NEW ENGLAND GREENHOUSE FLORICULTURE GUIDE

A Management Guide for Insects, Diseases, Weeds, and Growth Regulators

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SECTION A: GENERAL PESTICIDE INFORMATION

The pesticide information contained in this section is intended as an overview. For more specific information regarding pesticide use, contact your local Extension office, State Pesticide Coordinator or State Lead Agency (see Appendix II for contact information). All people who apply pesticides, even if only general use materials, should purchase and read their state's Pesticide Core Manual. Pesticide regulations change constantly; always check with your State Lead Agency for the most current information.

TOXICITY AND LABELS

Pesticides are poisons, both in name (*icide=to kill*) and by use. They can be absorbed through the skin (dermal poisoning), swallowed (oral poisoning), or inhaled (respiratory poisoning). A pesticide's toxicity is usually expressed in parts per million (ppm) or milligrams per kilogram (mg/kg) of body weight. A pesticide's "LD50" represents the dosage that kills 50 percent of the test animals, usually rats. A higher LD50 number signifies a less toxic product.

Reading the label is a quick way to learn how toxic a pesticide is. Highly toxic pesticides, which should be handled with extreme care, display a skull and crossbones symbol in addition to the signal words "DANGER–POISON." Moderately toxic pesticides are labeled "WARNING" and slightly toxic products are labeled "CAUTION." All labels bear the words "KEEP OUT OF REACH OF CHILDREN." A new icon appears on pesticide labels concerning bee precautions (see pollinator section below).

Read the label before purchasing or using a pesticide. Follow all label directions and safety precautions. Do not apply more pesticide than the label prescribes. Overdosage is wasteful, expensive, and illegal. Several registered products may contain the same active ingredient. Be sure the product you choose has the application site and/or crop listed on its label. If it does not list a target pest for a given crop, contact your local Cooperative Extension professional.

The "current policy is that it is not unlawful to use a pesticide in a greenhouse unless such use is prohibited on the label or the label allows use in a greenhouse only under certain circumstances (such as for home greenhouses only). In other words, if there is no reference to greenhouse use on the pesticide label then it is not unlawful to use the product (in accordance with label instructions) in a greenhouse as long as there are specific directions for the crop being treated. However, state Cooperative Extension Specialists may adopt more stringent policies when making recommendations to growers." While EPA has no formal written policy on this topic, this section's editor spoke with a representative from the Maine Board of Pesticides Control, who stated that this is indeed EPA's interpretation.

If a pesticide label has multiple sections, and one of those sections is for greenhouse application, then the label must be followed explicitly for greenhouses with no exceptions. For example, if the greenhouse section of the label states that this pesticide could be used at a particular rate for roses and carnations, then no other crops other than roses and carnations could be sprayed in the greenhouse with that product, even though another section of the label might state a rate for those other crops. That is the rate for outdoor applications on that crop and it can NOT be used for those crops in the greenhouse, since those crops are not included in the greenhouse section of the label.

In spite of the EPA policy, growers using a pesticide on a labeled crop inside a greenhouse where the label neither specifically allows nor prohibits greenhouse use do so with the possibility of increased risks to workers, customers and plants. Also, growers must be aware when fumigating or using a smoke generator for an entire greenhouse, that every crop in the greenhouse must be listed on the product label. Because of this, we advise against applying a product in the greenhouse unless the label specifically allows its use.

PROTECTING BEES AND OTHER POLLINATORS FROM PESTICIDES

Bees and other pollinators such as butterflies, flies, and hummingbirds are essential for pollination of a wide range of crops such as fruits, vegetables, and landscape and native plants. Populations of honey bees and native pollinators have declined worldwide in recent years. Many factors may contribute to this decline; the use of pesticides applied on crops or in the landscape is one factor, but this is usually considered of lower significance than various

parasites, diseases, loss of habitat, and habitat fragmentation. The current state of honeybee health is discussed in a joint comprehensive report released by the USDA and EPA: http://1.usa.gov/1kBLeJI (this is case sensitive).

Neonicotinoids

The role of pesticides including the neonicotinoid insecticides has been controversially implicated as a possible factor in bee declines. Neonicotinoid insecticides are neurotoxins. They are primarily systemic, which means that the active ingredient may be absorbed by plant roots or stems and transported throughout the entire plant into pollen and nectar. Besides direct acute poisoning leading to bee death due to exposure to high concentrations, which may occur from misapplication of insecticides to open blossoms or systemic application at high dosages, foraging bees may receive lethal or sublethal doses of systemic insecticides in pollen and nectar. Sublethal exposure may increase bee susceptibility to other stressors (such as diseases), may enhance toxicity in combination with exposure to other pesticides, and may have subtle effects on bees' ability to navigate or function within a colony.

Neonicotinoids are variably persistent, based on the active ingredient and the application method. The biggest concern is when neonicotinoids are inadvertently or illegally sprayed on open flowers attractive to insect pollinators or when they are applied at high dosages and move systemically into pollen and nectar at concentrations that may be toxic to pollinators.

For greenhouse ornamentals, insecticides classified as neonicotinoids with the designation Group 4A include imidacloprid (AmTide Imidacloprid, Benefit and Marathon), thiamethoxam (Flagship), acetamiprid (TriStar), and dinotefuran (Safari). Another neonicotinoid, clothianidin, is not currently used in greenhouses but is used in other green industries. There are also many neonicotinoid products currently available to home gardeners.

Steps to Reduce Pollinator Exposure to Pesticides

In addition to neonicotinoids, many other pesticides are also toxic to bees and native pollinators, including some pesticides used in organic production. Pesticides applied to protect crops can affect pollinators through multiple routes of exposure including direct contact with sprays, contact with treated surfaces, pesticide-contaminated dust or pollen particles that are collected or adhere to the body of the bee (and which may be taken back to the hive), and ingestion of pesticide-contaminated nectar or water. Growers' decisions make a difference in the level of exposure of bees and other beneficial insects to pesticides. It is important to take precautions in order to minimize pollinator exposure to pesticides.

Reduce or avoid using neonicotinoid insecticides. The Environmental Protection Agency (EPA) or state governments may ban or restrict the use of neonicotinoid insecticides in the future. Therefore, growers should avoid relying solely on neonicotinoid insecticides, and consider using environmentally sound alternatives whenever possible, and use neonicotinoids in ways that protect pollinators. Only use neonicotinoid insecticides when their use is justified based on overall pest management needs and sound integrated pest management principles. Monitor crops for pests and treat pests when necessary. Choose selective pesticides whenever possible.

