WHAT'S IN YOUR TOOLBOX?

Options for the management of pests in Wyoming gardens and greenhouses

Jeff Edwards, University of Wyoming Extension Specialist

You will eventually have pest problems whether growing fruit and vegetables in a traditional garden space or in a protected space such as a greenhouse, low tunnel, hoop house, and/or high tunnel.

These pests include insects, mites, or other arthropods. Greenhouse-like structures not only protect the plants from the elements but can also provide optimal conditions for pests. These structures may also exclude natural enemies from their pesky hosts. Critical to any good defensive management strategies are scouting, correct identification, understanding a little biology, the feeding damage, and reproductive methods of these pests. Understanding the variety of management options available and having a plan in place to quickly implement tactics that work best for your production strategy is important.

The Worker Protection Standard (WPS) regulations for workers and/or handlers must be followed if you have people working for you. The Worker Protection Standard can be found at: https://www.epa.gov/pesticide-worker-safety/agricultural-worker-protection-standard-wps

Knowing the Wyoming Department of Agriculture classifies hoop houses and high tunnels as **greenhouses is important** no matter what type of **pest management strategies** are followed. The EPA defines growing agricultural crops in all of these types of structures as **enclosed space production.** Using registered products in these structures is permissible only if the product label indicates it can be used in a greenhouse or in an enclosed space production. An exception has been made by the EPA concerning products with a 2(ee) label. These products can be used in enclosed space production, provided the crop is listed on the label. 2(ee) labels are considered supplemental labeling and many not be included with the product labels.

There are many control options available, and the best management plan utilizes **Integrated Pest Management strategies (IPM)**. IPM is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks. It **is the understanding of all possible management strategies and utilizing the best combination of tactics to keep the problem in check** – consider IPM as a tool box full of pest management options.

INTEGRATED PEST MANAGEMENT (IPM)

IPM components include

Pest detection, identification, and population monitoring – Checking for pests (scouting), including proper identification and monitoring pest populations, will assist in determining the best management strategy. Conduct continuous monitoring to ensure that chosen management strategies are keeping pest populations in check.

Cultural control – Using techniques such as crop rotation to disrupt life cycles of pests that complete their life cycles in one crop.

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Host plant resistance – Can include natural resistance or developing crop varieties resistant to common pests. When selecting seeds, look for indicators they are resistant to certain pests.

Biological control – Using natural enemies including predators, parasitoids, or diseases to suppress insect pest populations.

Chemical control – The use of registered products whether organic, bio-rational, or conventional chemistry to manage pest populations.

Pest detection and population monitoring and using traps

Pests must **first be identified** to implement a proper management strategy. Trapping what is there is one way to monitor pest populations. There are a variety of trap types available. Some are paper or plastic colored cards covered with a sticky glue; other traps incorporate cages with an attractant, and others are a combination that includes a sex pheromone. The sex pheromone is specific to one type of pest and will either attract male or female insects.

Commercially available (Table 1) yellow sticky traps in greenhouse production will catch most winged insects including aphids, leafminers, thrips, whiteflies, fungus gnats, and shore flies. Blue traps are sometimes better at detecting western flower thrips. Traps are used to assist in the detection, monitoring, and identification of the pests and how the population changes over time. Traps alone are usually not effective at controlling pests. You can make your own sticky traps by spreading a variety of household items or a product called Tanglefoot onto blue or yellow card stock – but purchasing pre-made traps is much more convenient and less messy.

Attach sticky traps to a wooden stake and place the stake vertically in or near a plant at or just above the top of the foliage. Placing the sticky trap just above the soil surface can trap other pests. Be sure to place some traps near vents, doors, and other areas where pests may enter. Some growers place traps outside greenhouses to help detect insects moving in from outside. The number of traps will depend upon your objectives and ability to inspect them. Discuss the size of the area you are monitoring with a supplier; they can make recommendations concerning the number of traps needed. A minimum number should be two to three per structure, but more will be better, especially if using traps to monitor whitefly population trends.

Visually inspect traps at regular intervals (weekly or more frequently) and **replace when counts of pests are recorded**. Captured insects should be **identified**, **counted**, and those numbers **recorded** to understand the infestation levels and population trends. Pest population density estimates are usually sufficient to determine if control measures are needed. Some people prefer to deploy traps for shorter periods, for example, a few hours or a day, to get a better picture of insect activity at that moment. **Number the traps and create a map for reference** so all traps can be monitored and for ease in the detection of hot spots. Plant pests can be generalist feeders (eat everything) or specialist feeders (prefer plants from one or several distinct groups). You will be better equipped to place traps in the correct locations (nearer to preferred host plants for instance) when you become familiar with a pest/host relationship. There are many good references available to assist with pest identification. Your local extension educators can assist or point you in the right direction.

Table 1. Sample of Commercial Sources for Insect Traps

Great Lakes IPM 10220 Church Street, NE Vestaburg, MI 48891 (989) 268-5693 www.greatlakesipm.com	**Trece, Inc.** P.O. Box 6278 Salinas, CA 93912 (408) 758-0204 www.trece.com (pheromone lures and traps)	**Gempler's** P.O. Box 270 Belleville, WI 53508 (800)382-8473 http://www.gemplers.com (general supplier)	**Olson Products Inc.** P.O. Box 1043 Medina, OH 44258 (216)723-3210 www.olsonproducts.com (sticky card traps)

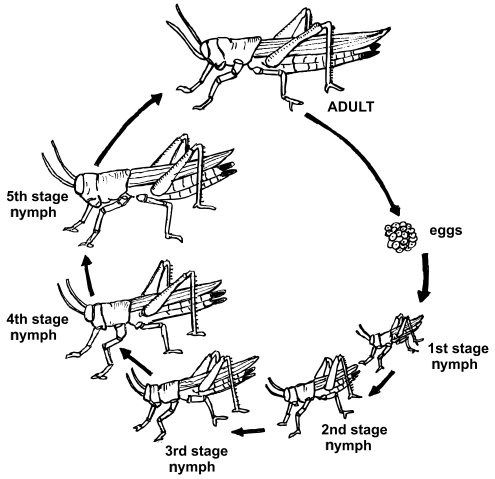
Pest Detection by Plant Inspection

Sticky traps will not replace plant inspection for pest detection. Whiteflies occur in localized infestations that may not be detected by using traps. Non-winged aphids and spider mites are not usually caught on traps. Plant inspection is an important part of a pest management program. Inspect plants in all areas, looking underneath leaves near the top, middle, and lower parts of plants. A 10-30X hand lens can aid in detecting plant pests, particularly mites and whiteflies. Identifying what is there and taking appropriate management measures when necessary is important.

