

# Insect, Disease and Nematode Control for Commercial Vegetables

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This MSU Extension bulletin was prepared to help commercial vegetable producers make informed decisions on pest management.

## How to Use This Bulletin

Recommendations are organized into sections by crop. Within a crop, specific pests are listed along with their control recommendations. Frequent users may want to insert tabs for easy location of each crop section.

This publication focuses on chemical tactics and should be used in conjunction with an overall sound program of integrated pest management. Chemical recommendations are included for insect, disease and nematode control, as well as handling pesticides safely to prevent human and environmental harm. The management suggestions in this bulletin are designed to help protect the grower's crop from the pre-plant stage to market and, in certain cases, through storage.

The suggestions include the basic information necessary for the chemical components of pest control. The majority of the suggested materials have been tested at Michigan State University to determine the most effective materials, rates of application, timing of applications, method of application and site of application on the plant or in the soil. When this information is coupled with week-to-week information on pest populations, as disseminated in Crop Advisory Teams (CAT) Alerts, the minimum number of chemicals and treatments need be applied to attain the desired level of control.

It is extremely important that growers monitor (scout) each individual field for potential pest problems. Pest populations (insects, nematodes, and diseases) vary not only from year to year, but also from field to field and even within a given field. Pest populations vary in first appearance, number of individuals and severity of damage. These observations are the prime responsibility of the grower.

Growers should make them known to county and university Extension personnel. Through this type of two-way communication, Michigan agriculture will remain in the forefront in quality and quantity.

A grower's choice of a particular pesticide should be based on pests present, beneficial insects present (including honeybees and predators and parasites of pests), available materials, days to harvest, environmental and personal safety and cost.

Materials and rates of application listed on pages 22-123 are based on the latest information available at the time this publication went to press. Materials marked with an asterisk (\*) are particularly recommended for problem infestations.

Recommendations are changed as products are removed from the market, new products are introduced, new uses are found for old products, or new restrictions are placed on their use.

Your county MSU Extension agent is informed of the changes as they occur through Crop Advisory Team (CAT) Alerts or the MSU Extension computer network. Recommendations may be updated in the on-line version of this bulletin (see Useful Websites). Check with your Extension agent for updates that have occurred since the publication of this bulletin. **Always read and follow the directions and limitations on the pesticide label.**

The information given here is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by MSU Extension is implied.

Some of the more hazardous pesticides are on the Restricted Use Pesticide (RUP) list. You will need to be certified by the Michigan Department of Agriculture in order to buy and use these RUP's. Your county Extension agent has a current listing of the RUP's and will advise you on the procedures for certification.

## Safety Tips and Special Warnings

Your county agricultural agent can supply information on the dangers of environmental and personal safety with insecticides, fungicides and nematicides. You can get help for insecticide, fungicide and nematicide poison cases by telephoning the nearest Poison Control Center (see back cover). A list of insecticides and nematicides and their relative toxicities (LD50) is given on the following pages. The potential to leach into the groundwater or runoff into surface waters is given for both insecticides and fungicides.

**Phosphate Insecticides.** The phosphate group includes Imidan, Guthion and other similar materials. Many of these are extremely dangerous to users at the time of application. Read the label on the container for instructions for safe use. If any insecticide cannot be used according to those directions, do not use it at all.

**Note to Aerial Applicators.** Pilots and loading crews should know the dangers of applying methyl parathion and other hazardous insecticides. Take special care to avoid skin, respiratory and oral absorption.

- Always read the label before buying or using pesticides. Use pesticides only for the purpose(s) listed and in the manner directed.
- Pesticides that require special protective clothing or equipment should be used only by trained, experienced applicators.

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- Do not apply more than the specified amount of pesticides; overdoses can harm you, the consumers and the environment.
- Keep pesticides away from food and dishes.
- Keep children and pets away from pesticides and sprayed areas.
- Do not smoke or eat while applying pesticides.
- Avoid inhaling pesticides.
- Never spray on a windy day.
- When mixing pesticides, use care to avoid splashing.
- Avoid breaking or spilling pesticide containers.
- Avoid contact with skin and clothing.
- If you spill a pesticide on your skin, wash with detergent and water. If spilled on clothing, change clothing immediately.
- Store pesticides in their original containers with proper labels in a locked storage area. Never transfer a pesticide to a container that would attract children, such as a soft drink bottle
- Dispose of empty containers safely. Triple rinse (or equivalent) containers and offer for recycling or dispose of in a licensed sanitary landfill. Refer to your dealer for directions for disposal of specific containers.
- Wash with soap and water after using pesticides and launder clothes separately before wearing again.
- Getting any pesticide into the eyes or mouth can be especially serious. Read and understand first aid instructions listed on the label **BEFORE** you use the pesticide. Follow instructions explicitly. Flush eyes or mouth with water as soon as possible after exposure. Do not induce vomiting unless it is specified on the label. See a doctor immediately if there is any chance of poisoning. Take the pesticide container or label with you so that the doctor can read the "Instructions to the Physician" that are included on the label. Many labels carry the telephone number of a 24-hour emergency service offered by the pesticide company. Call this number for authoritative advice on diagnosis and treatment. Your physician can use this service if needed. The physician can also receive advice, when needed, by calling the nearest Poison Treatment Center listed on the back cover.