Also, employees should be aware of risks to pollinators of any pesticide they are applying.

"Bee Friendly" plants. Avoid treating plants that are attractive to bees with neonicotinoid insecticides, unless the use pattern is known to result in residues of little concern to pollinators. This includes many perennial and native plants and also annual bedding plants. Many retailers market plants as "Bee Friendly". These plants should not in any way be treated with the nitroguanidine subclass of neonicotinoids (clothianidin, dinotefuran, imidacloprid, and thiamethoxam). Acetamiprid is about 1,000 to 2,000 times less toxic to bees than the nitroguanidine subclass, and can be used judiciously in a manner that does not pose a risk to bees.

Timing. When greenhouses are "opened up" for ventilation, for example when side-walls are rolled up, be aware of bee activity on plants, especially if pesticide applications are made during the day. Avoid any pesticide applications when bees are actively foraging in a greenhouse. Make applications in the early morning, late in the day or at night when pollinators are not foraging, to allow residues to dry before foraging begins. Some pesticide products are highly toxic when wet, but are less so after pesticide residues have dried. Apply pesticides when sufficient time is available for drying, before pollinator activity.

Control weeds under benches where bees and other pollinators may forage.

Formulation. Wettable powders, dusts and microencapsulated formulations are a greater toxic hazard than emulsifiable concentrates (or other liquid formulation with active ingredient in solution).

Drift. When applying a pesticide outdoors, avoid any drift to non-target areas, particularly onto flowering plants. Temperature inversion conditions, wind speed, application equipment characteristics, and operator skill may influence drift.

Pesticide toxicity. Do not apply insecticides rated as 'High' or 'Moderate' toxicity directly to bees that are actively foraging on blooming crops or weeds. EPA registration includes an acute, single-dose laboratory study designed to determine the quantity of pesticide that will cause 50% mortality (LD_{50}) in a test population of bees.

Read the label for bee hazard rating. In 2013, EPA introduced a label change for pesticides used outdoors that contain one or more of the neonicotinoids, in order to protect bees. A "Bee Hazard" warning and icon have generally been required to be included in the Environmental Hazards section of the label.

The new bee icon helps signal the pesticide's potential hazard to bees.

Some of these pesticides are also labeled for greenhouse use. The EPA bee toxicity groupings and label statements are as follows:

High (H) Bee acute toxicity rating: LD_{50} = 2 micrograms/bee or less. The label has the following statement: "This product is highly toxic to bees and other pollinating insects exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees or other pollinating insects are visiting the treatment area." A pesticide without the residues phrase does not show extended residual toxicity.

Moderate (M) rating: Product contains any active ingredient(s) with acute LD_{50} of greater than 2 micrograms/bee, but less than 11 micrograms/bee. Statement: "This product is moderately toxic to bees and other pollinating insects exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product if bees or other pollinating insects are visiting the treatment area."

Low (L) rating: All others. No bee or pollinating insect caution is required. But remember that the acute toxicity rating does not measure all important routes of harmful exposure. For example, insect growth regulator products can affect development of bee larvae although the product has low acute toxicity to adult bees. It is always advisable to avoid direct exposure of bees to sprays or fresh pesticide residues.

References and Resources

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STORAGE

Pesticide storage areas should be clean, cool, dry, well lit and well ventilated. Control switches should be outside the storage area so that you must turn switches on before entering. The floor should be sealed with a non-absorbent material. If the pesticide storage facility is a separate, specifically designed building, site it where it is not upwind of a sensitive area, and not in an area that could be prone to flooding or other natural disaster. If the pesticide storage area is in an existing structure such as a headhouse, be sure the pesticides are kept in a properly designed area or cabinet that is properly posted and locked at all times. Whether you have a separate pesticide storage building or a pesticide storage area in your headhouse, or if your operation is small enough that you do not have either of these facilities, contact your State Lead Agency for proper siting instructions and regulations. Clearly mark the storage area "POISON STORAGE–KEEP OUT" on all exterior sides with water-repellent ink that is readable at 20 feet. Attach "NO SMOKING" signs to the facility. Keep the storage area locked at all times.

Unsafe pesticide storage can lead to serious accidents. Do not leave pesticides where children, customers or animals can accidentally contact them. Store pesticides in original containers, away from hot (90°F or more) or cold (40°F or less) areas. Mark purchase dates on each container. Pesticide shelf lives vary; biologicals especially have quite short shelf lives. Write expiration dates on product labels and abide by them. If a pesticide is put in anything other than its original container, the second container must be labeled with product name, concentration of the active ingredient, signal word and warning statements, along with a copy of the pesticide label. Keep an inventory of stored pesticides in a secure place in case of emergency at the storage facility.

Read each label for specific storage recommendations. Note flammability precautions on labels and store accordingly. Keep combustible materials away from steam pipes and heat sources. Store highly toxic pesticides together, and store herbicides separately from all other pesticides. Some herbicides, such as 2,4-D, can volatilize and be absorbed by other pesticides. Properly dispose of all torn and/or leaking containers of old or unused products and those that are missing their labels. Contact your State Lead Agency (see Appendix II) or local Cooperative Extension office for information about proper disposal of pesticides. Keep absorbent materials (clay, kitty litter, activated charcoal, vermiculite, sawdust, or super-absorbent polyacrylamide gel products) on the premises to soak up spills. Dispose of contaminated materials properly.

Post the following outside the pesticide storage area:

- A list of Poison Control Centers with addresses and phone numbers (see inside back cover of this publication);
- Chemtrec's toll-free telephone number, 1-800-424-9300; and
- A list of the stored chemicals. Also, give a copy of this list and any known special hazards, along with the name of a contact person, to emergency personnel (fire and police departments), so that they can take appropriate action in case of an emergency at the pesticide storage facility.

Keep the following on file in your office:

- A copy of the booklet, *Recognition and Management of Pesticide Poisonings* (https://www.epa.gov/pesticide-worker-safety/recognition-and-management-pesticide-poisonings), or a similar booklet (see Appendix I);
- A copy of labels and Safety Data Sheets (SDS; formerly called MSDS). Read each pesticide's SDS and label before using it; and
- Any other Right-to-Know requirements in your state.

Shelf Life

Although pesticides may have long storage lives under optimum conditions, it is advisable not to buy more than will be used in one or two growing seasons. Exposure of liquid, wettable powder and granular formulations to humidity, air, light, and/or temperatures below 40°F and above 90°F (however, note that some pesticides may be affected at temperatures lower than 90°F) may decrease the efficacy of the chemical preparations.