INSECT IDENTIFICATION

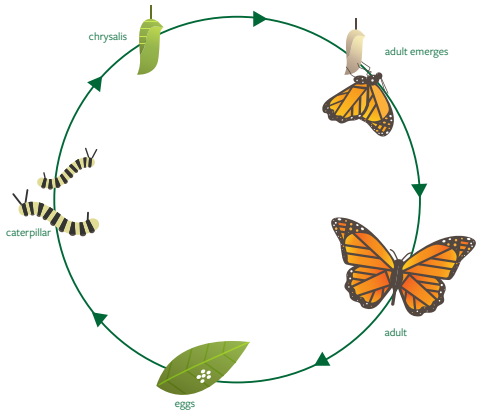
Understanding how insects grow and develop can aid in identification and management. Insect **metamorphosis** in most instances can be defined as **simple** or **complete**.

In **simple** metamorphosis, the life cycle starts as **eggs** that hatch into **nymphs**. Nymphs resemble smaller versions of adults. Nymphs will **molt** (leave previous exoskeleton and grow) several times and finally develop into an **adult**. You may be able to identify a pest by the **exoskeletons** that are left behind (these are also called **cast skins**). Adults may or may not have wings. True bugs or grasshoppers are the best examples of simple metamorphosis. There are no absolutes in biology, and aphids are an exception. Aphids do have simple metamorphosis; however, they can give birth to live young skipping the egg stage. Generally, all life stages of insects with simple metamorphosis feed on the same host plants.



Simple metamorphosis of a grasshopper.

Complete metamorphosis also starts with the **egg** stage. The eggs hatch into **larva**. Larva do not resemble adults. Larva will molt several times (larval **instars**) and then molt into a resting and non-feeding stage called the **pupa**. Finally, the pupa will molt into the **adult**. Sometimes the adult and larval stages feed or damage the same host plants, sometimes the adults do not damage plants.

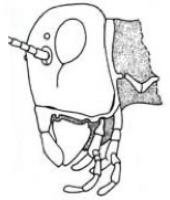
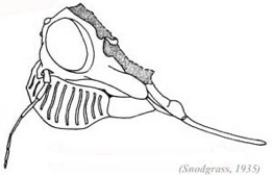
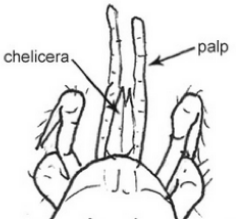


Complete metamorphosis of a butterly. Trgrowth, shutterstock.com.

The types of mouthparts and feeding damage they inflict can also assist identification. Examples of the three most injurious types are chewing, piercing-sucking, and scraping, shown in Table 2.

Some of the more common pests you may encounter are in Table 4, page 7. This table identifies the pest by name, provides a description, any telltale indicators you may notice, other comments, a line drawing of the pest, and an image to assist identification.

Table 2. Insect Identification via Damage to Plants

Mouthpart Type	Visible Damage	Examples
Chewing	Insects with chewing mouthparts are grazers and remove plant tissue. Leaf miners have chewing mouthparts and feed between the upper and lower leaf cuticle of a leaf.	Beetles, grasshoppers, caterpillars = Lepidoptera larvae  (Snodgrass, 1935)
Piercing-sucking (needle-like)	Insects pierce plant and suck sap (phloem). Feeding wounds may not be evident or will be pinhole sized and may show up as white or brown spots - plant may be wilted or covered with sticky honeydew.	Whiteflies, aphids, mealybugs, scale insects  (Snodgrass, 1935)
Scraping – modified cone shaped, piercing sucking	Pierce or scrape the plant surface and suck the plant juices from the wound. Feeding disrupts cell membranes, and the insects will consume cell fluid as it leaks. Feeding damage described as being mottled or blotchy.	Thrips and spider mites 

MANAGING PEST POPULATION METHODS

Some management strategies can be implemented ahead of time to mitigate a potential problem. Other strategies must be started immediately once the pest is identified. Regardless, there must be a strategy that can be best implemented to suit your needs.

Cultural Control

The goal is to make the crop environment less suitable for insect pests. Most of the time, cultural control is used as a preventative measure. By anticipating insect problems, the control techniques avoid or minimize the pest's impact on a crop. Cultural control techniques are most effective when the target insect pests have few suitable host plants, do not disperse far or frequently, and/or have complex nutritional or environmental requirements during their life cycles.

Proper irrigation, fertilization, and weed control can improve plant vigor and minimize yield loss when damage occurs. Selecting genetically resistant and tolerant crop varieties can minimize plant damage.

Other Entomological Facts

Insects have an **open circulatory system** (no veins or arteries – the blood is bathing all organs). Their heart runs along their back and pumps blood into their heads.

Insects' nervous systems run along their bellies.

Insects breathe through holes in their sides called **spiracles.** These holes lead to individual **trachea** or tubes that reach into their bodies (similar to an arterial system).

There are four main strategies for cultural control of pest insects

- Disrupt pest habitat in and around a crop.
- Alter planting time and/or plant density.
- Create a diversion.
- Minimize yield loss by preventing injury by insects.

1) Disrupt pest habitat in and around a crop

Insect pest habitat can include crop residue, spilled seed, weeds along crop edges, volunteer plants, and soil. The methods used to alter pest habitats include tillage, plowing, burning, and sanitation.

- **Tillage** can reduce some pest populations. For pests that overwinter in the soil, mortality is increased when tillage occurs before a cold winter. The soil disturbance exposes the insect to harsher temperatures and reduced soil moisture conditions, reducing likelihood of survival.

- **Burning, plowing, or mowing** of plants around field (or garden) edges where pests may overwinter or develop during the cropping season. This may also reduce habitat for natural enemies. Altering grasshopper habitat may backfire – if you remove their weedy hosts, they are certain to move into the garden.

- **Sanitation** is important in the field and in storage and processing. Destroying or removing crop residue from the field by plowing, shredding, chopping, burning, or feeding it to livestock can remove or kill insect pests. Sanitation in storage and processing can be achieved by keeping facilities clean and eliminating spillage. These practices can reduce the spread and development of insect pests.