### **Pesticide Emergency Preparedness**

At the time that the pesticide is purchased, ask the chemical dealer for a complete specimen label and Material Safety Data Sheet (MSDS are required for farms with employees) of the product you bought. This label and labeling information packet is an exact duplicate of the label information that is affixed to and/or must accompany the pesticide container. Use the specimen label material as a reference during any pesticide emergency. Bring the label along with any person who has become poisoned and needs medical attention.

Closely follow all the warning statements outlined in the Precautionary Statements section of the pesticide label. Be certain that you use all protective clothing and equipment as specified by the label. Make certain all persons involved in the operation of the farm know and can carry out the information in the Statement of Practical Treatment. (See also the section on SARA Title III.)

You can develop an emergency farm plan that will prepare you and your employees for pesticide and other farm emergencies, by completing the form in Extension Bulletin E-2575.

### **Pesticide Registration**

Recommendations in this bulletin are based on field trials conducted in Michigan and other North Central Region states over a period of several years. All pesticides must be currently registered with the U.S. Environmental Protection Agency (E.P.A.) and the Michigan Department of Agriculture before they can be used legally in Michigan.

The pesticide label is a legal document on pesticide use. Read the label carefully and follow all instructions closely. Use of any pesticide in a manner not consistent with the label can lead to civil or criminal punishment and/or condemnation of the illegally sprayed crop. Do not mix and apply together any pesticides and fertilizers if it is forbidden on either product label.

### **Pesticide Tolerances (Residues) on Vegetable Crops**

Tolerances are established by the E.P.A. for every pesticide registered in the United States. These tolerances are the maximum allowable residues in parts per million (ppm) of a pesticide that may be on or in a specified crop at the time of harvest. If residues of a pesticide on a crop exceed the tolerance established for that pesticide, that crop may be seized and destroyed.

To keep below the tolerance levels established for a pesticide, apply only the formulated amount of pesticide per acre as instructed by the product label. Do not exceed this restriction. Also, to meet the label-required pre-harvest interval, discontinue the use of pesticides the number of days before harvest that the label specifies. Always remember the following restrictions on the use of all pesticides: 1) The legal amount of active material per acre that can be applied during a given growing season; and 2) The number of days before harvest that chemical application on a crop must be discontinued.

### **Use of Pesticides for Pests Not on Label**

The law regulating pesticides in the United States is the Federal Insecticide, Fungicide and Rodenticide Act, or FIFRA. FIFRA is administered by the Environmental Protection Agency (EPA) and in Michigan by the Michigan Department of Agriculture (MDA). FIFRA governs the registration, distribution, sale and use of all pesticides. Within FIFRA there exists a provision that allows the use of a pesticide for a pest not noted on the label as long as the application is made to a crop specified on the label. This provision is referred to as 2(ee). All rates and restrictions, including pre-harvest intervals, for the labeled crop must be followed. Please note, however, that the manufacturer will not assume responsibility for product performance so 2(ee) applications are made at the grower's risk. For more information about 2(ee) applications, contact your local MSU Extension or Michigan Department of Agriculture office.

### **Record Keeping**

The 1990 Farm Bill requires that all applicators who apply restricted use pesticides (RUP) keep records and maintain them for two years. Records to be kept include:

- brand name or product name and the EPA registration number,
- total amount of the product used,
- size of the area treated,

- crop, commodity, stored product or site to which the pesticide was applied,
- location of the application,
- month, day and year of the application,
- name and certification number of the applicator or applicator's supervisor.

Any record form is acceptable as long as the required data is included. Penalties are up to \$500 for the first violation and up to \$1,000 for subsequent violations. Provisions for protecting the identity of the individual producers are included in the law. Commercial applicators must furnish a copy of the required records to the customer of the RUP application.

### **Agricultural Chemical Use Precautions**

The use of any pesticide, especially a restricted-use-pesticide (RUP), entails a significant amount of responsibility and liability on the part of the grower. Therefore, handle all pesticides with extreme caution and respect for the following reasons:

- to protect yourself and others.
- to protect your crop and soil from chemical damage.
- to protect the environment from chemical damage.

