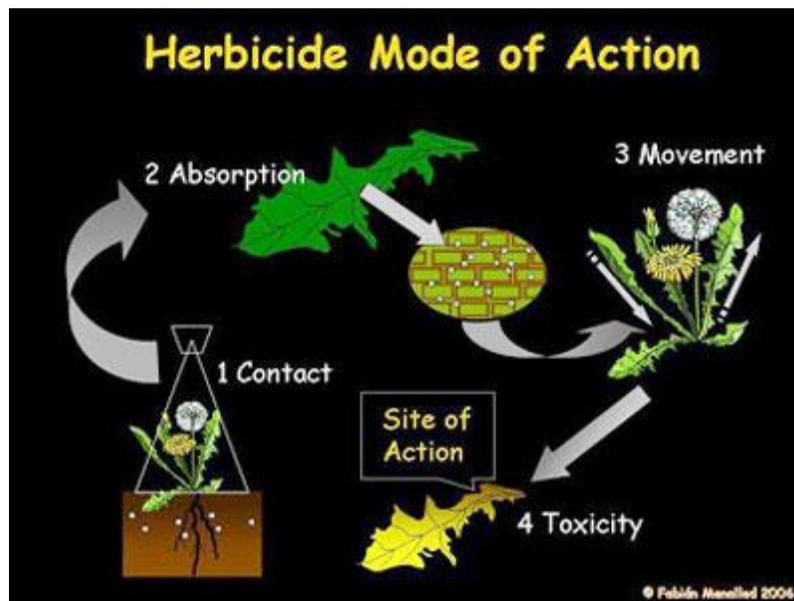


How Pesticides Work

Mode of action describes where and how a particular pesticide acts to affect or kill the target pest. Pesticides with the same mode of action typically produce similar effects or symptoms.

Herbicides

Some weed problems are best controlled with herbicides. This is accomplished through one or a combination of processes: damaging leaf cells and causing them to dry up, altering the uptake of nutrients, interfering with growth and development, or interfering with photosynthesis.



(Image: www.old.wssa.net)

To be effective, herbicides must:

1. adequately contact plants,
2. be absorbed into the plants,
3. be delivered to the site of action in the plant without being deactivated, and
4. accumulate at toxic levels at the site of action.

Herbicide Selectivity



Selectivity refers to whether a herbicide impacts the target plant. A selective herbicide controls or suppresses certain plant species without seriously affecting the growth of plant species. It may be due to plant age and stage of growth, plant morphology, absorption, translocation, deactivation, or environmental conditions. Selective herbicides are used to kill weeds without harming nearby desirable plants.

For example, 2,4-D may be used for selective control of many broadleaf weeds without significant injury to desirable grasses.

However, **desirable plants growing under environmental stress may be injured by herbicides that normally do not harm them.**

Plant age and stage of growth

Young, rapidly growing plants are more susceptible to herbicides than are larger, more mature plants. In general, plants in the vegetative and early bud stages are very susceptible to translocated herbicides.

Plant morphology



Plant structure or shape affects herbicide performance. For example, growing points that are covered or those below the soil surface are protected from contact herbicide sprays. Similarly, herbicide spray droplets tend to bounce off or run off narrow, upright leaves as opposed to broad, flat leaves. A thick, waxy cuticle and/or leaf hairs may slow **absorption** or movement of a herbicide into the leaf. Typically, the leaf cuticle becomes thicker with age.

Other factors

In systemic herbicides, differences in **translocation** between the weed and desirable plant may give selectivity.

Deactivation or metabolism - some plants can stop the activity of the herbicide so the plant is tolerant to a particular product.

Nonselective herbicides, such as glyphosate and diquat, control plants regardless of species if applied at an adequate rate. These herbicides are commonly used where plant growth is not wanted, such as fencerows, irrigation and drainage ditch banks, and greenhouse floors and benches.

Application Timing

Herbicides can be grouped when they are applied relative to crop or weed growth stage and/or weed seed germination. They are generally either soil active or foliar active.

Soil-applied herbicides generally affect seed emergence or seedling growth.

Foliar-applied herbicides control weeds through contact with leaves and stems after the plants have emerged from the soil.

Although the majority of herbicides may be classified into one category, a few are considered soil active and foliar active herbicides.

Pre-plant herbicides are applied before seeding. Some must be incorporated into the soil to be effective; these are referred to as **pre-plant incorporated (PPI)** herbicides. Pre-plant herbicides are applied from a few days to several months before crop planting, depending on their soil persistence.

A **pre-emergence herbicide** is applied before weed germination to form a barrier at or just below the soil surface. Most pre-emergence herbicides prevent cell division during weed seed germination as the emerging seedling comes into contact with the herbicide. Some products do not move within the plant so injury symptoms appear only at the site of uptake.