2) Alter planting timing and/or plant density

Planting dates and plant densities can be easily adjusted in gardens and greenhouses.

- **Changing planting in time** means altering the normal planting time by waiting one or several weeks to plant. Change it up a bit; try planting certain crops midsummer instead of being the first to plant a garden. Try planting early if gardening in an enclosed space. Cold-tolerant crops can be planted in high tunnels in Wyoming on the first day of spring. This strategy is considered avoidance.

- **Adjusting planting density** means changing the number of plants and where they are relative to other crops. Dense planting increases humidity, creating a less favorable environment for some pests. Increasing the humidity may also increase the possibility of plant diseases.

3) Create a diversion

Create an area or areas that prevent pests from reaching the host plant. Techniques include physical barriers and trap cropping.

- **Physical barriers** including screens can be useful in reducing the movement of some insects into greenhouses. Whiteflies, leafminers, Lepidoptera (moths), and winged aphids can be excluded relatively

easily. Thrips are very difficult to exclude because of the small, screen mesh size required. Colored plastic mulches have shown repellency to some pest insects. The use of barriers around plants can prevent cutworm damage.

- **Trap cropping** is planting a preferred host plant of an insect pest near the primary crop to be protected. The pest then infests the preferred or trap crop instead of the primary crop. If necessary, the pests can then be killed in the trap crop. Trap crops can be any species the pest prefers – even be the same species as the primary crop. If the trap crop is the same species as the primary crop, it should be planted at a time that will best lure the pest away from the primary crop.

4) Minimize yield loss by preventing insect injury

The techniques already mentioned focus on reducing crop exposure to insect pests, but reducing yield loss is possible even when insect damage happens. Once damage occurs, harvesting as early as possible can prevent further yield loss.

Biological Control

Biological control of insects and mites on vegetable crops is practiced worldwide and happens naturally. Biological control represents one alternative to insecticides. Biological control is the conscious use of living, beneficial organisms, called **natural enemies**, to manage pest populations. The natural enemies of insects are a diverse group of organisms that includes **predators**, **parasitoids**, **nematodes**, and **microorganisms**. Biological control is a key component of IPM. The intent of biological control is not to eradicate pests, but to keep them at levels at which they cause no appreciable harm.

Natural enemies can be purchased from commercial sources for the management of many common insect or mite pests. If you choose a commercial supplier, be certain to ask about recommended release rates and timetables. Biological control is not a once and done activity – you REALLY need to have a good monitoring program in place to keep track of the pests and the biological control agents to make certain everything is working properly.

Keeping predators and parasitoids in the structure or on the infested plants long enough for them to reproduce are the keys to success while using beneficials. Monitoring the pest population to see that the biological agent is managing the pest population is also important. Keeping predators and parasites around long enough can be achieved by caging the predators and parasites with the prey species (or adequate alternative food and water source) for at least seven days. Tables 4-6, page 7, provide data on available predator and prey species and United States suppliers from whom they can be ordered. Additional references concerning insect suppliers and biological control are in Table 3.

Western flower thrips are the most difficult pest to manage. Many growers are able to use biological control as their primary pest management method. Other growers will try to integrate into their program pesticides with few or no harmful effects on beneficials, or apply selected pesticides only to localized areas where pest infestations exceed acceptable levels. Some growers will use biological controls for part of the year, changing to pesticides if pests become too numerous. Even more than when using pesticides, biological control requires a good pest scouting and monitoring program.

Chemical Control

Many products used to control pest insects can also be harmful to beneficial insects; however, sometimes pesticides will be the only management choice that makes sense. Potential harmful effects can be mitigated with proper use. One of the ways to lessen these effects is to not use pesticides for at least 30 days before beginning a biological control program and do not use them anywhere in a structure after beginning a biological control program. Local or spot applications generally are less harmful to natural enemies than treating the entire growing area. Some registered pesticides are less toxic to beneficial insects and predatory mites. These less toxic products are considered bio-rational **pesticides** and are listed in Table 8, page 16. All of these products are **OMRI (Organic Materials Review Institute) listed** and include *Bacillus thuringiensis*, which is a bacterium specific for controlling certain pest species. Insecticidal soaps, an insect-specific fungus *Beauveria bassiana*, azadirachtin (extract from seeds of the neem tree), and pyrethrum tend to be less harmful than conventional materials. **This does not mean these formulations are approved for organic production or that materials are harmless, but that natural enemies can be re-introduced soon after an application without deleterious effects.**

Table 3. Additional Information Sources Concerning Biological Control
Association of Natural Biological Control Producers http://www.anbp.org/

Application method and formulation will affect the toxicity, or lack thereof, of pesticides to natural enemies. A number of studies have conflicting information concerning how long a particular pesticide will remain harmful to a natural enemy. When in doubt, be conservative.

A list of conventional products registered in Wyoming for use in gardens and greenhouses is in Table 9, page 17. Several of these are insect growth regulators. Insect growth regulators (IGRs) disrupt the development of insects and are classified as reduced risk products. IGRs are insect-specific and have been proven nontoxic to mammals.

When managing pesticide resistance, recognizing the different **modes of action (MOA) is important**; however, this information may not be on the label. The MOA indicates how the product works on the insect. Rotating between products with **different Insecticide Resistance Action Committee (IRAC) action** numbers is a good idea. Different numbers indicate different MOAs. Changing the products will reduce the chance of a pest becoming genetically resistant to a particular MOA. Table 10, page 18, provides more detailed information on IRAC modes of action and is provided for your information and own research.

Always read, understand, and follow label instructions when using a pesticide, whether a bio-rational product or conventional. READ AND FOLLOW THE label before purchasing and using any pesticide. Read the label each time you use a pesticide. The label is the law. One does not need to be afraid of pesticides, but they do need to be handled with respect.

Calibrate your application equipment (please see UW Bulletin MP-124.18 *1/128th Method of calibration: Calibrating single nozzle hand held sprayers and high pressure hand guns* at http://wyoextension.org/publications/Search_Details.php?pubid=227&pub=MP-124.18) Once the applicator is calibrated, you will be able to find the correct dosage on the label for the pest you are attempting to manage and mix the proper amount in the spray tank.