These points cannot be emphasized enough. Pesticide accidents occur most often during mixing and tank filling operations. Although accidental ingestion of chemicals is considered to be the greatest health hazard, there is also great danger of poisoning when pesticides contact skin or eyes or when dust or vapors are inhaled. To prevent such accidents, wear protective clothing at all times when handling and applying pesticides and cleaning spray equipment. Such mandatory garments include chemical resistant gloves and boots, splash-guard goggles and a respirator manufactured specifically for the type of chemical compound that is being used. Care for these items as you would your farm implements. They may save your life in case of an accident. Always heed all the precautionary statements on the product label and cover-up to protect yourself. (See MSU Extension Bulletins E-1546, Take Cover! Protect Yourself from Exposure, E-2215, Using Pesticides Safely: A Guide for the Applicator; NC-204, Protective Clothing for Handling Pesticides, and AM-106, EPA Chemical Resistance Category Chart, for more information.)

Protecting yourself during any application of an agricultural chemical is required. Give the same consideration to any field worker(s) you may employ. Farm workers assisting in the application of any pesticide should also wear protective clothing, as specified by the product label.

Protect your crops and land by applying any pesticide at the label directed rate and under favorable environmental conditions. To do otherwise may be a violation of the label and could cause damage to the crop and carry over in the soil. Excessive pesticide residues in the soil may also leach into surface and groundwater. Overdosing will also increase residues on the crop and the number of days before the crop can be harvested legally. To avoid any pesticide damage and/or illegal residues on crops and in the soil, follow the recommended rates of application and use properly calibrated implements.

Pesticide drift from aerial and ground application is a serious problem. Drift can be a particular problem if houses, schools or urban areas are nearby. Drift can also contaminate sensitive crops and the environment (crop land and surface water). Avoid pesticide drift from all pesticides. Because few chemicals are allowed

on forage for all types of livestock, exercise extreme caution when using any pesticides to avoid contaminating hay, pasture and stover. Where problems with pesticide drift exist, use the least hazardous materials with additives labeled to reduce spray drift. These additives add elasticity to spray suspensions to reduce the shearing effect (break up of spray stream) caused by spray dispensing equipment and air movement.

### **SARA Title III Emergency Planning and Community Right to Know Act**

The Emergency Planning and Community Right to Know Law, under SARA Title III, requires farmers to notify their State Emergency Response Commission (SERC), Local Emergency Planning Committee (LEPC), and local fire department that they store extremely hazardous materials, along with the name and telephone number of the facility representative. Check with your state Department of Natural Resources or MSU Extension to receive a list of EPA established "Extremely Hazardous Substances" and their threshold planning quantities.

The LEPC and fire chief may request maps of your storage facility and detailed lists of materials you store.

This law also requires that, in the event of a spill, the SERC, LEPC and National Response Commission be notified. The reportable quantities for spills is much less than for storage and can be obtained from the above sources. See Extension Bulletin E-2575 for more details on SARA Title III and a list of commonly used extremely hazardous substances.

### **Worker Protection Standard**

New federal rules for farm worker protection, issued during 1992, require farmers to provide additional training and notification to farm workers to prevent accidental or occupational exposure to pesticides. Farmers should contact Extension agents to learn the details of this standard and availability of training materials for education of workers and handlers.

Read and follow the label instructions on Restricted Entry Intervals (REI) for every pesticide used. Some pesticide labels require both oral warning and posted signs to notify workers of pesticide applications. If the label doesn't require both forms of notification, notify workers either orally or by posting warning signs at entrances to treated areas. (Greenhouses must post warning signs for every application.) When using posted signs, post 24 hours or less before the pesticide application and remove signs within three days after the end of the restricted entry interval. Keep workers out during the entire time the signs are posted (except for early-entry workers wearing the proper personal protective equipment).

### **Michigan Groundwater Stewardship Program (MGSP)**

The Michigan Groundwater Stewardship Program is a cooperative effort between the Michigan Department of Agriculture (MDA), Michigan State University Extension, Conservation Districts, and the USDA Natural Resources Conservation Service. The program is funded through fees assessed on sales of pesticides and nitrogen fertilizers. MGSP-sponsored education, technical assistance and cost share help individuals reduce the risk of groundwater contamination associated with pesticide and nitrogen fertilizer use.

Producers who complete the environmental risk assessments for their farmstead and cropping systems (Farm\*A\*Syst and Crop\*A\*Syst) will be able to determine what structural, management and record-keeping changes (if any) will be needed for their farming systems to be in conformance with Michigan Right to Farm guidelines and state and federal environmental laws.

Once a producer develops and implements a plan to address the risks indicated by the environmental assessments, he or she can contact the MDA to request farming system verification under the Michigan Agriculture Environmental Assurance Program (MAEAP). MAEAP-verified farms are eligible for various incentives.