Post-emergence herbicides are applied directly to emerged weeds. This group of herbicides provides little, if any, soil residual control of weeds. They either kill plants on contact or move to a site of action.

Foliar-applied herbicides are effective generally against young weed seedlings. A spray can be applied broadcast over the crop and weeds, used as a basal spray if there is limited crop selectivity, or applied under shields if there is no crop selectivity. Foliar sprays also are used to control emerged weeds present at planting in conservation-tillage systems. They are called "**burndown herbicides**".



Foliar-applied herbicides are referred to as **contact herbicides** when only the treated part of the plant is affected. Thorough spray coverage is required for them to be effective. **Systemic or translocated**

herbicides enter the plant and move to the site of action. They are particularly effective against perennial weeds because the chemical reaches the root system. However, control may take up to 3 weeks or longer.

Herbicide Persistence

After application, herbicides are broken down at different rates by factors such as microorganisms, sunlight, or moisture.

Persistent herbicides, also called residual herbicides, are stable chemicals. They do not change for a long time after application. Persistent herbicides give long-term weed control without repeated applications. However, if sensitive plants are seeded too soon after an application, herbicide carryover may injure them. Check the Rotational Crop Restrictions section of the label for waiting periods to minimize potential problems.

For example:

ROTATIONAL CROPS*

Treated areas may be replanted with any crop specified on an imidacloprid label, or any crop for which a tolerance exists for the active ingredient, as soon as practical following the last application. For crops not listed on an imidacloprid label, or for crops for which no tolerances for the active ingredient have been established, a 12-month plant-back interval must be observed.

IMMEDIATE PLANT-BACK: All crops on this label plus the following crops not on this label: barley, canola, corn (field, pop & sweet), rapeseed, sorghum, and wheat.

30-DAY PLANT-BACK: Cereals (including buckwheat, millet, oats, rice, rye, and tritiale), safflower

12-MONTH PLANT-BACK: All Other Crops

*Cover crops for soil building or erosion control may be planted any time, but do not graze or harvest for food or feed.

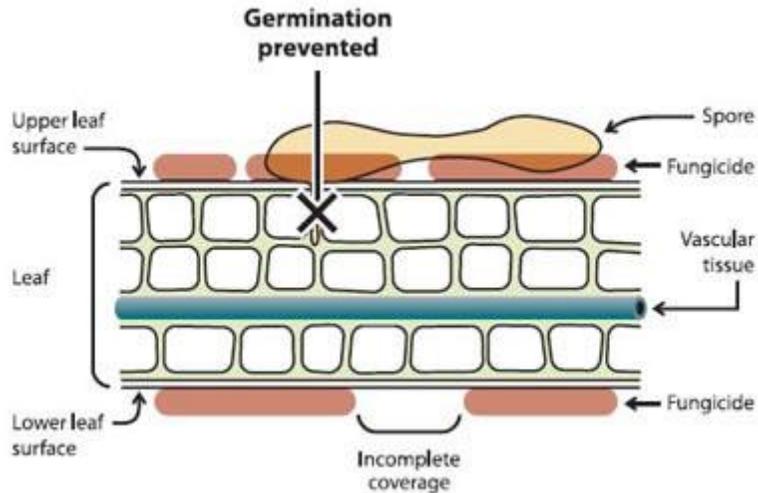
Fungicides

Depending on the target pest, **pesticides used to control plant disease agents are classified as fungicides, bactericides, or nematocides**. Fungicide use appears to be the fastest growing segment of crop protection in the US. When used properly, these chemicals can be important pest management tools. However, they are not a substitute for good crop management practices. Pesticides are the last line of defense for controlling crop diseases.

Classification

Fungicides control diseases caused by fungi. They may be applied to seeds, soil, or foliage. These pesticides may be classified in several ways.

Protectant fungicides are applied before an infection period begins to protect leaves, fruit, etc. from becoming infected. They will be effective only on the plant tissue present when the pesticide is applied. Protectant fungicides can stop both spore germination and host penetration but have little or no effect once the fungus has entered or colonized host plant tissue.



Mode of action of protectant fungicide (www.agr.gc.ca)

Protectants must be applied before or during an infection period. Persistent fungicides may protect plants for a relatively long time. Non-persistent fungicides control the pathogen on contact or for a short time so they have to be applied more frequently. The product label tells how long to wait between treatments. The interval varies with the persistence of the pesticide; environmental conditions (humidity, temperature, or rainfall) may make more frequent applications necessary.

Curative or eradicant fungicides have the ability to **inhibit or stop the development of infections that have already started**. With some fungicides, this includes a degree of anti-sporulant activity that helps to slow disease development by limiting the reproductive potential of the fungus. This post-infection activity makes fungicide effective if the disease is established at a low level. It is very important to remember that the curative activity may be limited.