READING A PESTICIDE LABEL

Pay particular attention to sections of the label listing the **personal protective equipment (PPE)**, the **restricted entry interval (REI)**, and the **pre-harvest interval (PHI)**.

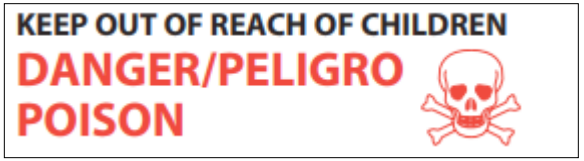
- The **PPE** is the protective equipment that must be worn while handling, mixing, and applying pesticides. The amount and type of PPE to be worn will be described on the product label. The PPE must also be worn if you return to the treated area before REI has passed. Many products available for homeowner use do not list the PPE. At a minimum, one should wear long-sleeve shirts, long pants, socks, waterproof boots, and nitrile gloves.

- The **REI** is the amount of time (usually in hours) that must pass before entering the treated area. This is the same amount of time for your children and your pets. Again, if you must return to the treated area before the REI has expired, you will need to wear the recommended PPE.

- The **PHI** is the amount of time (usually in hours or days) put in place so if the product has been applied according to the label rates, there should be no detectable residue remaining on the harvested crop.

Other sections of the label include the **signal word.** These words indicate the **acute oral toxicity to humans** and include Caution, Warning, Danger, or Danger with Skull and crossbones.

- **Caution** is considered low toxicity to relatively non-toxic.
- **Warning** is moderately toxic.
- **Danger** is toxic.
- **Danger with skull and crossbones** is highly toxic.



OTHER INFORMATION CONCERNING TOXICITY

In addition to the signal word, one may find values associated with relative toxicity of the products. This is usually known as the Acute Oral Toxicity, reported as LD50. The LD50 is the value of a one-time oral exposure to kill 50 percent of a test population (usually mice or rats). **This information will never be listed on a product label; it can be found on the product Safety Data Sheet** (SDS). The LD50 is included as another point of reference to compare these products. If you would like to read and understand more about the toxicity of pesticides, please refer to UW publication MP124.8 *Pesticide Residues in Perspective* at

http://wyoextension.org/publications/Search_Details.php?pubid=786&pub=MP-124.8. Do some research. All product labels and safety data sheets are available on the internet. Just type the product brand name plus "label" or "SDS" in your browser of choice.

Appendix

If you would like further explanation of the mode of action or any other terminology in this paper, simply enter the term into your web browser to search on the topic.

Table 4. Insects Commonly Found in Gardens and Enclosed Space Production

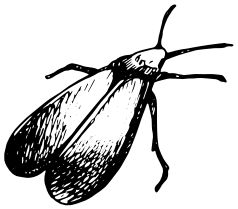
Pest	Description	Telltale indicators	Other comments	
Whiteflies	Adults are small, white, resemble moths and poor fliers. Immature whiteflies are small green/yellow discs. All life stages have piercing-sucking mouthparts and feed on plant sap. Color image contains adults and cast skins of the nymphal stage. Wide host range.	Plants off-color, wilted, surface may be sticky –look off-color (dark) or blotchy (stippled). Ants and other hymenopterans may be present. Prolific honeydew producers black, sooty mold may be present.	Generally found on the underside of plant leaves.  Duda Vasilili, shutterstock	 Scott Bauer, USDA Agricultural Research Service, Bugwood.org
Aphids	Small, tear-drop shaped. Long slender legs. Immature aphids look just like adults only smaller. Cornicles (pipe-like protrusions) on abdomen are defensive structures. Some adults may have wings. Poor fliers. Can be any color. All life stages have piercing-sucking mouthparts and feed on plant sap. Parthenogenic (reproduce without males) and ovoviviparous (born pregnant) = high reproductive rate.	Plants may wilt, surface may be sticky – look off-color (dark) or blotchy (stippled). White cast skins may be present. Ants and other hymenopterans may be present.	Honeydew-plant sap excreted from the anus. Sooty or black mold (fungus) may be growing on honeydew. Found on underside of leaves and plant stems.  Aphids	 Merle Shepard, Gerald R. Carner, and P.A.C Ooi, Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia, Bugwood.org

Table 4. Insects Commonly Found in Gardens and Enclosed Space Production

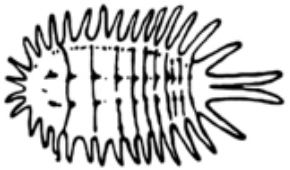
Pest	Description	Telltale indicators	Other comments	
Mealybugs	Small, oval, immature stages have waxy white fuzz over back side of body. Immature stages most common and more easily noticed; adults are winged. All life stages have piercing-sucking mouthparts and feed on plant sap.	Plant leaves may be distorted and yellow. White fuzzy stuff on leaves and stems of plants.	Usually found near plant veins or nodes on stems or cracks in bark. 	 Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org
Scale insects	Adult females are round to oval and attached to host. Males are winged. Scale insects are categorized as being soft, hard, or cottony. Most likely will only see adult females. All stages have piercing-sucking mouthparts. Pest of perennial plants including ornamentals and fruit.	General decline of plant, plant may be sticky.  Scale (*Eriococcus confusus*) Lesley Ingram, Bugwood.org	Immature scale insects overwinter underneath the dead female and emerge in the spring as crawlers. Crawlers move to new locations on the plant and can be mistaken for mites.	 European peach scale (*Parthenolecanium persicae*) Lesley Ingram, Bugwood.org