Read each label for shelf life statements. Most pesticides are designed to last for two years or longer when stored properly. Always check for expiration dates, especially on biological pesticides. Wettable powders stored at cool temperatures and low humidity may be stable for at least two years if kept dry. Bags should be tightly sealed during storage, for example with spring-loaded clips. Liquid formulations generally do not last as long as powders, but may also last two years if kept sealed and away from extreme

temperatures. One of the best ways to determine the usability of a product is to record the physical state of the pesticide when new, and examine it before each use to note changes which may indicate shelf-life problems (see Table A–1 below).

Table A–1: Deterioration of stored pesticides

Formulation	General signs of deterioration
Emulsifiable concentrates	Milky coloration does not occur with the addition of water. Sludge is present. Separation of components in the container.
Oil sprays	Milky coloration does not occur with the addition of water.
Wettable powders	Lumping occurs when mixed. Powder does not suspend in water.
Dry flowables	Excessive lumping.
Granulars	Excessive lumping.
Aerosols	Aerosol nozzle becomes obstructed.

DISPOSAL

Proper disposal of pesticides is an important part of pest control. An improperly discarded product can be hazardous to people and the environment.

Rinse liquid pesticide containers three times when emptied: fill the containers about one-third full and swish the diluent around. Allow the containers to drain well between each rinse (30 or more seconds). Pour the rinse material into a spray tank and apply to a registered site. Triple-rinsed containers are considered non-hazardous and should be disposed of according to state recommendations.

Before throwing out powders or granular pesticide containers, be sure the containers are completely empty.

Plan ahead in preparing spray mixtures. Mix only the amount of pesticide you need to do the job. Clean the equipment immediately after use. Be sure that the rinse water will not contaminate groundwater or be accessible to children, pets or unauthorized and untrained individuals. Never leave hazardous equipment and material unattended because that may endanger children.

Many states have "attractive nuisance" laws, which may make you liable for damages. Never reuse an empty pesticide container. If an empty triple-rinsed container cannot be disposed of immediately, store it in a safe, locked area.

For current state regulations on pesticide disposal, consult your State Lead Agency (see Appendix II) or local Cooperative Extension office.

SAFETY RECOMMENDATIONS & EQUIPMENT

This section provides general guidelines about safety equipment. Refer to the Worker Protection Standard on page A.14 for specifics.

To reduce the risk of exposure to pesticides, always wear proper safety equipment. Always consult the label to determine the amount and type of equipment that must be worn. In case of an accident, always keep at least a five-gallon container of clean, fresh water and a squeeze container of liquid dish detergent on any pesticide application job. These allow a pesticide to be washed off the victim immediately. (See First Aid recommendations in Appendix I.)

Gloves

Safety gloves should be made of a chemical-resistant material and be free of holes and tears. These can be purchased at safety supply houses. Read pesticide labels for specific recommendations. Gloves made of polyvinyl chloride (PVC) or rubber (butyl, nitrile, or natural rubber) must be at least 14 mils thick. Wear gloves tucked inside sleeves with the end of the glove folded into a half-inch cuff to prevent pesticides from running onto wrists and arms when arms are raised. Keep several pairs of gloves available; replace worn or damaged gloves. To prevent contamination of hands, wash gloves with detergent and water *before* removing.

Cotton or leather gloves should not be used to apply pesticides, as they become contaminated easily.

Boots

Wear boots made of a chemical-resistant material. Read pesticide labels for specifically recommended

materials. Wear boots inside pant legs. Wash and air-dry the boots after each use.

Coveralls

Wear clean, dry coveralls made of Tyvek or a similar material, as listed on the label. Coveralls should cover the entire body from the neck down, and should be worn when mixing and applying pesticides. Launder re-usable coveralls after each use, separately from other laundry. Destroy disposable coveralls after use, according to directions. Research has shown that cotton coveralls contaminated with highly toxic pesticides may remain contaminated even after repeated washings. If coveralls are contaminated with concentrated pesticide, dispose of them immediately.

Head and Neck Coverings

Wear a waterproof, wide-brimmed chemical resistant cap when applying pesticides. Avoid hats with cotton or felt bands, because they may absorb chemicals. Wash headgear after each use.

Laundering Pesticide-Soiled Clothing

Follow these steps when laundering pesticide-soiled clothing:

1. Wear rubber gloves when handling clothing.
2. Pre-rinse clothing before laundering.
3. Use heavy-duty liquid detergent and pre-treat heavily contaminated garments.
4. Wash separately from other laundry, ideally in a washing machine dedicated to pesticide-contaminated clothing.
5. Wash only a few garments in each load.
6. Use hot water (l40°F), full water level and normal wash cycle.
7. Rinse with two full warm rinses.
8. After laundering, clean the washer by running it with hot water and detergent only (no clothes), through an entire wash/rinse cycle.
9. Hang clothing to dry. Do not use clothes dryer because of the potential for contamination.

Goggles or Face Shield

Eye protection is extremely important when working with hazardous chemicals. Wear a full-face shield that attaches to a hardhat or eye goggles that are ventilated to prevent fogging. Wear eye protection when preparing and applying pesticide mixtures. Headbands of goggles should be made of non-absorptive material.

Respirators

Read each pesticide label to determine what type of respiratory protective gear you must wear. Respirators prevent you from inhaling fumes. Wear them during any pesticide exposure, and especially when mixing and pouring concentrates. Cartridge respirators, which cover the nose and mouth and have either one or two cartridges to filter pesticide fumes, vapors, etc., may be worn when applying pesticides labeled "CAUTION." They can also be worn when working with very low concentrations of more highly toxic pesticides. Change the cartridges after eight hours of use, or whenever pesticide odors can be detected. Different chemical cartridges may be needed for specific pesticides. Be sure that your cartridge is approved for the pesticide you intend to use.

If you wear glasses, have a beard or for some other reason do not like the way that nose/mouth respirators fit, check with your equipment dealer for a helmet-type respirator. A helmet respirator resembles a space helmet with a hose leading to a large cartridge filter that attaches to a belt worn around the waist. It provides the same protection as a cartridge respirator, but may be more comfortable. A helmet respirator is usually worn when working with moderate to highly toxic pesticides or fumigants, or when heavily concentrated fumes are present.

A gas mask respirator covers the entire face, including the eyes. Its attached canister has a greater capacity for absorbing toxic fumes than a cartridge respirator.