### **Protect Nontarget Organisms**

Bees and other pollinating insects are essential for successful production of tree fruits, small fruits, most seed crops and certain vegetables. Many insecticides are highly toxic to pollinating honeybees and wild bees. Be aware of how bee poisonings can occur from applying pesticides and how to prevent them. Take the following precautions to reduce the chance of bee poisoning:

- Do not apply pesticides that are toxic to bees if the site contains a crop or weeds which are in bloom. This applies not only to the fruit bloom but also to dandelions and clovers that may be reached by the spray. Mow cover crops and weeds to remove the blooms prior to spraying.
- Select pesticides that are least harmful to bees and select the safest formulation. Dusts are more hazardous to bees than sprays. Wettable powders and microencapsulated products are more hazardous than emulsifiable concentrates or water soluble formulations because particulate pesticide material may be carried back to the hive. Granular insecticide formulations are generally the least hazardous to bees.
- Reduce drift during application. Use drift control materials whenever possible.
- Time pesticide applications carefully. Evening applications are less hazardous than early morning; both are safer than midday applications.
- Do not let puddles of spray accumulate on the ground where bees might drink it. Supplying fresh water near bee's hives can reduce this hazard.
- Do not treat near hives. Bees may need to be moved or covered before using insecticides near colonies.

The best way to avoid injury of beneficial insects and microorganisms is to minimize pesticide usage. Use selective pesticides when ever possible and apply only when necessary as part of a total pest management program.

Pesticides can be harmful to all kinds of vertebrates such as fish and wildlife. Most recognizable are the direct effects from acute poisoning. Fish kills can result from water polluted by a pesticide (usually insecticides). Pesticides can enter water via drift, surface runoff, soil erosion, and leaching.

Bird kills from pesticides can occur when birds ingest the toxicant in granules, baits, or treated seed; are exposed directly to the spray; consume a treated crop; drink and use contaminated water; or feed on pesticide-contaminated prey.

### **Endangered Species Act**

To minimize the adverse impact of pesticides on endangered species, the EPA has initiated The Endangered Species Act. Every implicated pesticide will have an endangered species warning statement regarding use of the product within the geographic area where endangered species restrictions apply. Users must obtain a county-specific endangered species bulletin from the local Extension office, which will identify the specific area where use restrictions apply. Application of listed pesticides in the identified geographic areas in that county will be restricted or prohibited.

### **Right to Farm**

Farmers in Michigan are protected from nuisance lawsuits under the Right to Farm Act if they follow acceptable management practices. The Generally Accepted Agricultural and Management Practices for pesticide utilization and pest control, nutrient utilization, and manure management have been completed and are revised annually. Contact your Extension agent or regional office of the Michigan Department of Agriculture to obtain copies.

### **Pesticide Name**

The insecticide trade name (first letter capitalized; Lorsban, for example) is used when an insecticide is sold under only one well known brand name. The accepted common name of an insecticide is used when it is sold under several brand names, with some trade names are shown on the following line(s). The fungicide and nematicide trade names are listed underneath the chemical formulation name.

### **Pesticide Formulations**

Fungicides, insecticides and nematicides can be purchased in a variety of formulations. Not only is it important that a grower purchase the correct pesticide for the intended pest control (i.e., pesticide product labeled for both the crop and the pest), but also that the grower chooses the formulation best suited for the particular job. Such a decision should be based on the pesticide product's effectiveness, cost, practicality and relative safety to the applicator, the crop and the environment. The following are some additional considerations worth remembering when choosing a specific formulation:

- Some formulations require constant spray tank agitation; others do not.
- Dusts and granules do not require water for application, but accurate calibration of equipment and uniform distribution are often difficult to achieve and maintain.
- The potential hazard to the applicator and the potential of drift and environmental contamination vary substantially among formulations.
- Dry formulations are generally less affected by subfreezing temperatures during storage than liquid formulations.
- Some crops may be treated with any formulation of a particular pesticide; others require using a specific formulation.
- The price per pound of active ingredient varies for different formulations.

Also remember that for two products with the same active ingredient but different formulation, the application rate to be used

on a specific site and pest may be different. **Always read and follow the label instructions carefully.**

### Restrictions

The pre-harvest interval, the minimum number of days required between last application and harvest or other use of the crop, is listed. Special limits on the use of the pesticide are also given when they apply. Follow these restrictions exactly to avoid possible deleterious residues on the crop at harvest. Pesticides that are relatively safe around honeybees are also noted when pertinent.

### Compatibility

When two or more chemicals are mixed together in a spray tank, they may or may not mix well, or the mixture may cause injury to germinating seeds or plants. This relationship is called compatibility. The lack of compatibility could affect the application and effectiveness of the chemical spray.