Table 4. Insects Commonly Found in Gardens and Enclosed Space Production

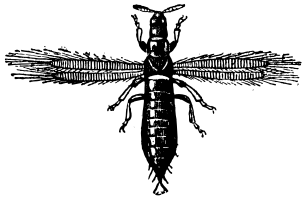
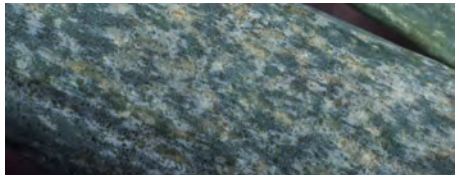
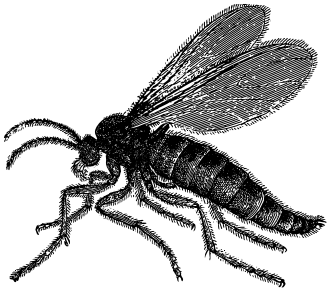
Pest	Description	Telltale indicators	Other comments	
Thrips	Small, rod or cigar-shaped. Immature and adults look similar – adults will have wings. Scraping mouthparts.	Feeding damage appears to be thin scrapes on plant surface. Can be found on all parts of the plant. Damage can make plant have tan/brown or frosted color.	Can use yellow sticky traps to monitor these pests.  Morphart Creation, shutterstock	 Alton N. Sparks, Jr., University of Georgia, Bugwood.org  Damage - Alton N. Sparks, Jr., University of Georgia, Bugwood.org
Flies	Fungus gnat adults are small, dark grey, and relatively poor fliers. Larvae are white, slender, legless (=maggots) with a black head and smooth, semi-transparent skin revealing digestive tract contents. They feed on root tissue – can be a pest in potted plants.	Pesky small flies in and around plants.  Hein Nouwens, shutterstock	Can use sticky traps to catch, monitor, and identify. Larvae feed on root tissue and can be annoying pests of plants grown in potting mixes with high organic content or mulched with compost.	 Whitney Cranshaw, Colorado State University, Bugwood.org

Table 4. Insects Commonly Found in Gardens and Enclosed Space Production

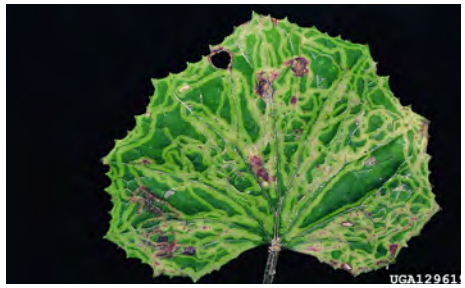
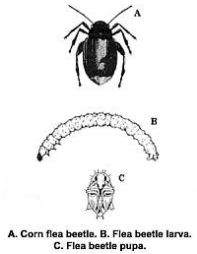
Pest	Description	Telltale indicators	Other comments	
Leafminers	Usually small, maggot-like larvae. Can be legless or have legs depending on to which Order they belong. Can be the larvae of beetles, flies, or moths.	Larvae cause damage. They feed and develop between the tissue layers of leaves. Tunnels in the leaf.  http://gardening.yardener.com/Leafminer	Many different pests in this group. Most damage is cosmetic. Control can be as simple as removing infested leaves.	 Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org
Flea beetles	Small dark beetles 1/15th to 1/6th of an inch. About the same size as aphids. Unmanaged, they can consume or kill plants. Larvae are found in the soil and feed on plant roots or organic matter. Eggplant is a common host.	Adults cause damage. Chewing mouthparts chew tiny holes in leaves.  A. Corn flea beetle. B. Flea beetle larva. C. Flea beetle pupa. https://www.fluvannamg.org/flea-beetles-2/	Can be present in large numbers, powerful hind legs, jump away when threatened.	 https://extension.umd.edu/hgic/flea-beetle-vegetables
Pill bugs & sow bugs	Distant relatives of crustaceans. Sow bugs have appendages that resemble legs on the hind end. Pill bugs do not have these appendages and have the ability to roll into a ball (rolly-pollies)  Joseph Berger, Bugwood.org	They may clip young, tender seedlings at ground level. Pill bug  Joseph Berger, Bugwood.org	These are generally feeders of organic matter; however, they can be an issue in the garden. Damage may resemble cutworms. Seedlings may be clipped at soil level and consumed.	Sow Bug  Joseph Berger, Bugwood.org

Table 4. Insects Commonly Found in Gardens and Enclosed Space Production

Pest	Description	Telltale indicators	Other comments	
Colorado potato beetle	The adults are robust beetles with five yellow and black stripes on back. Larvae are reddish-orange, humpbacked, with two rows of black spots on each side	Adults and larvae cause damage. Chewing mouthparts – remove large portions of plants while feeding.  Larva. Whitney Cranshaw, Colorado State University, Bugwood.org	Plant hosts include potato, eggplant, and tomato.	 Schankz, shutterstock
Mexican bean beetle	Adult bean beetles are pale yellow to copper-colored with 16 black spots on their outer wings. They are sometimes mistaken for a lady bug. Adults lay egg clusters in early summer; the yellow eggs will appear on the underside of the leaves. Larvae are yellow with black spines	Adults and larvae cause damage. Chewing mouthparts. Can cause major damage to beans. They feed on the leaves and bean pods. In heavy infestations, the tissue between the leaf veins may be completely skeletonized.  Larva. Eugene E. Nelson, Bugwood.org	Plant hosts include dry beans, cowpea, black-eyed pea, soybean, and may also feed on mung bean, velvet bean, alfalfa, and clover.	 Muhammed Naaim, shutterstock
Caterpillars	Worm-like larvae, adults are butterflies and moths.  http://etc.usf.edu/clipart/69500/69524/69524_insects_moth.htm	Larvae cause damage. Chewing mouthparts – remove large portions of plants while feeding.	Aggressive feeders, many host plants, may produce webbing.	 Charles Ray, Auburn University, Bugwood.org

Table 4. Insects Commonly Found in Gardens and Enclosed Space Production

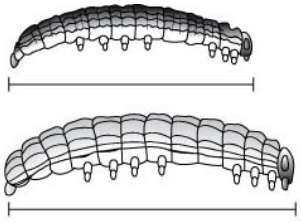
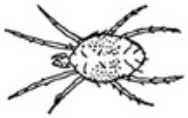
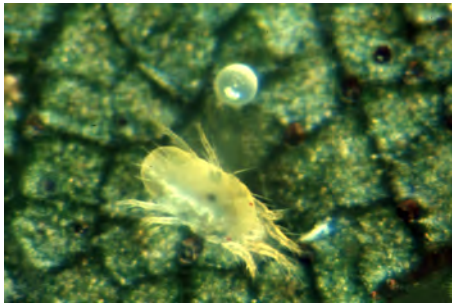
Pest	Description	Telltale indicators	Other comments	
Caterpillars cutworms	Worm-like larvae, adults are butterflies and moths. Most of these larvae feed at or near the soil surface. Larvae are cryptic feeders – usually stay hidden during the day.	Larvae cause damage. Have chewing mouthparts – clip plants at soil surface  http://www.dummies.com/home-garden/lawn-care/7-lawn-pests-and-what-to-do-about-them/	Do not produce webbing. Key identification comment: Defensive strategy is to circle themselves when touched.	 Clemson University - USDA Coop Ext Slide Series
Spider mites	Extremely small, may need a 10X hand lens to see (about the size of a period on this page). Eggs are round, smooth, and shiny.	Ultra-fine silk strands often on the undersides of infested leaves. Plant will be stippled – very small feeding wounds intermixed with more normal tissue. Leaves may appear dry, dusty, off-color, and slightly wilted. Damaged tissue can turn brown described as bronzing.	Leaves may become misshaped; galls may form.  Spider mite	 Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org