All respirators should be approved by the National Institute for Occupational Safety and Health (NIOSH). Look for the NIOSH approval numbers beginning with the letters "TC."

Follow these precautions when using respirators:

1. *Read the label* on the pesticide container. Note the required safety equipment.
2. *Read the label* on the respirator cartridge or gas mask canister. Be sure the chemical filter provides protection against the pesticide you intend to use.
3. Make sure all valves, mechanical filters, and chemical filters (cartridges or canisters) are properly positioned and sealed.
4. Fit the respirator on your face to ensure a tight but comfortable seal. Workers with eyeglasses or beards may have to take extra care in fitting, or use a special respirator.
5. Ideally, you should conduct a respirator fit test every time you use a respirator. However, since

this isn't always practical, conduct the respirator fit test at least every time you change cartridges. Test for air leakage by placing your hand over the outside exhaust valve. Exhale to cause slight pressure inside the face piece. With the cartridges removed, do the same test for the intake valve. If air escapes, readjust the headbands until a tight seal is achieved, or purchase a respirator test kit that includes an aromatic oil and follow the instructions.

6. Change filters whenever any leakage is detected by smell, taste or irritation to eyes, nose or throat; or when breathing becomes difficult. If nausea, dizziness or signs of distress develop, seek fresh air immediately.
7. As a fundamental rule of safety, never use a cartridge for longer than eight hours.
8. After each use of the respirator, remove all mechanical and chemical filters, and wash the mask with soap and warm water. Rinse thoroughly with clean water to remove all traces of soap. Wipe with a clean cloth and allow to air-dry in a clean and well-ventilated area.
9. Store the clean respirator mask, cartridges, canisters, and mechanical filters in a clean, dry place, preferably in a tightly sealed plastic bag. Never store pesticide protective equipment (PPE) inside the pesticide storage facility.

Warning: If you have a respiratory impairment or have trouble breathing in a respirator, do not attempt to work where a respirator is required. If you absolutely must wear a respirator as part of your job, check with your physician before using the respirator.

Cholinesterase Testing

Cholinesterase is an enzyme necessary for the proper function of the nervous system in humans and several other animals. Carbamate pesticides (Sevin/carbaryl, fenoxycarb, etc.), organophosphates (malathion, acephate, etc.) and many other natural and synthetic chemicals interfere with the action of cholinesterase. If you apply these types of pesticides regularly, it is wise to have a cholinesterase activity test. This simple blood test, available at many hospitals, establishes your baseline level of the enzyme, so that if you suspect you might have pesticide poisoning at a later date, another blood test could be performed for comparison. The best time to establish your baseline is prior to your major pesticide application season, or at a time when you have not been exposed to these pesticides for at least 3–4 weeks. Discuss this with your physician before having a test done.

Effect of pH

A pesticide label may caution you against mixing the product with an alkaline material such as lime or lime sulfur. Many insecticides, including organophosphates (acephate, chlorpyrifos), carbamate (methiocarb) and pyrethroid (bifenthrin, cyfluthrin, fenpropathrin, fluvalinate, lambda-cyhalothrin) undergo a chemical reaction called alkaline hydrolysis when the pH of the spray solution is higher than 7.0. This chemical degradation reduces the product's effectiveness.

You can quickly determine the pH of water with an inexpensive pH meter so that you can take steps to buffer the solution to a desired pH. For more information on the effects of pH on pesticides and growth regulators, visit http://ag.umass.edu/greenhouse-floriculture/greenhouse-best-management-practices-bmp-manual/water-quality-for-crop

Formulations and Application Equipment

Various pesticide formulations and application equipment are used in the greenhouse (see Table A–2 on page A.9). All pieces of application equipment have one thing in common: they must be kept clean. After each use, carefully clean the equipment and put it in a safe storage area.

LICENSING

"General use" pesticides can be purchased and used by the general public. "Restricted use pesticides" can be purchased and used only by certified and licensed pesticide applicators. Certification and license requirements vary from state to state, as described below:

Connecticut: A written exam must be passed. The core exam is a closed book exam, and commodity exams are open book. Twelve recertification credits are required every 5 years.

Maine: A written exam must be passed for a private applicator's license. Six recertification hours must be earned in a 3-year period. The Agricultural Basic Pesticide Applicator License, initiated in 2016, is required for anyone producing more than $1,000 of plants intended for human consumption (this includes vegetable bedding plants). A closed-book, written core exam must

be passed. Three recertification hours must be earned in each 3-year period.

Massachusetts: A written exam must be passed, and 12 credit hours must be earned in a 3-year period.

New Hampshire: A written exam must be passed. Fifteen recertification credits must be acquired earned every 5 years.

Rhode Island: A 2-day training session must be completed, followed by a written exam. Four recertification credits must be earned every 5 years.

Vermont: A written exam must be passed. Eight recertification credits must be acquired annually.

Contact your State Lead Agency (see Appendix II) or local Cooperative Extension office for more information on your state's certification guidelines.

OSHA Hazard Communication Standard

The Occupational Safety and Health Administration (OSHA) Hazard Communication Standard often called the "worker's right-to-know" law, requires employers to inform employees of any chemical hazards to which they may be exposed while performing their work. In most states, the Bureau of Labor Standards (or a comparable agency) is responsible for administering and enforcing these regulations.

These laws apply to agricultural producers and other pesticide users, but those who employ ten or fewer people during a year and do not have temporary labor camps are exempt from inspection. Other agricultural producers and businesses must comply with OSHA's regulations through the following means:

1. Develop a written policy about how they comply with the law;
2. Inventory all hazardous materials;
3. Obtain Safety Data Sheets (SDS) for all hazardous materials or products (request copies from pesticide suppliers or download them from the producer's or vendor's websites);
4. Attach warning labels to secondary containers that hold hazardous materials;
5. Report information on chemicals used and other information as requested, to the proper state agency; and
6. Provide documented *annual* training for each employee that includes the following information:
   - Explanation of your written hazard communication program, chemical inventory, SDS and secondary warning label system. Inform employees of these documents' location and provide access to them;
   - The physical and health hazards of the chemicals used;
   - Areas or tasks where hazardous materials are present;
   - Methods of detecting the presence or release of hazardous chemicals in work areas;
   - Protective measures, including the use and limitations of personal protective equipment; and
   - Emergency procedures.

Follow the above practices, regardless of the size of your operation. Check with your Cooperative Extension office for resource materials on the Hazard Communication Standard. Some states in the region have videotaped training materials directed to agricultural chemical users. Some New England states have developed training materials specifically for greenhouse application.

