Fluacrypyrim 20D: Bifenazate
	21	Mitochondrial Complex I Electron Transport Inhibitors	21A: AMETI Acaricides and Insecticides 21B: Rotenone
	24	Mitochondrial Complex IV Electron Transport Inhibitors	24A: Phosphides 24B: Cyanides
	25	Mitochondrial Complex II Electron Transport Inhibitors	25A: Beta-keto Nitrile Derivatives 25B: Carboxanilides
Midgut	11	Microbial Disruptors of Insect Midgut Membranes	11A: Bacillus Thuringiensis 11B: Bacillus Sphaericus
	31	Baculoviruses	Granuloviruses, Nucleopolyhedroviruses
	8	Miscellaneous Non-specific (Multi-Site) Inhibitors	8A: Alkyl Halides 8B: Chloropicrin 8C: Fluorides 8D: Borates 8E: Tartar Emetic 8F: Methyl Isothiocyanate
	UN	Compounds of Unknown or Uncertain MOA	Lime Sulfur, Sulfur, Azadirachtin, Benzoximate, Bromopropylate, Dicofol, Chinomethionat, Mancozeb, Pyridalyl

The development of a pest management strategy involving pesticides must also consider the chemical and environmental concerns of the agents being applied and how those agents will react with each other and the environment.

Chemical compatibility is when two or more chemicals can combine safely. The combination could produce a synergistic action where each chemical is aided by the addition of the other or an additive effect where the potency or action is increased by the combination of agents. There is also an opposite or antagonistic chemical incompatibility. These incompatibilities can be issues of physical insolubility, chemical precipitation or unintentional toxicity. Potentiation occurs when the combination of two or more compounds becomes more toxic than the individual components. This effect is usually not intended by the formulator.

Common Pests

Agricultural crops are subject to a wide variety of pests from the smallest viruses (tobacco mosaic virus) to animals such as birds, rodents and burrowing animals. But, some of the most destructive and common pests are insects and fungi.

Some of these common parasites and pests can be effectively treated by combinations of pesticides with different modes of action (where permitted by state regulation and registry) (See Table 2). The most applicable against a variety of pests are the broad spectrum nervous system disruptors (Groups 1, 2, 3, etc.) which include organochlorine pesticides, pyrethrins and neonicotinoid pesticides.

Table 2. Pesticide groups for targeted pests

MOA Group	Target	Aphids	Whiteflies	Mites	Caterpillars
1A	Nerve	X	X	X	X
1B	Nerve	X	X	X	X
2A	Nerve	X	X	X	X
2B	Nerve	X			X
3A	Nerve	X	X	X	X
4A	Nerve	X	X		X
5	Nerve				X
6	Nerve			X	X
7B	Growth				X
7C	Growth	X			
9B	Nerve	X	X		
9C	Nerve	X	X		
10A	Growth			X	
10B	Growth			X	
11	Midgut				X
12A	Respiration	X	X	X	
12B	Respiration			X	
12C	Respiration			X	
13	Respiration			X	X
14	Nerve				X
15	Growth	X		X	X
16	Growth	X	X		
18	Growth				X
19	Nerve			X	
20B	Respiration			X	
20C	Respiration			X	
21A	Respiration	X		X	X
22A	Nerve	X			X
22B	Nerve				X
23	Growth	X	X	X	
25	Respiration			X	
28	Nerve				X
UN	Unknown			X	

Conclusions

Since the start of the production boom in the 1940's to present day, a huge catalog of thousands of insecticides, herbicides, and general pesticides was developed, including organochlorides (DDT, BHC), organophosphates (parathion, malathion, azinphos methyl), carbamates (aldicarb, carbofuran, etc.), and neonicotinoids (imidacloprid and acetamiprid). As modern pesticides develop, there has been a shift to understand and apply the chemical properties and interactions of pesticides with both the environment and animals other than the target pests. Early pesticides were, for the most part, persistent chemicals that affected the nervous system of invertebrates. These pesticides had, in many cases, limited solubility and persisted for years or decades after delivery. More modern pesticides take into consideration environmental impact and a larger pest management strategy.

Chemical pesticides are now an integral part of the world's agricultural arsenal, offering protection to crops from destructive pests. However, some disastrous side effects of their use include probable leaching of these chemicals into the environment and their ultimate presence in the human food chain. Because of this, pesticide residue analysis has become a serious testing process for several laboratories, most recently cannabis.

Each pesticide group in historical or modern use has their own set of physical and chemical properties which can make pesticide analysis a challenge. If the complexity of cannabis products are added into the analysis, it can further complicate an already extensive analysis. The lack of clear regulations, documentation and methods has, over the past decade, become a hurdle to effective pesticide residue testing. Fortunately, as the next decade arrives, more governments and organizations will become involved in the regulatory and testing processes to help the cannabis industry develop their own effective pest management strategies that are effective, safe and sustainable into the future.

References

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