Table 5. Common Predators and their Prey

Predators	Classification	Common name	Predatory life stage	Prey	Supplier (see Table 7)
Cybocephalus nipponicus	beetle	Scale picnic beetle	Larvae & adult	general predator (anything they can catch)	2
Chrysoperla carnea	lacewing	Aphid lion; Pearly green lacewing	Larvae	aphids, caterpillars, leafhoppers (nymphs), mealybugs, spider mites, scales, thrips, whiteflies	2, 3, 4, 5, 6, 8, 9
Chrysoperla rufilabris	lacewing	Aphid lion; Green lacewing	Larvae	aphids, mites, and insect eggs	1, 7
Cryptolaemus montrouzieri	ladybird beetle	Mealybug destroyers	Larvae & adult	mealybugs (as well as aphids, whiteflies, soft scales when mealybugs not present)	1-8
Delphastus catalinae	ladybird beetle	Whitefly predatory lady beetle	Larvae & adult	sweetpotato whitefly and greenhouse whitefly	1, 3
Delphastus pusillus	ladybird beetle	Whitefly exterminator	Larvae & adult	sweetpotato whitefly and greenhouse whitefly	2, 4, 6
Rhyzobius lophanthae	ladybird beetle	NA	Larvae & adult	Scales in citrus, interiorscapes, ornamentals	1, 2
Hippodamia convergens	ladybird beetle	Convergent ladybeetle	Larvae & adult	aphids, thrips, whiteflies, and other soft-bodied insects	2, 3, 4, 5, 6, 7, 8
Stethorus punctillum	ladybird beetle	Spider mite destroyer	Larvae & adult	two-spotted and red spider mites	2, 3, 4
Atheta coriaria	rove beetle	NA	Larvae & adult	fungus gnats and shore flies (rove beetles also eat each other)	1, 2
Tenodera ardifolia sinensis	mantis	Chinese mantid	All but eggs	aphids, scale, mites, mosquitoes	2, 3, 4, 8
Aphidoletes aphidimyza	midge	Cecidomyiid fly	All but eggs	aphids	1, 2, 5, 6, 7
Amblyseius cucumeris	mite	NA	All but eggs	thrips	1-8
Amblyseius degenerans	mite	NA	All but eggs	thrips in greenhouse sweet peppers	1, 2
Amblyseius fallacis	mite	NA	All but eggs	mites in apples, mint, strawberries	1, 2
Amblyseius swirskii	mite	NA	All but eggs	mites, thrips, whiteflies in cucumbers, eggplant, peppers, and strawberries	1, 2
Feltiella acarisuga	mite	NA	All but eggs	red spider mites on tomatoes	2, 3, 4
Galendromus occidentalis	mite	NA	All but eggs	mites of corn, grapes, tomatoes (russet mite)	1, 2, 3, 5
Mesoseiulus longipes	mite	NA	All but eggs	mites in greenhouses and interiorscapes for use on grapes, strawberries, and ornamentals	1-5
Phytoseiulus persimilis	mite	NA	All but eggs	mites in greenhouses, interiorscapes, tomatoes	2, 3, 4, 5, 6, 7, 8
Stratiolaelaps scimitus	mite	Hypoaspis mites	All but eggs	whiteflies, aphids, lepidoptera larvae, fungus gnat larvae, and soil-dwelling insects in greenhouses	1, 2, 3, 4, 7
Dicyphus hesperus	true bug	NA	All but eggs	whiteflies on tomatoes	2
Orius insidiosus	true bug	Minute pirate bug	All but eggs	thrips on greenhouse vegetables	3, 4, 7
Podisus maculiventris	true bug	Spined soldier bug	All but eggs	Mexican bean beetle, cabbage looper, and imported cabbageworm	3
Xylocoris flavipes	true bug	Warehouse pirate bug	All but eggs	general predator (anything they can catch)	2

Table 6. Common Parasitoids of Insect Pests in Greenhouses (all of these parasitoids are small-to-minute wasps harmless to humans)

Parasites	Host	Supplier (see Table 7)
Aphelinus abdominalis	potato aphid	1, 2
Aphidius colemani	aphids	1, 2, 3, 5, 7
Aphidius ervi	potato aphid	1, 2, 7
Aphidius matricariae	aphids	2, 4, 6, 7
Aphytis melinus	red scale, yellow scale, and San Jose scale	1, 2, 3, 4, 6, 7
Cotesia plutella	lepidoptera larvae	2, 3
Diglyphus isaea	leafminers in greenhouse tomatoes	1, 2, 3, 4
Encarsia formosa	whiteflies in greenhouse cucumbers, peppers, tomatoes	1-8
Eretmocerus eremicus	silverleaf and sweetpotato whiteflies	1, 2, 3, 7
Eretmocerus mundus	sweetpotato whitefly in greenhouses	2
Leptomastix dactylopii	mealybugs	2
Metaphycus spp.	scale insects	7
Pediobius foveolatus	Mexican bean beetle	2, 3
Trichogramma spp.	eggs of: armyworm, bollworm, caneborer, codling moth, fruitworm, loopers	1, 2, 3, 4, 5, 7, 8, 9, 10

Table 7. U.S. Suppliers of Predators and Parasitoids (reference number corresponds with information in Tables 5 and 6)