It is usually not advisable to mix different formulations such as wettable powders and emulsifiable concentrates together in a spray tank. This is especially important if other materials, such as foliar nutrients, are included in the spray and applied in low gallop per acre. Always be sure to read and follow the directions and limitations on the pesticide label before mixing.

### Pesticide Additives

During the development of a pesticide, chemical companies attempt to formulate the active ingredient to optimize performance, mixing and handling under diverse conditions. Every commercially available pesticide formulation contains its own particular set of additives to accomplish this action. However, sometimes additional additives are required for specific applications or when compatibility or mixing problems occur. The pesticide label will describe the need and use of these additives. Avoid indiscriminate use of additives because they may not improve pesticide performance and may actually reduce pest control or cause crop injury.

The following are some definitions of pesticide spray additives. For more information on types of spray additives and when to use them with herbicides, see MSU Extension Bulletin E-1858, Using Spray Additives with Herbicides.

- Adjuvant—any substance that enhances pesticide effectiveness, an added ingredient.
- Surfactant—a surface active material that can facilitate emulsifying, dispersing, spreading, wetting, sticking or other surface-modifying characteristics of a pesticide solution.
- Emulsifier — an agent that promotes the dispersion of one liquid in another.
- Wetting Agent Spreader— an ingredient that reduces water surface tension causing better contact between the spray solution and treated surfaces.
- Soap—sodium or potassium salts of fatty acids. These additives can form insoluble materials in hard water. Detergents are synthetic materials used for cleaning.
- Sticker—a deposit builder that increases pesticide adhesion to plant surfaces.
- Defoaming Agent—reduces or eliminates foaming in the spray tank.

- Drift Control Agent—an agent that prevents the formation of very fine spray droplets that are especially subject to drift; improves coverage.
- Compatibility Agent or Co-solvent — an inert ingredient that may aid in the dispersion of otherwise incompatible mixtures.

Pesticides are applied in a number of ways, so adding and using an additive is up to the applicator. Sometimes, additives are only required for pest control treatments made during adverse climatic conditions. In other cases, the nature of the pesticide may require adding an additive to the spray mixture rather than the formulation. The pesticide label always gives directions for the use of additives, if they are required.

### Soil Type Considerations

Soil texture (sand, silt, clay) and organic matter content influence the effectiveness of soil-applied pesticides. In general, lower rates of pesticides are required on sandy (coarse-textured) soils than on clays or soils with high organic matter content (fine-textured) to obtain the same level of control. Pesticide rate recommendations in this bulletin are given for medium-textured soils with greater than 3 per cent organic matter content, unless otherwise noted. Clay and organic matter absorb pesticides, making them less available to kill soil-borne pests. Soils with high clay and organic matter content require greater pesticide rates for adequate pest control. Sandy soils with low organic matter content require careful pesticide rate selection to avoid crop injury.

Poor application of soil insecticides, such as plowing or drilling the insecticides deeper than about 4 inches, or using sidedressings when broadcast treatments are best, reduces the value of pesticide treatments. Do not expect the impossible in your efforts to control soil-borne pests. As with foliar sprays, materials need to be carefully applied to achieve maximum effectiveness.

### Pesticides and the Environment

Many people obtain their drinking water from wells. Well water is groundwater. Groundwater is stored in water-bearing geological formations called aquifers. It moves through aquifers and is obtained at springs, streams, or wells.

The upper level of the saturated zone in the soil is called the water table. The water table depth fluctuates, depending on the amount of water removed from the ground and the amount of water added by recharge.

Both surface water and groundwater are subject to contamination by point and non point source pollution. Point source contamination refers to movement of a pesticide into water from a specific site. Nonpoint source contamination generally results from land runoff, precipitation, acid rain, or percolation rather than from discharge at a single location.

Several factors influence the fate of pesticides in groundwater.

**Adsorption** is the binding of chemicals to soil particles. The amount and persistence of pesticide adsorption varies with pesticide properties, soil moisture, soil pH, and soil texture. Soils high in organic matter or clay are the most adsorptive; coarse, sandy soils are much less adsorptive.

A soil-adsorbed pesticide is less likely to volatilize, leach or be degraded by microorganisms. It is also less available for absorption by plants. Therefore, pesticides used on highly adsorptive

soils may require higher rates or more frequent applications to compensate for soil adsorption.

**Volatilization** occurs when a solid or liquid turns into a gas. A pesticide in a gaseous state can be carried away from the treated area by air currents. This is called vapor drift. Unlike the drift of sprays and dusts that can sometimes be seen during application, vapor drift is invisible.

Avoid applying volatile pesticides when conditions favor volatilization, such as temperature inversions. Pesticide labels usually mention the potential for volatility of pesticides. Volatilization can sometimes be reduced through the use of low volatile formulations or soil incorporation of the pesticide.