Recordkeeping

Many states and the National Farm Bill legally require applicators to keep records concerning each pesticide application. Such records are important for professional reasons as well, as they provide a history of pest management failures and successes. Keep the following records for a minimum of two years: applicator's name, equipment used, date and time of application, temperature of greenhouse, crop, target pest, pesticide formulation, adjuvants used, application rate and EPA registration number.

Check with your local State Lead Agency (see Appendix II) about which records must be kept in your state. Check with Cooperative Extension in your state to obtain record keeping logbooks, or visit https://www.ams.usda.gov/rules-regulations/pesticide-records to download the USDA's record-keeping manual for private pesticide applicators.

Table A–2: Commonly used pesticide formulations, their application equipment, and their advantages and disadvantages

Formulation	Equipment	Advantage	Disadvantage
Aerosol (A)	packaged in a pressurized sealed container	ready to use; portable; easily stored; convenient way to buy small amount; long shelf life	flammable; inhalation risk; limited uses; difficult to target a site or pest
Dry Flowable (DF) or Water-Dispersible Granule (WDG)	portable power sprayers; compressed air sprayers	easy to measure/handle/mix; low dust so low inhalation risk	requires continuous agitation in the tank
Dust (D)	applied dry with portable power dusters, hand dusters	ready to use; simple equipment; effective where moisture might be a problem	drift occurs easily; may irritate membranes; may not stick as well as liquid; hard to distribute evenly
Emulsifiable concentrate (EC or E)	used with many kinds of equipment, from small portable sprayers to hydraulic sprayers; mist blowers	easy to handle/transport/store; does not settle out in tank; not abrasive; does not plug nozzles; little visible residue	easy to make calibration errors; phytotoxicity; absorbed readily into skin; solvent may damage hoses, gaskets
Flowable (F); Liquid (L)	portable power sprayers; compressed air sprayers	easy to handle and apply	subject to spilling/splash; may abrade nozzles and pumps; may settle in tank
Fog (produced by vaporizing oil-based formulations of pesticides on a heated surface)	pulse foggers	easy way to fill entire volume of a greenhouse	specialized equipment; hard to confine to target pest; inhalation risk
Fumigant (pesticide released as a gas; does not include soil fumigants)	product container with contents under pressure	broad spectrum control; penetrating	extremely hazardous, requiring special PPE
Bait (B)	hand-applied	usually safest formulation; ready to use	threat to pets on premises; dead vertebrate pests may produce odors
Granules (G)	spreaders similar to dust spreaders	ready to use; very little drift hazard; little risk to applicator	hard to calibrate equipment; does not stick to surface; may need to incorporate into media; hazard to nontarget species
Soluble Powder (WSP or SP))	many sprayers	dissolves easily; no agitation needed while applying	inhalation hazard when mixing
Wettable powder (WP or W)	can be applied as dust, or mixed in water and applied by sprayer (check label)	easy to handle; easily measured and mixed; less skin/eye absorption	threat of inhalation; requires constant agitation in spray tank; abrades pumps and nozzles; clogs nozzles and screens

DELIVERY CALCULATIONS

It is essential that the recommended dosage of a pesticide be applied in all pest control treatments. If the dosage applied is insufficient, material is wasted, time is lost, and most importantly, the desired control is not attained. This may lead to additional pesticide applications that may accelerate the build-up of pest resistance to the chemical and increase the hazards to humans and the environment. Dosages that exceed recommendations can be equally wasteful and injurious.

Keep records of not only dosage but also the total amount of material applied and environmental conditions such as light, temperature and relative humidity. To ensure that the correct dosage is applied, you need the following information:

- Labeled dosage rates;

- The size of the area to be treated: greenhouse volume in cubic feet for fumigants (smoke, fog, mist, etc.) or square feet of planted area and type and height of plant material for sprays, dusts, aerosols and soil applications;
- The capacity in pounds, gallons, etc., of the equipment to be used or, as in the case of smoke generators, the volume in cubic feet treated by each unit; and
- The extent and characteristics of the pest population.

Dosages for most liquid pesticides (such as liquids and emulsifiable concentrates) are listed on the labels in fluid ounces per 100 gallons of water. Dosages for solid pesticides (such as wettable powders and water soluble packets) used in the greenhouse are listed on the labels in ounces by weight per 100 gallons of water. Apply the resulting spray formulations to plant material to the run-off point. Do not over-apply, as droplets on the surface of plants may coalesce and even run off, resulting in less protective residue.

Aerosol labels indicate the length of time the nozzle should be directed at the plant material to deliver the necessary dosage. Smokes state the volume in cubic feet of greenhouse covered by one generator.

When using smoke generators, mist generators or foggers, first determine the pesticide rate and then calculate the greenhouse volume for the area requiring treatment. The diagrams at right show how to calculate the volume of common greenhouse dimensions.

Before using sprays and aerosols, or making soil applications of pesticides, calculate the square feet of planted area, by adding the bench space or floor area to be treated. (Note: If plants are to be sprayed to the "runoff" point, area calculations may not be necessary. However, the volume of spray needed varies with the type and height of the plant material). Aerosol directions often indicate how long and in what direction a spray should be applied.

After you have established the pesticide rate and the treatment area size, determine your equipment's capacity (see Table A–3 on page A.11). Many spray tanks display a mark that indicates capacity. In the case of smokes, pesticide and equipment form one unit. Foggers and mist blower equipment include filling instructions based on greenhouse volumes.

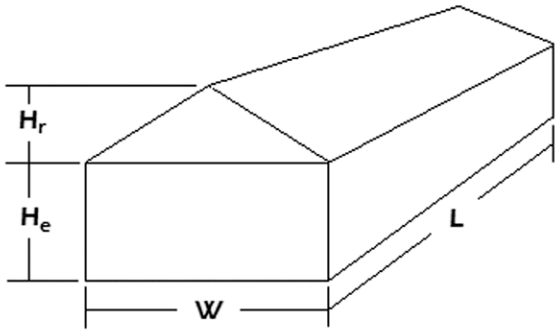

Figure A–1: Even-span structures

$$\text{Vol. in cubic feet} = \left[(H_e \times W) + \frac{W \times H_r}{2}\right] \times L$$