1	2	3	4	5
IPM Laboratories, Inc. P.O. Box 300 Locke, NY 13092-0300 315-497-2063 www.ipmlabs.com	**Rincon-Vitova Insectaries, Inc.** P.O. Box 1555 Ventura, CA 93002-1555 805-643-5407 www.rinconvitova.com	**ARBICO Organics** P.O. Box 8910 Tuscon, AZ 85738-0910 520-825-9785 www.arbico-organics.com	**Nature's Control** P.O. Box 35 Medford, OR 97501 541-245-6033 www.naturescontrol.com	**Harmony Farm Supply** 3244 Hwy. 116 N. Sebastopol, CA 95472 707-823-9125 www.harmonyfarm.com
6	**7**	**8**	**9**	**10**
Hydro-Gardens, Inc. 8765 Vollmer Rd. Colorado Springs, CO 80908 719-495-2266 www.hydro-gardens.com	**M&R Durango, Inc.** P.O. Box 886 Bayfield, CO 81122 970-259-3521 www.goodbug.com	**Natural Pest Controls** 8320-B (barn) Hazel Ave. Orangevale, CA 95662 916-871-3159 www.natural-pest-controls.com	**Beneficial Insectary, Inc.** 9664 Tanqueray Ct. Redding, CA 96003 530-226-6300 www.insectary.com	**A-1 Unique Insect Control** 5504 Sperry Dr. Citrus Heights, CA 95621 916-961-7945 www.a-1unique.com
Additional sources for biologicals — not referenced in Tables 5 and 6				
Alternative 349 East 86th Street, Suite 259 Indianapolis, IN 46240 (317) 823-0432	**Associates Insectary** P.O. Box 969 Santa Paula, CA 93061 (805) 933-1301 www.associatesinsectary.com	**Biotactics, Inc.** 7765 Lakeside Drive Riverside, CA 92509 (909) 320-1366 www.insectary.com/	**The Green Spot** 93 Priest Road Nottingham, NH 03290 (603) 942-8925	**Koppert Biological Systems, Inc.** 28465 Beverly Road Romulus, MI 48174 (800) 928-8827 (734) 641-3763 www.koppert.com/
Planet Natural P.O. Box 3146 Bozeman, MT 59772 (800) 289-6656 www.planetnatural.com				

This list is for information only. Contact the individual company for information on prices and ability to supply the required biological controls.

Table 8. OMRI (Organic Materials Review Institute) Listed Bio-rational Pesticides (not all are registered for organic production)

Active ingredient	Trade name(s)	Action	Classification	Mode of action	General targets	Label signal word	Toxicity information	PPE	REI (hours)
Azadirachtin	AzaGuard, Azatin XL Plus, Neemix, Neemgold, + multiple others	Insect growth regulator, insecticide	IRAC Group 18B Classified as a botanical	Insect molting hormone disruptor	Aphids, beetles, borers, caterpillars, flies, leafhoppers, leafminers, nematodes, scales, thrips, weevils, whiteflies	Caution	(Rat): Oral LD50 >5000 mg/kg.	Chemical-resistant gloves, long-sleeved shirt and long pants, protective eyewear, shoes plus socks.	4
Bacillus thuringiensis subsp. Kurstaki	Dipel, Foray XG + others	Insecticide	IRAC Group 11A1 The active ingredient (A.I.) are spores and crystalline toxin. Classified as a bacterium	Microbial disruptor of insect midgut membranes	lepidopterous larvae	Caution	Nontoxic	Chemical-resistant gloves, long-sleeved shirt and long pants, shoes plus socks.	4
Beauveria bassiana	Mycotrol O, Botanigard, + multiple others	Insecticide	No IRAC group Classified as fungus Different strains available with different target pests.	Fungal pathogen	Aphids, mealybugs, psyllids, thrips, weevils, and whiteflies	Caution	Nontoxic	Long-sleeved shirt and long pants, shoes plus socks, waterproof gloves.	4
Diatomaceous Earth	Diatomaceous earth, Insecta-kill, Perma-Guard Crawling Insect Control, + others	Insecticide	No IRAC group Fossilized remains of diatoms – silicon-dioxide shelled algae.	Physical membrane disruptor, desiccant	Crawling insects	Caution	Nontoxic – Avoid breathing dust	None specified	None Specified
Fatty Acids	Insecticidal Soap, M-Pede, + others	Fungicide, herbicide, insecticide, plant health product, repellent	No IRAC group Classified as a soap	Physical membrane disruptor	Insects, weeds, pathogens	Danger, Warning Caution	Toxic to birds and fish	Chemical-resistant gloves, coveralls over short-sleeved shirt and short pants, chemical resistant footwear plus socks. Protective eyewear.	12
Horticultural Oil	Sunspray, Scalecide, Saf-T-Side + others	Fungicide, insecticide, miticide	No IRAC group Refined plant, or petroleum oils	Physical membrane disruptor	Scales, aphids, mites	Caution Can be phytotoxic	Temporary eye irritant (Rat): Oral LD50 >5000 mg/kg	Chemical-resistant gloves, long-sleeved shirt and long pants, shoes plus socks.	4
Spinosad	Entrust, Monterey Insect Spray, + multiple others	Insecticide, Seed Treatment/ Protectant	IRAC Group 5 Classified as spinosyn	Nicotinic acetylcholine receptor agonist (allosteric)	Lepidoptera, Diptera, Thysanoptera, and some Coleoptera	Caution	(Rat) Oral LD50 >5000 mg/kg	Long-sleeved shirt and long pants, shoes plus socks.	4
Pyrethrins or Pyrethrum	PyGanic + others	Insecticide	IRAC group 3 Classified as a botanical	Sodium channel modulator	chewing and sucking insects including spider mites	Caution	Toxic to fish and bees (Rat): Oral LD50 1500 mg/kg.	Chemical-resistant gloves, Long-sleeved shirt and long pants, shoes plus socks. Approved respirator for fogging concentrates.	12

Table 9. Conventional Pesticides (Wyoming registered uses for gardens and greenhouses)