Uni-site fungicides target a specific function of fungal development so they are **very prone to resistance development**. Just one mutation on the target site or any other means of avoiding or countering the effect of the fungicide, can lead to a significant loss of efficacy of the fungicide. Biosynthesis of compounds essential to the development of the fungus, respiration and cellular division are the most common targets of unisite fungicides.

Multi-site fungicides act on several functions of fungal development. They are **less prone to resistance development** because mutations in the fungus must occur at all target sites for resistance to develop.

Broad-spectrum - active against many fungal pathogens.

Narrow-spectrum - effective against only a few types of fungi. The label lists specific diseases controlled by a product.

Systemics - move from the application site to plant parts where disease is occurring. Movement is usually upward toward plant tops and leaf tips.

Locally systemic pesticides enter the plant where they land and move only a short distance. They may act as both a protectant and an eradicator.

Bactericides kill bacteria. These protectants cannot eradicate existing infections so they must be applied before infection occurs.

Nematicides are used to **control diseases caused by nematodes.** They are usually toxic to warm-blooded animals and should only be used with extreme caution. Nematicides may or may not be fumigants.

Factors That Affect Fungicide Performance

1. **Timing** is the most important part of fungicide application. Diseases can develop and spread quickly. Most fungicides cannot cure a disease infection, they can only protect against it. **If an application misses the window, control is lost.**
2. **Water volume** is the **most important application parameter for fungicide application.** In years of study, increasing water volume had a greater effect on fungicide performance than changes in droplet size or spray pressure. More water is needed for fungicides than herbicides because of the greater amount of plant material present. Getting coverage on leaf areas deeper into the canopy requires more water. Although finer sprays can also help with coverage, this practice is riskier due to drift potential and higher evaporation rates.
3. **Double nozzles**, especially the asymmetric types, are becoming more popular for fungicide applications. They have proven **effective for diseases where an exposed vertical part of the plant canopy is the primary spray target.** Double nozzles are also useful for keeping spray droplets from getting too coarse.
4. **Travel speed** is important. Canopy penetration sometimes improves with slower travel speeds; this can be used to advantage by eliminating the need for a special fungicide nozzle.



Insecticides

Insecticides are chemicals used to kill insects and some other arthropods (mites, ticks, spiders, etc.) or to prevent them from causing damage. They are classified based on their structure and mode of action. **Acaricides** are pesticides that are targeted to control mites; they may have little or no activity against insects.

Many insecticides **act at specific sites in the insect's nervous system.** These usually provide very quick knockdown of insects that may ultimately die from dehydration or starvation. The insecticides usually are sprayed on infested plants or surface on which they rest. Depending on the pest, the insecticide may kill by

direct contact with the spray droplets, ingestion of treated foliage, or prolonged contact with the residue on a treated surface.

Some Types of Insecticides

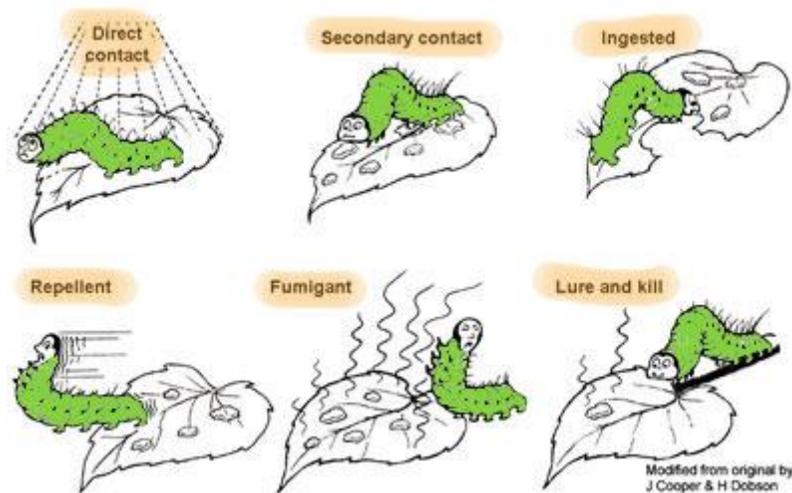
Cholinesterase inhibitors interfere with nerve impulse transmission at the synapse gap. Organophosphate (malathion, diazinon, acephate) and carbamate (carbaryl) insecticides belong to this group. They can be used as contact or residual insecticides. Once widely used for insect control, these insecticides have largely been replaced with other groups.

Bacterial toxins are produced by certain soil microorganisms. Examples include *Bacillus thuringiensis* (Bts) and spinosyns. **Bt toxins disrupt the digestive tract of caterpillars** so they are specific insecticides that must be eaten.