**Photodegradation** is the breakdown of pesticides by the sunlight. Pesticides applied to foliage or the soil surface may be broken down by exposure to light. Soil incorporation can reduce pesticide exposure to sunlight.

**Microbial degradation** occurs when microorganisms such as fungi and bacteria use a pesticide as a food source. It can be rapid and thorough under favorable soil conditions, including warm temperatures, favorable pH levels, adequate soil moisture, oxygen and fertility. The amount of adsorption also influences microbial degradation. Adsorbed pesticides are more slowly degraded because they are less available to some microorganisms.

**Chemical degradation** is the breakdown of a pesticide by soil processes not involving a living organism. Adsorption of the pesticides, soil pH, soil temperature and moisture influence the rate of degradation. Some pesticides are more rapidly degraded on low pH soils.

**Absorption** is the process by which plants and microorganisms take up chemicals. It is another process that can transfer pesticides in the environment. Once absorbed, most pesticides are degraded within plants. Residues may persist inside the plant or be released back into the environment as the plant decays.

**Runoff** moves pesticides in surface water, either mixed in the water or bound to soil particles. The amount of pesticide runoff depends on the grade or slope of the field, the type of soil, the amount of rainfall, (especially close to the time of application), and properties of the pesticide. For example, a pesticide applied to a saturated clay soil is highly susceptible to runoff. Established vegetation or plant residues reduce runoff.

Pesticide runoff is greatest when heavy rainfall occurs shortly after application. No-tillage, minimum-tillage, and soil incorporation reduce runoff. Surface grading, drainage ditches and dikes, and the use of border vegetation can help reduce pesticide movement into surface water.

**Leaching** is the movement of pesticides through the soil into groundwater. Several factors influence leaching including water solubility of the pesticide, soil structure and texture, and persistence of pesticide adsorption to soil particles. If a pesticide is strongly adsorbed to soil particles, it is less likely to leach, regardless of its solubility, unless the soil particles themselves move with the water flow.

### Keeping Pesticides Out of Groundwater and Surface Water

It is very difficult to purify or clean contaminated groundwater or surface water. Management practices can be implemented to effectively reduce pesticide runoff and leaching and protect groundwater and surface water.

Use integrated crop management programs —Minimize pesticide use by combining chemical control with other pest management practices such as tillage, cultivation, crop rotation, and pest scouting.

- Reduce compaction—Surface water runoff increases when soils are compacted.
- Rotate crops —Crop rotations may provide more surface crop residue and may reduce the application of the same pesticides to a field.
- Use conservation tillage practices —Include no-till, minimum till, cover crops, grass waterways and buffer strips.
- Consider the geology of your area—When planning pesticide applications, be aware of the water table depth and the permeability of the geological layers between the surface soil and groundwater.
- Select pesticides carefully—Choose pesticides with the least potential for leaching into groundwater or for runoff into surface water.
- Transport pesticides safely—Have pesticides delivered directly to your pesticide storage facility to avoid liability and potential accidents and spills in transit whenever possible. DOT shipping rules must be followed for transporting large quantities of pesticides, including proper placarding of the vehicle, liability insurance, special handling requirements, etc.
- Follow label directions—The label carries crucial information about the proper rate, timing, and placement of the pesticide.
- Calibrate accurately—Equipment should be calibrated carefully and often.
- Measure accurately—Concentrates need to be carefully measured before they are placed into the spray tank. Do not “add a little extra” to ensure the pesticide will do a better job.
- Avoid back-siphoning —The end of the fill hose should remain above the water level in the spray tank at all times to prevent back-siphoning of chemicals into the water supply. Use an anti-backflow device when siphoning water directly from a well, pond, or stream. These practices also reduce the likelihood of the hose becoming contaminated with pesticides.
- Consider weather and irrigation—If you suspect heavy or sustained rain, delay applying pesticides. Control the quantity of irrigation to minimize the potential for pesticide leaching and runoff.
- Avoid spray drift and volatilization—Do not spray when the wind is greater than 10 miles per hour and/or weather conditions (e.g. inversions) are conducive to pesticide drift from the target area. Make every effort to **AVOID PESTICIDE DRIFT!**
- Clean up spills—Avoid spills. When they do occur, contain and clean them up quickly with an absorbent material like cat litter. Chemicals spilled near wells and sinkholes can move directly and rapidly into groundwater. Chemicals spilled near ditches, streams or lakes can move rapidly into surface water.
- Change the location of mixing areas —Mix and load pesticides on an impervious pad, if possible. If mixing is done in

the field, change the location of the mixing area regularly. Do not mix pesticides adjacent to the water source, and do not let the water run inadvertently on the soil near the mixing area. This will increase pesticide leaching and/or runoff.

