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Natural Products for Insect Pest Management[1]

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Ideally, insecticides should reduce pest populations, be target-specific (kill the pest but not other organisms), break down quickly, and have low toxicity to humans and other mammals. Although, synthetic insecticides (e.g., chlorinated hydrocarbons, organophosphates, and pyrethroids) have been an important part of pest management for many years, the disadvantages and risks of using them have become apparent. As a result, many people are looking for less hazardous alternatives to conventional synthetic insecticides.

Some alternatives include less-toxic or natural products, such as insecticidal soaps, horticultural oils, microbials (see ENY-275 -http://edis.ifas.ufl.edu/IN081), mineral and botanical insecticides ("botanicals"). Most of these groups will be discussed in this publication. In particular, botanicals are toxins that are derived or extracted from plants or plant parts. Many botanical insecticides have been known and used for hundreds of years, but were displaced from the marketplace by synthetic insecticides in the 1950s. These old products, and some newer, plant-derived products, deserve consideration for use in pest control.

Botanical insecticides have different chemical structures and modes of action. However, some general traits of botanicals and other natural products include the following:

Fast Breakdown. Botanicals degrade rapidly in sunlight, air, and moisture, and by detoxification enzymes. Rapid breakdown means less persistence and reduced risks to nontarget organisms. However, precise timing and/or more frequent applications may be necessary.

Fast Action. Although death may not occur for hours or days, insects may be immediately paralyzed or stop feeding.

Selectivity. Rapid break down and fast action make botanicals more selective to certain plant-feeding pests and less harmful to beneficial insects.

Toxicity. Most botanicals have low to moderate mammalian toxicity, but there are exceptions (e.g., nicotine). See Table 1 for a summary of insecticide toxicity to animals. Even though botanicals are naturally derived and are relatively safe if used

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properly, they are nevertheless poisons and should be handled with the same caution as synthetic insecticides. All products must be used according to the label on the product container. They are most effective when used in an integrated pest management (IPM) program, which includes sanitation, cultural practices, mechanical controls, use of resistant plant varieties, and biological control.

Synergism. Some botanicals quickly break down or are metabolized by enzymes inside bodies of their target pests. Breakdown may occur rapidly, so that the insecticide only temporarily stuns, but does not kill the insect. A synergist may be added to a compound to inhibit certain detoxification enzymes in insects. This enhances the insecticidal action of the product. Synergists are low in toxicity, have little or no inherent insecticidal properties, and have very short residual activity.

Pyrethrins are often mixed with a synergist such as piperonyl butoxide (PBO), MGK 264, rotenone, or ryania to increase their effectiveness. PBO and MGK 264, however, should not be mixed with lime or soap solutions because of accelerated breakdown. PBO was implicated as a carcinogen in the past, and may not be used in some organic certification programs.

Phytotoxicity. Most botanicals are not phytotoxic (toxic to plants). However, insecticidal soaps, sulfur, and nicotine sulfate may be toxic to certain sensitive vegetables or ornamentals.

Cost and Availability. Botanicals tend to be more expensive than synthetics, and some are not produced in great supply or are no longer commercially available (e.g., nicotine). The potency of some botanicals may vary from one source or batch to the next.

Research. Data on effectiveness and long-term (chronic) toxicity to mammals are unavailable for some botanicals. Tolerances for residues of some botanicals on food crops have not been established.

State Registration. Several botanicals are registered by the United States Environmental Protection Agency (EPA) and are available by mail order, but are not registered for legal sale in certain states. Check the label before buying or applying these products.

Organic Production. Lists of products that are acceptable in organic plant production can be found at the Organic Materials Review Institute (http://www.omri.org) and the Florida Certified Organic Growers and Consumers, Inc. (http://www.foginfo.org) websites.

I. Botanical Insecticides

Limonene and Linalool

Citrus oils are extracted from oranges and other citrus fruit peels and refined to make the insecticidal compounds d-limonene and linalool. Both natural compounds are generally regarded as safe for mammals by the United States Food and Drug Administration, and are used extensively as flavorings and scents in foods, cosmetics, soaps, and perfumes.

Limonene and linalool are contact poisons (nerve toxins) that may be synergized by piperonyl butoxide (PBO). They have low oral and dermal toxicities. Both compounds evaporate readily from treated surfaces and have no residual. They have been registered for use against fleas, aphids and mites, but also kill fire ants, several types of flies, paper wasps and house crickets. Commercial products (usually called “d-Limonene”) are available as liquids, aerosols, shampoos, and dips for pets. Topical application can irritate the skin and eyes of some animals, and although symptoms are usually temporary, use these products cautiously and sparingly.

Neem

Neem or neem oil is extracted from the seeds of the neem tree, *Azadirachta indica*, a native of India. The neem tree supplies at least two compounds with insecticidal activity (azadirachtin and salannin), and other unknown compounds with fungicidal activity. Azadirachtin acts as an insect feeding deterrent and growth regulator. The treated insect usually cannot molt to its next life stage and dies. It acts as a repellent when applied to a plant and does not produce a quick knockdown and kill. It has low mammalian

toxicity and does not cause skin irritation in most formulations.