Botanical insecticides are **defensive chemicals extracted from plants** and used for pest control. Pyrethrins are extracted from the flowers of certain Chrysanthemum species. Pyrethroid insecticides are synthetic chemicals based on the molecular structure of the natural insecticide. Nicotine found in some solanaceous plants is the basis for neonicotinoid family or insecticides. Both groups work on the nervous system. Azadirachtin is a chemical from the neem tree that has insect and disease control activity.

Insect growth regulators (IGRs) are chemicals based on hormones that regulate arthropod development. They **disrupt metamorphosis** so they are active against immature stages but not adults.

How Insecticides Enter the Target



Ways insecticides can enter pests (www.dropdata.org)

1. **Direct contact** - the target insects are hit directly with spray droplets.
2. **Secondary or indirect contact** by crawling over or resting on treated surfaces. The insecticide is **absorbed through thin portions of the exoskeleton**. These are especially effective against soft-bodied insects such as aphids, some caterpillars, thrips, etc. They are less effective against insects with thick or hard exoskeletons or hard wing covers (beetles), or hairy caterpillars. Insecticides on treated surfaces may enter insects through thin portions of the exoskeleton, especially the flexible areas of the feet.
3. **Ingestion** of spray residues of contact insecticides on plants by pests with chewing mouthparts (beetles, caterpillars) or of systemic insecticides in sap by aphids, leafhoppers, plant bugs, etc.
4. **Repellents** prevent insects from staying on or eating treated surfaces. Chemicals called **anti-feedants** stop insects from eating treated tissue.
5. **Fumigants** are pesticides that become gases when released into the air or soil. Fumigants can be used to control nematodes and pathogens in the soil or insects in wood or stored products.
6. **Pheromones**, chemicals used by insects for communication, can be used in insect control. For example, some female insects release sex pheromones to attract males for mating. Synthetic sex pheromones of some species can be released from dispensers in sufficient amounts to confuse males so they cannot locate females.

Broad spectrum insecticides kill a variety of arthropods, including beneficial and harmful species.

Narrow spectrum or selective products work on a limited, often related group of species. For example, "Bt" insecticides must be eaten in order to kill caterpillars. They are specific stomach poisons.

Factors That Affect Insecticide Performance

Successful control of an insect pest requires proper application, including coverage and timing of the treatment. Some products are effective against specific pests, such as caterpillars. Higher labeled rates are required for specific pests (such as fall armyworms) or pests that are in the later stages of their development (small grasshopper nymphs *vs* the larger adults).

Other Pesticides

Molluscicides are pesticides that are toxic to slugs and snails. They must be eaten so they are formulated as baits that may require specialized application equipment. The two common active ingredients in slug baits are metaldehyde and iron phosphate. **Metaldehyde** prevents slugs from producing the mucus that they need to move and feed. However, **metaldehyde can poison and even kill dogs and other mammals** that might feed on it. **Iron phosphate** is a stomach poison that damages their digestive tissue. Snails may stop feeding on plants after consuming this pesticide but can take up to 7 days to die. Iron phosphate may be more effective than metaldehyde during periods of high humidity or if there are rainy conditions.



Rodenticides, pesticides used to kill rats and mice, are available in three main forms: **poison baits, tracking powders, and fumigants.**

Poison baits are rodenticides that are formulated as food-based toxicants containing seeds or grain to attract the rodents. Many baits are **anticoagulants** that kill by interfering with normal clotting of the rodent's blood. This causes the rodent to die from internal bleeding. The newer anticoagulants are normally lethal to rodents after a single feeding. However, the rodent usually lives for 3 to 5 days before it dies. The older anticoagulants required several feedings and two or more weeks for death to occur.

There are some **non-anticoagulant rodenticide baits**. Most of them kill rodents after a single feeding. Some kill rodents in 2-3 days by causing paralysis. One causes an excess of calcium in the blood which leads to heart failure in 3-4 days. Zinc phosphide kills rodents in 1-24 hours by forming phosphine gas in the circulatory system.

Commercial baits, in pelleted or meal form, are available in sealed plastic, cellophane or paper packets (known as “place” packs), as loose bait, or molded into paraffin (wax) blocks. The wax block formulation is very useful for both outdoor and indoor baiting locations because it resists dampness and moisture.

Regardless of which bait formulation is used, **be sure to place baits in areas that are inaccessible to children, pets, and wildlife** or in tamper-resistant bait stations. Dogs, in particular, will seek out and find baits placed in areas that are accessible. **Other than when placing baits directly into a rodent burrow, it makes good sense to confine baits in an enclosed bait box.**

Bait boxes help to

- reduce accidental contact with people and non-target animals
- keep bait fresh by protecting it from dirt, moisture, and dust
- provide a protected and attractive place for rodents to feed, and
- allow label, company contact number, and other pertinent information to be provided at the baiting site.

Avicides are available to control nuisance birds in some situations. They must be applied according to label instructions to prevent harming non-target species.