- Dispose of wastes and containers properly—All pesticide wastes must be disposed of in accordance with local, state, and federal laws. Pesticide containers are considered hazardous waste until they are cleaned or disposed of properly. When possible, reduce the number of pesticide containers by using bulk or returnable containers.

All pesticide containers can be rendered non-hazardous waste by triple rinsing (or equivalent). The rinsate should be added to the spray tank. After triple rinsing, perforate both ends so the container cannot be reused.

All metal and plastic triple-rinsed containers should be recycled, if possible. If this option is not available, dispose of them in a state licensed sanitary landfill. Dispose of all paper containers in a sanitary landfill or a municipal waste incinerator. Do not bury or burn any pesticide containers. Do not reuse any empty pesticide containers for any purpose.

Store pesticides away from water sources —Pesticide storage facilities should be situated away from wells, cisterns, springs, and other water sources. Pesticides must be stored in a facility that will protect them from temperature extremes, high humidity, and direct sun light. The storage facility should be heated, dry and well ventilated. It should be designed for easy containment and cleanup of pesticide spills and made of materials that will not absorb any pesticide material that leaks out of a container. Store only pesticides in such a facility and always store them in their original containers.

Do not store any protective clothing or equipment in the pesticide storage facility. Store pesticides separately from insecticides and fungicides to avoid contamination of one material by another and accidental misuse.

Keep the facility locked at all times when not in use to prevent animals, children, and irresponsible adults from entering and becoming poisoned. Post the facility as a Pesticide Storage Facility to warn others that the area is off limits. Maintain an accurate inventory of the pesticides stored in the facility at all times in case of emergency.

Always read and follow the Storage and Disposal section of pesticide labels for specific storage and handling instructions.

For additional information on pesticide storage, refer to Midwest Plan Service Bulletin 37, Designing Facilities for Pesticide and Fertilizer Containment, available from Agricultural and Biosystems Engineering Dept., 122 Davidson Hall, Iowa State University, Ames, IA 50011; and MSU Bulletin E-2335 On-Farm Agrichemical Storage and Handling. Your state's water resources currently provide a vast supply of clean water for agriculture, homes, and industry. They can ensure high water quality for future needs only if they are protected now. Be sure to understand how your activities, including pesticide usage, can affect them.

### Handling and Mixing Pesticides

Always wear protective clothing and equipment when handling, mixing, and applying pesticides and during the cleanup of application equipment. Protective clothing should include full coverage clothing, chemical resistant gloves and boots, eye protec-

tion, hard hat, and a MSHA/NIOSH approved respirator with a chemical absorbent material as specified on the pesticide label.

Mix pesticides downwind and below eye level. Avoid excessive splashing and sloshing. If pesticides are spilled on you, wash them off immediately with lots of water and change clothing. Resume spraying only after cleaning up any spills. Try to use closed handling/mixing systems when appropriate.

Mix only what is required for the area to be sprayed according to label directions. Avoid mixing excessive amounts. To do otherwise will create a hazardous waste which is difficult and expensive to dispose of. Keep unauthorized persons out of the area in which you handle pesticides.

### Application Equipment

Efficient use of application machinery is very important to any pesticide application program. In many cases, improper use of machinery will result in poor pest control. With such occurrences, the grower may blame the efficacy of the pesticide for the failure of the control program when poor coverage is at fault.

Proper equipment and its maintenance are very important for any pesticide control program. Spray equipment should have the following features:

- The equipment should be made of non-corrodible materials.
- A tank with sufficient capacity so that the number of mixing and filling operations are minimized.
- A pump with a capacity of at least 5 gal/minute and pressure up to 100 psi.
- An agitation system from the pressure control to the bottom of the tank.
- A plumbing system with 50-mesh screens in the intake line and at each nozzle.
- A pressure gauge that accurately measures pressures up to 100 psi.
- A spray boom that can be adjusted for distance above application site and nozzle placement along the structure.
- Nozzles of the proper size, arrangement, airstream placement and dispersal pattern.

Pest control on vegetable crops has been applied successfully with standard low-pressure sprayers, air-blast sprayers, aircraft, irrigation systems and soil application equipment. Use the proper implements for the crop and soil situation. In the case of insect and disease control, the location of the pests on the plants determines how the machinery should be adjusted and used. For example, if the pests are on the underside of the leaves, adjust the implement so that the chemical is applied on those areas. A general rule to follow with application implements is that the best control results when the chemical treatments are aimed directly at the pests.

### Cleaning and Care of Pesticide Application Equipment

It is important to clean pesticide application equipment, especially if it is used for more than one crop and for applying insecticides, fungicides and herbicides. The need for extensive cleaning can be minimized if one sprayer is only used to apply herbicides and another is used for insecticide and fungicide applications.