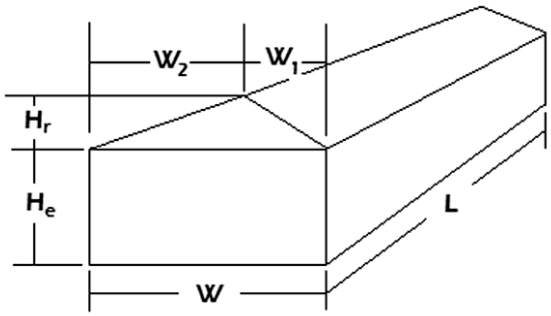

Figure A–2: Uneven-span structures

$$\text{Vol. in cubic feet} = \left[(H_e \times W) + \frac{W_1 \times H_r}{2} + \frac{W_2 \times H_r}{2}\right] \times L$$

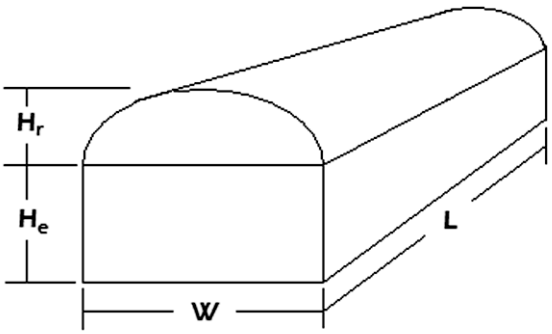

Figure A–3: Quonset structures

$$\text{Vol. in cubic feet} = \left[(H_e \times W) + \frac{3.14 \times H_r \times H_r}{2}\right] \times L$$

Table A–3: Calculating capacity of sprayer tanks

Type of Tank	Calculation of capacity (in gallons)
Tank with round cross-section	Multiply length in inches by square of diameter of end in inches; then multiply by 0.0034 to obtain gallons.
Tank with elliptical cross-section	Multiply length in inches, by short diameter of end in inches by long diameter of end in inches; then multiply by 0.0034 to obtain gallons.
Tank with square or rectangular cross-section	Multiply length by width by depth, all in inches; then multiply product by 0.004329 to obtain gallons.

Once you know how much the tank can hold, you can calculate the amount of pesticide concentrate needed. Many greenhouse spray tanks have a capacity of less than 100 gallons, although this is the figure generally used on pesticide labels. Use the following formula to adjust amounts of concentrate needed for smaller tanks.

Table A–4: Formula to calculate the capacity of pesticide application equipment tanks

Formula:

$$\frac{\text{Amount of pesticide recommended for 100-gal solution, expressed in oz or fl oz}}{\text{100 gallons}} \times \text{tank capacity in gallons} = \text{amount of concentrate needed}$$

Example:

If 3 pounds of a wettable powder is recommended for 100 gallons of spray, how much WP is required for a 25-gallon tank?

Note: First convert the 3 pounds to ounces: 3 lbs x 16 oz / lb = 48 oz

$$\frac{\text{48 oz of recommended WP concentrate}}{\text{100 gallons}} \times \text{25 gallons/tank} = \text{12 oz of WP needed}$$

Some pesticide labels list rates of product per acre. In greenhouses, space is more often calculated in square feet. Use the following formula to convert per-acre rates to per-sq ft rates.

Table A–5: Formula to convert per-acre pesticide rates to per-square-foot rates

Formula:

$$\frac{\text{Crop area to be treated, expressed in square feet}}{\text{43,560 square feet / acre}} \times \text{Amount of concentrate recommended per acre, expressed in oz or fl oz} = \text{Amount of concentrate needed}$$

Example 1:

An insecticide is recommended at a rate of 2 gallons per acre. How much should be used on a 10,000 square-foot area?

Note: First convert the 2 gal to fl oz: 2 gal = 128 fl oz/gal x 2 gal = 256 fl oz

$$\frac{\text{10,000 square feet}}{\text{43,560 square feet}} \times \text{256 fl oz} = \text{58.75 fl oz of concentrate needed}$$

Example 2:

A granular pesticide is recommended at a rate of 15 pounds per acre. How much should be applied to 100 square feet?

Note: First convert the 15 pounds to ounces = 15 lb x 16 oz/lb = 240 oz

$$\frac{\text{100 square feet}}{\text{43,560 square feet}} \times \text{240 oz} = \text{.55 oz of granules needed}$$

Use Table A–6 (below) when preparing pesticide spray formulations of emulsifiable concentrates (EC) in volumes of water less than 100 gallons. Example: If the pesticide label specifies 3 pints of liquid concentrate in 100 gallons of water, then 3 teaspoons of the same preparation (bottom of same column) is needed in one gallon of water.

Table A–6: Amount of emulsifiable concentrate needed for volumes of spray smaller than 100 gallons

Water	Amount of concentrate★					
100 gals	0.5 pt	1 pt	2 pts	3 pts	4 pts	5 pts
50 gals	4 fl oz	1 cup	1 pt	1.5 pts	2 pts	2.5 pts
25 gals	2 fl oz	4 fl oz	1 cup	1.5 cups	1 pt	1.25 pts
5 gals	1 tbsp	2 tbsp (=1 fl oz)	4 tbsp (=2 fl oz)	6 tbsp (=3 fl oz)	8 tbsp (=4 fl oz)	10 tbsp (=5 fl oz)
1 gal	0.5 tsp	1 tsp	2 tsp	3 tsp	4 tsp	5 tsp

★ see Table A–7 below for key to abbreviations and conversion among quantities

Table A–7: Equivalents useful for measuring small quantities of liquids (Note: all amounts across the table within one row are equal)

Gallons (gal)	Quarts (qt)	Pints (pt)	Cups (c)	Fluid Ounces (fl oz)	Tablespoons (tbsp)	Teaspoons (tsp)	Milliliters (ml)
1	4	8	16	128			
	1	2	4	32			
		1	2	16	32		
			1	8	16	48	240
				1	2	6	30
					1	3	15
						1	5

★ To accurately measure small amounts of liquids, use graduated cylinders of 100- and 50-milliliter capacity.

Note: *Throughout this publication: ounces by weight are denoted by "oz"; fluid ounces are denoted by "fl oz".*

Spray Adjuvants

A spray adjuvant is a material added to another substance to increase the efficiency of that other substance. Horticultural producers use several spray adjuvants. *Activators* accelerate or increase the effect of a pesticide. *Foam suppressants* reduce a chemical's tendency to foam in solution. *Spreaders* increase the area that a given volume of liquid can cover. *Stickers* increase the retention of sprays on plants by resisting various weathering factors. *Wetting agents* increase a pesticide solution's ability to make complete contact with plant surfaces. The most commonly used of these materials, spreaders, stickers and wetting agents, are **surf**ace **act**ive age**nts: surfactants** or surfactant-like materials**.** Horticultural surfactants may be cationic, anionic or nonionic.