Neem has some systemic activity in plants. Currently registered products for ornamental pest control claim activity against a variety of sucking and chewing insects. Neem is most effective against actively growing immature insects. Neem oil is used to control powdery mildew.

Pyrethrum / Pyrethrins

Pyrethrins are highly concentrated active compounds which are extracted from the daisy-like flower of *Chrysanthemum cinerariaefolium*, commercially grown in Kenya. When the flower is ground into a powder, the product is called a pyrethrum. Pyrethrum is the most widely used botanical insecticide in the United States. Synthetic insecticides that mimic the action of the pyrethrins are known as pyrethroids (e.g., bifenthrin, cyfluthrin, and permethrin).

Most insects are highly susceptible to low concentrations of pyrethrins. The toxins cause immediate knockdown or paralysis on contact, but insects often metabolize them and recover. Pyrethrins break down quickly, have a short residual, and low mammalian toxicity, making them among the safest insecticides in use. However, people may have allergic skin reactions and cats are highly susceptible to poisoning (e.g., flea drops and powder).

Pyrethrins may be used against a broad range of pests including ants, aphids, roaches, fleas, flies, and ticks. They are available in dusts, sprays, and aerosol "bombs," and may be mixed with synthetic pesticides or other botanicals.

Rotenone

Rotenone is a broad-spectrum contact and stomach poison that is used against leaf-feeding insects, such as aphids, certain beetles (asparagus beetle, bean leaf beetle, Colorado potato beetle, cucumber beetle, flea beetle, strawberry leaf beetle, and others) and caterpillars, as well as fleas and lice on animals. Rotenone is extracted from the roots of two tropical legumes, *Lonchocarpus* and *Derris*, and is is commonly formulated as a dust or wettable powder.

Insects quickly stop feeding and death occurs several hours to a few days after exposure. Rotenone degrades rapidly when exposed to air and sunlight. It is not phytotoxic, but is extremely toxic to fish, and moderately toxic to mammals. Protective clothing and a mask should be worn to protect skin and the respiratory tract. It may be mixed with pyrethrins or piperonyl butoxide to improve its effectiveness.

Ryania

Ryania is extracted from the stems of a woody South American plant, *Ryania speciosa*. Although a slow-acting stomach poison, it causes insects to stop feeding soon after ingestion. It works well in hot weather. Ryania is moderate in acute or chronic oral toxicity in mammals. It is generally not harmful to most natural enemies, but may be toxic to certain predatory mites. Ryania has longer residual activity than most other botanicals.

It has been used commercially in fruit and vegetable production against caterpillars (European corn borer, corn earworm, and others) and thrips. Ryania may be difficult to find in stores but may be available from online vendors alone or mixed with rotenone and pyrethrin.

Sabadilla

Sabadilla comes from the ripe seeds of the tropical lily *Schoenocaulon officinale*. Sabadilla is a broad-spectrum contact poison, but has some activity as a stomach poison. Baits, dusts or sprays may be used in organic fruit and vegetable production against squash bugs, harlequin bugs, thrips, caterpillars, leaf hoppers, and stink bugs. The alkaloids in Sabadilla affect insect nerve cells, causing loss of nerve function, paralysis, and insect death. The dust formulation of sabadilla is the least toxic to mammals of all registered botanical insecticides, but protective clothing and a mask should still be worn to protect skin and the respiratory tract. Sabadilla breaks down rapidly in sunlight and air, leaving no harmful residues. However, it is highly toxic to honeybees, and should only be used when bees are not present (e.g., in the evening, after bees return to their hives).

II. Soaps and Oils

Horticultural Oil

Various oils can be used to manage some pest insects and mites. Horticultural oils used to be called either “dormant” or “summer” oils. Dormant oils originally referred to heavier weight, less well-refined oils that were unsafe to use on plants after they broke dormancy. However, these older oils have been replaced with more refined, light-weight oils that may be applied to plant foliage (summer or foliar oils). A dormant or summer oil now indicates the time of application rather than any particular type of oil. Dormant applications are ideal for treating the overwintering life stages of pests that are more difficult to control during the growing season.

Oils may affect the target pests in several ways. Petroleum oils and vegetable oils may block the insects air or breathing holes (spiracles), so the insect dies by suffocation. Oils prevent gas exchange through egg membranes, so eggs are often targets of control with oils. The fatty acids in oils may disrupt cell membranes and interfere with normal metabolism. Other oils may also have antifeedant properties or may clog stylets (stylet oils), which may help prevent insects, like aphids and leafhoppers, from transmitting viruses to plants. In general, oils are most effective against small, immobile or slow-moving, soft-bodied insects (e.g., aphids, scales, leafhopper nymphs, whiteflies) and mites that are thoroughly coated by an oil spray. Because oils lack residual activity, they do not provide control of insects moving into a treated area.