When cleaning a sprayer that is used for applying only one type of pesticide, a thorough water rinse is necessary. Rinse the entire sprayer, inside and out, including the boom, hoses and

nozzles. Partially fill the spray tank with water and keep the pump running so that the rinse water circulates throughout the entire system. Spray the water rinsate out through the nozzles, making sure to properly collect the rinsate. To save money and protect the environment, rinse the equipment in the field using a water-filled nurse tank and apply the collected water rinsate to the crop.

To clean application equipment used to apply a variety of pesticides, thoroughly wash the entire spray system with one of the following cleaning agents in 100 gal of water:

- 1 gal household ammonia. Allow to stand in the spray tank and system overnight. **OR**
- 5 lb of sal soda. **OR**
- 8 lb trisodium phosphate.

Run the pump so that the cleaning solution circulates throughout the entire system. Leave the cleaning solution in the spray system for at least 2 hours, and do not apply it to any crop or crop land. Discard the cleaning solution in an appropriate pesticide rinsate degradation pit. Rinse the entire system with water at least three times after all the cleaning solution has drained from the sprayer. Do not leave pesticide solutions or cleaning solutions in the tank overnight unless otherwise instructed.

Corrosion and mechanical damage to pumps, tanks, nozzles, etc., may result from leaving water in the spray system over the winter. To prepare the spray equipment for storage, disconnect all hoses and allow all water to drain out. Coat all bare metal parts with oil or a rust inhibitor.

Disassemble metal nozzles and store them in oil. Prepare the spray pump for storage based on the manufacturer's recommendations.

### Notes on Nematode Management

Nematodes are microscopic worms that live in the soil and roots of plants. A few species feed on foliage or modified tissue, like onion bulbs. Nematode-infected vegetables do not grow well, yields are low and quality is often poor. Some nematodes cause root swellings called knots or galls (root-knot nematode), while others cause necrosis (root-lesion nematode, onion bloat nematode), and still others cause root stunting (stubby-root nematode). All of these nematodes can cause reduced yields or quality of various vegetable crops.

Plant parasitic nematodes can be present in most soil types, but usually cause the greatest damage in sandy soils. Some species, however, cause serious problems in muck soils. Nematode damage is frequently blamed on other causes, such as nutrient deficiencies or disease-causing organisms, like fungi and bacteria. Nematodes can also reduce plant resistance to certain fungi and bacteria.

Most soil-borne nematodes are beneficial and help control insects, decompose organic matter and regulate soil nutrition. While plant-parasitic nematodes cannot be eliminated completely from a field, control measures such as crop rotation, fallowing and applying chemical nematicides help prevent nematode damage in vegetable production.

1. Rotate vegetable crops so that plants injured by nematodes are not grown on the same soil more often than once every 3 years. For example, Irish potatoes, tomatoes, peppers, carrots, celery and other crops are injured by root-knot nematodes. Grasses are non-hosts for the northern root-knot nematode therefore no development and reproduction occur on these plants.

Other vegetables are less susceptible than the ones mentioned above but they are still hosts to this species of root-knot nematode.

2. In some cases, fallowing can be used to reduce nematode populations. Fallowed ground must be worked several times to keep it dry and free of weeds.

3. Sudax is a good cover crop for lowering population densities of root-knot and to a lesser extent root-lesion nematodes.

4. Whenever necessary, use an appropriate nematicide. Specific nematicide recommendations for each crop are presented in this bulletin. Information about how to submit soil and root samples for nematode analysis is given in MSU Extension Bulletin E-2199, Detecting and Avoiding Nematode Problems. Use root and soil samples to identify nematode problem sites.

Use chemical nematicides only when nematode population densities exceed specific nematode-crop action thresholds. The rate of nematicide selected for use should be based, in part, on the nematode type and population density present in a specific production site. The procedure for nematode analysis is presented in Appendix C.

### For More Information

For more information on the use of pesticides, see the MSU Extension bulletins available through your local MSU Extension office or the Educational Materials Distribution Center.

<http://web2.msue.msu.edu/bulletins/mainsearch.cfm>

### Useful Web Sites

E-312 On-line  
<http://web4.msue.msu.edu/veginfo/E312>

Michigan State University IPM Program:  
<http://www.ipm.msu.edu>

Michigan State University Vegetable Crop Advisory Team Newsletter:  
<http://www.ipm.msu.edu/veg-cat.htm>

Michigan State University Vegetable Area of Expertise Team:  
<http://www.msue.msu.edu/vegetable>

Michigan Department of Agriculture:  
<http://www.michigan.gov/mda>

Insecticide Registration, Product Labels and MSDS Sheets:  
<http://www.cdms.net>