Cationic surfactants are positively charged and are heavily attracted to plant surfaces. Extreme caution should be used with these surfactants around plants.

Anionic surfactants are negatively charged. This helps them spread across leaf surfaces without penetrating, since the leaf surface also has a slight negative charge. This type is also used to prevent a pesticide from being washed off the plant during watering. Anionic surfactants tend to increase foaming and may not be suited for a sprayer that has an agitator in the tank.

Nonionic surfactants do not have a charge and are widely used in horticulture. These materials may help the pesticide penetrate the leaf's surface. Generally, nonionic surfactants are the least hazardous surfactants to plants, if used according to label directions.

Spreader-stickers are the most common spray adjuvants used in greenhouse production. Spreader-stickers have two functions: to wet the leaf completely in order to promote good coverage by a pesticide mixture, and to make the pesticide stick to the leaf surface and reduce its weathering from the plant surface. Spreader-stickers enhance the overall efficacy of pesticides. *Wetting agents* are sometimes added to growing media to aid in the water uptake of the media to get a uniformly wetted mixture. If wetting agents are used with pesticides, care should be taken to use proper rates. If the rate is too high, phytotoxicity may occur.

Read pesticide labels for adjuvant recommendations. Spreader-stickers can cause plant damage if they alter the suspension chemistry of a pesticide, or if they are used at higher concentration than recommended. Follow these common sense rules to prevent damage:

1. Do not use an adjuvant if your pesticide already contains one. Many emulsifiable and liquid products used on ornamentals contain adjuvants. Read labels carefully to determine if an adjuvant is already in the product.
2. Always test a new spreader-sticker on a small number of plants before using it on a whole crop. When testing, use the product with the pesticide to be applied to the crop, and perform the trial under your normal spray conditions. For example, do not apply the product on a hot, sunny day when the plants are most likely to suffer spray damage.
3. Experiment with dosage. Start at the low end of the stated dosage range and increase the amount through trial and error, until you are using enough adjuvant to wet the foliage completely according to your water supply, spray technique, and spray equipment. Keep records of crops sprayed, pesticide products used and amount of adjuvant added.
4. If you repeatedly spray a crop over a period of several days, either use an adjuvant with the first pesticide application only, or use a reduced rate of adjuvant with each spray. Repeated use can cause a buildup that may burn plant tissue.
5. Application method may impact plant damage.
6. Greenhouse conditions such as temperature, sunlight, watering, etc., can enhance plant problems associated with adjuvants.
7. Some adjuvants may heighten dermal absorption and exposure of a pesticide, causing increased incidence of skin rashes and other reddening. Applicators of pesticide solutions containing an adjuvant should be aware of this possibility.

GROUNDWATER PROTECTION

In recent years, people have become very concerned about groundwater contamination by pesticides. This has resulted in numerous studies at both the state and federal level to better understand the extent of the problem and what preventive measures are necessary.

Many factors affect pesticide persistence and movement in soils. These factors should be considered when developing a pest management strategy, in order to protect crops and also our groundwater and surface water resources.

Some pesticides are more soluble in water than others. Highly soluble pesticides have a greater tendency to move by runoff or leaching from the point of application. Pesticide persistence is usually expressed in terms of *half-life*, which is the typical length of time needed for one-half of the total amount of chemical applied to break down to non-toxic substances. Sunlight, temperature, soil and water pH, microbial activity and other soil characteristics may affect the breakdown of pesticides. Microbial degradation is the breakdown of chemicals by microorganisms. Soil organic matter and soil properties such as moisture, temperature, aeration and pH all affect microbial activity. Weather is also an important factor, as it affects both the persistence and movement of pesticides. Rainfall and irrigation can move surface-applied pesticides into the soil. The longer a pesticide persists in the environment, the longer it is subject to movement deeper into the soil profile. Runoff is the movement of chemicals in water over a sloping surface. Runoff can carry pesticides mixed in water or bound to eroding soil. In addition, pesticides can move from the point of application by volatilization and by plant uptake.

Chemicals bind to soil particle surfaces through adsorption. Pesticide adsorption varies with the properties of the chemical, as well as the soil's texture (ratio of sand, silt and clay), moisture level and amount of organic matter. Soils high in organic matter or clay tend to be most adsorptive, while sandy soils low in organic matter tend to be least adsorptive.

Groundwater contamination occurs when pesticides move with the infiltrating water through the soil profile to the water table. The closer the water table is to the surface, the greater is the risk that it may

become contaminated. In some situations, pesticides that are tightly bound to the soil may only move a few inches from the point of application regardless of the amount of infiltrating water, while in other situations pesticides have been shown to move many feet.

Pesticides that are highly water soluble, relatively persistent, and not readily adsorbed by soil particles have the greatest potential for movement. Relatively level sandy soils low in organic matter are the most vulnerable to groundwater contamination due to their lower adsorptive capacity and higher infiltration rates.

Worker Protection Standard

In greenhouses, the EPA Worker Protection Standard (WPS) affects employers, handlers and workers. The information below summarizes the current WPS, based on the 2015 revisions to the 1992 Agricultural Worker Protection Standard.

Definitions

Greenhouse means any operation engaged in the production of agricultural plants inside any structure or space that is enclosed with nonporous covering and that is of sufficient size to permit worker entry. This term includes, but is not limited to, production greenhouses, polyhouses and similar structures.

Agricultural plants are plants grown or maintained for commercial or research purposes. Examples are food; feed; fiber plants; and trees, turfgrass, flowers, shrubs, seedlings and other ornamentals.

Agricultural employer means any person who hires or contracts for the services of workers, to perform activities related to the production of agricultural plants, or any person who owns or manages an agricultural establishment that uses such workers.

Handler means any person, including a self-employed person, who mixes, loads or applies agricultural pesticides; cleans or repairs pesticide application equipment; or assists with pesticide application.

Worker is a person who performs tasks related to growing and harvesting plants on farms or in greenhouses, nurseries or forests.

SDS are Safety Data Sheets, formerly called MSDS, Materials Safety Data Sheets.

REI is restricted-entry interval, the time after pesticide application when entry rules to the site apply.

Minimum Age Requirement

Early-entry workers and all handlers must be a minimum of 18 years of age.

Transfer of Pesticide Safety, Application and Hazard Information

Employers must display or make available the following information in a central location on the business premises: (1) EPA's WPS safety poster; (2) application information that includes product name, EPA registration number, and active ingredient(s) of pesticides; crop or site treated, location and description of the treated area; date, start and end times of application, and duration of REI (restricted-entry interval; and (3) a copy of the safety data sheet for the formulated product for each WPS-labeled pesticide applied.