Insecticidal Soap

Insecticidal soaps are made from plant oils (cottonseed, olive, palm, or coconut) or animal fat (lard, fish oil), but are generally not considered botanicals. They are made from the salts of fatty acids, which are in the fats and oils of animals and plants.

The mode of action is still unclear, despite years of use. Soaps are thought to physically disrupt the insect cuticle (outer skin), but additional toxic action is suspected. Soaps act on contact and must be applied directly to the insect to be effective. No residues remain on plants. They are effective against soft-bodied insects like aphids, some scales, psyllids, whiteflies, mealybugs, thrips, and spider mites. Hard-bodied insects (e.g., adult beetles or wasps) are not harmed because of their tough, chitinous bodies.

Some plants may be sensitive to soaps, resulting in leaf burn. Plants that have hairy leaves may be more susceptible to soap injury than smooth-leaved plants. Consult the label to see which plants are listed. Apply the soap spray on a small area of the plant to check for phytotoxicity. Commercial soaps are less likely to be phytotoxic.

III. Mineral Insecticides

Diatomaceous Earth

Diatomaceous earth is a nontoxic insecticide mined from the fossilized silica shell remains of diatoms (single-celled or colonial algae). It absorbs the waxy layer on insect bodies, abrades the skin, and causes the insect to dry out.

Diatomaceous earth is sold as a dust, and is sometimes combined with pyrethrin. It may control slugs, millipedes and sow bugs, as well as soft-bodied insects like aphids. It has low mammalian toxicity. Two kinds of diatomaceous earth are available, a "natural grade" and a filtering agent in swimming pools, but the "natrual grade" is the one used as an insecticide.

Sulfur

Sulfur is probably the oldest known pesticide in current use. It can be used as a dust, wettable powder, paste or liquid, primarily for disease control (e.g., powdery mildews, rusts, leaf blights, and fruit rots). However, mites, psyllids and thrips also are susceptible to sulfur. Most pesticidal sulfur is labeled for vegetables (e.g., beans, potatoes, tomatoes, and peas) and fruit crops (e.g., grapes, apples, pears, cherries, peaches, plums, and prunes). Sulfur is nontoxic to mammals, but may irritate skin or especially eyes.

Sulfur has the potential to damage plants in hot (90°F and above), dry weather. It is also incompatible with other pesticides. Do not use sulfur within 20 to 30 days on plants where spray oils have

been applied; it reacts with the oils to make a more phytotoxic combination.

References

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Table 1. Summary of insecticide (botanical, mineral, synthetic) toxicity to mammals

Chemical Name (Trade Name)	Class	Oral LD_{50} [1]	Dermal LD_{50} [2]	Mode of Action	Signal Word
Azadirachtin (Azatin® XL)	Botanical	4,242	>2,000	Undetermined	Caution
Bifenthrin (Talstar®)	Pyrethroid	632	>2,000	Contact & stomach activity	Caution
Carbaryl (Sevin®)	Carbamate	590	>2,000	Contact & stomach activity	Warning/ Caution
Cyfluthrin (Tempo®)	Pyrethroid	960 - 1,150	>2,000	Contact & stomach activity	Caution
d-Limonene (VIP®)	Botanical	>5,000	-	Contact poison	Caution
Diatomaceous Earth	Mineral	-	3,160 - 8,000	Cuticle disruption	Caution
Horticultural Oil (Supreme Oil®)	Oil	>5,000	-	Suffocation	Caution
Imidacloprid (Merit® 75WP)	Neonicotinyl	1,858 - 2,591	>2,000	Contact & stomach activity	Caution
Insecticidal Soap (Safer®)	Soap	16,500	-	Cuticle disruption	Caution
Linalool	Botanical	2,440 - 3,180	3,578 - 8,374	Contact poison	Caution
Malathion (Malathion® 5)	Organophosphate	885 - 2,800	4,100	Contact & stomach activity	Caution
Neem	Botanical	13,000	-	Insect growth regulator, repellent	N/A
Nicotine Sulfate	Botanical	60	140	Contact poison	Danger
Permethrin (Astro®)	Pyrethroid	998	>2,000	Contact & stomach activity	Caution
Piperonyl butoxide (PBO)	Synergist	>7,500	7,500	--	Caution
Pyrethrins	Botanical	1,200 - 1,500	>1,800	Contact activity	Caution
Rotenone	Botanical	60	>1,000	Inhibits cellular respiration	Caution
Ryania	Botanical	750 - 1,200	4,000	Stomach poison	Caution
Sabadilla (Red Devil®)	Botanical	4,000	-	Contact & stomach activity	Caution
Sulfur (Tracite Liquid Sulfur 6)	Mineral	>5,000	>2,000	Contact poison	Caution

[1] An LD_{50} is the median lethal dose, in milligrams (mg) of toxicant per kilogram (kg) of body weight of the test animal, that kills 50% of the population of test animals. A low LD_{50} indicates a more toxic substance. The larger the LD_{50}, the less toxic the substance.

[2] Most of the oral and dermal LD50 values were obtained from product MSDS sheets (CDMS website: http://www.cdms.net/LabelsMsds/LMDefault.aspx?t=2)