Active ingredient	Trade name(s)	Action	Classification	Mode of action	Target	Signal word	Mammalian toxicity	PPE	REI (hours)
Acephate	Acephate 75SP, Orthene 75S, + others	Insecticide	IRAC group 1 Classified as organophosphate	Acetylcholine esterase inhibitor	Leafhoppers, plant hoppers, & aphids	Caution	(Rat): Oral LD50 1447 mg/kg	Long-sleeved shirt and long pants, shoes plus socks, waterproof gloves.	24
Bifenazate	Acramite 4SC	Insecticide, miticide	IRAC group 25 Reduced risk product	Neuroactive (unknown mode of action)	Mites on ornamentals and nonbearing fruit trees	Caution	(Rat): Oral LD50 >5000 mg/kg;	Long-sleeved shirt and long pants, shoes plus socks.	12
Carbaryl	Sevin 4F	Insecticide	IRAC group 1 Classified as carbamate	Acetylcholine esterase inhibitor	Insects on wide variety of plants	Warning Caution	(Rat): Oral LD50 500-850 mg/kg.	Long-sleeved shirt and long pants, shoes plus socks.	12
Chlorfenapyr	Pylon	Insecticide, miticide	IRAC group 13	Uncoupler of oxidative phosphorylation via disruption of proton gradient	Insects and mites on vegetables	Caution	(Rat): Oral LD50 441 mg/kg (male); 1152 mg/kg (female).	Long-sleeved shirt and long pants, chemical-resistant gloves, shoes plus socks.	12
Imidacloprid	Admire 2F, Alias 2F, Couraze 2F, + others	Fungicide, seed treatment, insecticide	IRAC group 4 Classified as neonicotinoid	Nicotinic acetylcholine receptor agonist/ antagonist	Aphids, Colorado potato beetle, thrips, whiteflies, on vegetables	Caution	(Rat): Acute Oral LD50 4,690 mg/kg	Long-sleeved shirt and long pants, chemical-resistant gloves, shoes plus socks.	12
Pyriproxyfen	Distance IGR	Hormone mimic	IRAC Group 7 Classified as a juvenile insect hormone Reduced risk product	Inhibits molting and adult emergence	Whiteflies & thrips	Caution	(Rat): Acute Oral LD50 >5000 mg/kg;	Coveralls over short-sleeved shirt and short pants or long-sleeved shirt, long pants, chemical-resistant gloves.	12
Zeta-Cypermethrin	Mustang Max EC	Insecticide Restricted use product (RUP)	IRAC group 3A Classified as synthetic pyrethroid	Sodium channel modulator	Psyllids, leafminers, mites	Warning	(Rat): Acute Oral LD50 810 mg/kg	Chemical-resistant gloves, long-sleeved shirt and long pants, protective eyewear.	12

Table 10. IRAC* Mode of Action and Pest Activity

Mode of Action	IRAC*	Pest control materials active ingredient	Type	Pest activity (based on label)								
				Whitefly	Aphids	Thrips	Mealybugs	Spider mites	Fungus gnats	Shore flies	Leafminers	Lepidoptera caterpillars
Acetylcholine Esterase Inhibitors	1B	Acephate	C,S,T	X	X	X	X					
	1B	Chlorpyrifos	C		X	X	X		X	X	X	X
	1A	Methiocarb	C		X	X						
Prolong Opening of Sodium Channel	3	Bifenthrin	C	X	X	X	X	X	X			X
		Cyfluthrin	C	X	X	X	X		X			X
		Fenpropathrin	C	X	X	X	X	X			X	X
		Fluvalinate	C	X	X	X		X				X
		Lambda-cyhalothrin	C	X	X	X	X	X			X	X
Nicotinic Acetylcholine Receptor Disruptors	4A	Acetamiprid	C,S,T	X	X	X	X		X		X	X
		Dinotefuran	C,S,T	X	X	X	X		X		X	
		Imidacloprid	C,S,T	X	X	X	X		X		X	
		Thiamethoxam	C,S,T	X	X		X		X			
Nicotinic Acetylcholine Receptor Agonist and GABA Chloride Channel Activator	5	Spinosad	C,T, ST			X		X			X	X
GABA Chloride Channel Activator	6	Abamectin	C,T	X	X	X		X			X	X
Juvenile Hormone Mimics	7B	Fenoxycarb	C	X	X	X	X	X			X	X
	7A	Kinoprene	C	X	X	X	X		X			
	7C	Pyriproxyfen	C,T	X	X		X		X	X	X	
Chitin Synthesis Inhibitors	16	Buprofezin	C	X			X					
	17	Cyromazine	C						X	X	X	
	15	Diblubenzuron	C	X					X	X	X	X
	10B	Etoxazole	C,T					X				
	15	Novaluron	C	X		X					X	X
Growth and Embryogenesis Inhibitors	10A	Clofentezine	C					X				
	10A	Hexthiazox	C					X				
Selective Feeding Blockers	9C	Flonicamid	C,S,T	X	X	X	X					
	9B	Pymetrozine	C,S,T	X	X							

Table 10. IRAC* Mode of Action and Pest Activity

Mode of Action	IRAC*	Pest control materials active ingredient	Type	Pest activity (based on label)								
				Whitefly	Aphids	Thrips	Mealybugs	Spider mites	Fungus gnats	Shore flies	Leafminers	Lepidoptera caterpillars
Disruptors of Insect Midgut Membranes	11A1	*Bacillus thuringiensis* var. israelensis	ST						X			
	11B2	*Bacillus thuringiensis* var. kurstak	ST									X
Oxidative Phosphorylation Uncoupler	13	Chlorfenapyr	C,T			X		X	X			X
Ecdysone Antagonist	18B	Azadirachtin	C	X	X	X	X		X	X	X	X
Mitochondria Electron Transport Inhibitor	20B	Acequinocyl	C					X				
	25	Bifenazate	C					X				
	21	Fenazaquin	C	X				X				
	21	Fenpyroxinate	C				X	X				
	21	Pyridaben	C	X				X				
	21A	Tolfenpyrad	C	X	X	X						X
Desiccation or Membrane Disruptors		Neem oil	C	X	X		X	X				
		Paraffinic oil	C	X	X	X	X	X	X	X		X
		Petroleum oil**	C	X	X	X	X	X	X	X		X
		Potassium salts of fatty acids ***	C	X	X	X	X	X				
Lipid Biosynthesis Inhibitor	23	Spiromesifen	C,T	X				X				
	23	Spirotetramat	C,S,T	X	X		X	X				
Unknown		Beauveria bassiana	C	X	X	X	X					X
		Pyridalyl	C,T,ST			X						X

Type Codes

C = Contact

S = Systemic

T = Translaminar – moves across cell membranes (usually leaf tissue)

ST = Ingested

*Insecticide Resistance Action Committee (IRAC) designation, which appears on product label.

**Products = PureSpray Green, Ultra-Pure Oil, SuffOil-X

***Products = Insecticidal Soap and M-Pede

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