Employers must also display EPA's WPS safety poster where decontamination supplies are located at permanent sites and where decontamination supplies are provided for 11 or more workers.

Employers must allow workers and handlers unrestricted access to all of the information and keep all of the displayed information current and legible.

Employers must display EPA's WPS safety poster before an application takes place and for 30 days after the REI expires.

Employers must display the safety data sheet and application information within 24 hours of the application, and before workers enter treated areas. This information must be displayed for 30 days after the REI expires and kept in records in the business until 2 years after the REI expires.

Employers must provide the safety data sheet information upon request from a worker, handler, designated representative or medical personnel, within 15 days.

Pesticide Safety Training

Workers must be trained before performing tasks in a pesticide treated area. Handlers must be trained before performing any handler activity. Details of this training include:

1. Workers and handlers must be trained annually.
2. Training must be presented using EPA-approved materials, either orally or in written form or audio-visually. (This information will be expanded in January 2018.)

3. Trainers must be certified applicators, or have completed an EPA-approved train-the-trainer program, or be designated by the state's pesticide enforcement agency.
4. Training must be understandable by workers, and the trainer must be present and respond to questions.
5. Training records must be maintained in the business for two years from the training date for each worker and handler who must be trained.
6. Workers and handlers must be told where to find EPA's WPS safety poster, application information, SDS and decontamination supplies.

Decontamination Supplies

The following points must be addressed:

1. Decontamination supplies must be located together, within ¼ mile of all workers and handlers.
2. Water that is safe and cool enough for washing, eye-flushing and drinking must be provided.
3. Decontamination supplies must be provided to handlers in places where mixing and loading occurs, and where PPE is removed at the end of tasks. Those decontamination supplies must be kept out of treated areas, or any areas under an REI, unless they are in closed containers that provide protect against contamination.
4. Eye-flush accommodations must be provided to handlers who use a closed system under pressure or to handlers when a product requires protective eyewear (see details online).
5. Worker decontamination supplies should not be put in areas being treated or under an REI.

Employer Information Exchange

Before any application, employers must be aware of location and description of area to be treated; date of application, estimated start and end time of application; product name, EPA registration number, active ingredient(s) and REI; whether the product label requires both oral warnings and treated area posting; and all other safety requirements on labeling for workers or other people. In addition, handlers must be aware of specific location and description of any treated areas where any REI is in effect that the handler may be in or may enter with ¼ mile of; and any restrictions on entering those locations.

Emergency Assistance

If any worker or handler is believed to have been exposed to pesticides, then employers must, within 72 hours, promptly make transportation available to an appropriate emergency medical facility; and promptly provide the following information to the treating medical personnel: SDS; product name, EPA registration number, and active ingredient(s); description of how the pesticide was used; and circumstances that could have resulted in exposure.

Summary of New Changes to WPS

The major changes to the WPS regulation include:

1. Annual mandatory training to inform workers on the required protections. This training was previously required only every 5 years.
2. Expanded training includes instructions to reduce take-home exposure from pesticides on worker clothing and other safety topics.
3. Children under age 18 are now prohibited from handling pesticides.
4. Expanded mandatory posting of no-entry signs for the most hazardous pesticides; these signs prohibit entry into pesticide-treated areas until residues decline to a safe level.
5. Farmworkers and their representatives must now be able to gain access to pesticide application information and SDS both in a central posting area and by request.
6. Mandatory record-keeping to improve states' ability to follow up on pesticide violations and enforce compliance. Application-specific information and worker training information must now be kept for 2 years.
7. Changes in PPE are now consistent with the Department of Labor's OSHA standards, to ensure that respirators are effective, including a fit test, medical evaluation and training.
8. Specific amounts of water for routine washing, emergency eye flushing and other decontamination must be provided on site.
9. Owners and their immediate family continue to be exempted, with an expanded definition of "immediate family" (see details online).

For additional details on the current rule, see: www2.epa.gov/pesticide-worker-safety/revisions-worker-protection-standard

GREENHOUSE ENTRY RESTRICTIONS

Table A–8 below presents details of REIs (restricted entry intervals). Use this table as follows:

1. When a pesticide application described in column A in Table A–8 occurs in a greenhouse, the employer can allow or direct only a trained and equipped handler to enter or remain in the area specified in column B of Table A–8 until the time specified in column C of Table A–8 expires.
2. After the time specified in column C in Table A–8 has expired or until the expiration of any REI, the employer shall not allow or direct any worker to enter or to remain in the treated area as specified in column D of Table A–8, except as provided in part 170.112 of the Worker Protection Standard.
3. When column C in Table A–8 specifies that ventilation criteria must be met, ventilation shall continue until the air concentration is measured to be equal to or less than the inhalation exposure level that the labeling requires to be achieved. If no inhalation exposure level is listed on the labeling, ventilation shall continue until after ONE of the following has transpired:
   - Ten air exchanges
   - Two hours of ventilation using fans or other mechanical ventilating system
   - Four hours of ventilation using vents, windows, or other passive ventilation
   - Eleven hours with no ventilation followed by one hour of mechanical ventilation
   - Eleven hours with no ventilation followed by two hours of passive ventilation
   - Twenty-four hours with no ventilation.

Table A–8: Greenhouse entry restrictions associated with pesticide applications.
If any information disagrees with the label, follow the label.

A. When a pesticide is applied:	B. Workers are prohibited in:	C. Until:	D. After time in column C expires until REI expires, entry-restricted area is:
(1) As a fumigant	Entire greenhouse plus any adjacent structure that can not be sealed off from the treated area.	The ventilation criteria of paragraph 3 above this table are met.	No entry restrictions after criteria in column C are met.
(2) As a Smoke or Mist or Fog or Aerosol	Entire enclosed area.	The ventilation criteria of paragraph 3 above this table are met.	Entire enclosed area is the treated area.
(3) Not in 1 or 2 above and for which the product labeling requires respiratory protection device for application	Entire enclosed area.	The ventilation criteria of paragraph 3 above this table are met.	Treated area.
(4) Not in 1,2,3 above, and –From a height of > 12 in. from the planting medium, or –As a fine spray, or –Using spray pressure > 40 psi	Treated area plus 25 feet in all directions in the enclosed area.	Application is complete.	Treated area.
(5) Otherwise	Treated area.	Application is complete.	Treated area.