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ABSTRACT

This manual is intended to assist pesticide applicators in vegetable crops prepare for certification under the Michigan Pesticide Control Act of 1976. The primary focus of this publication is on vegetable pest control. The three sections presented describe: (1) Insect pests of vegetable crops; (2) Weed pests of vegetable crops; and (3) Causes of vegetable diseases. Section three discusses disease cycles and examples of vegetable disease cycles. Also described are the types of inorganic and organic fungicides and how they have been used for disease control. A list of self-help questions and instructions for completing the questions are presented at the end of each section. (HM)

## *Vegetable Pests*

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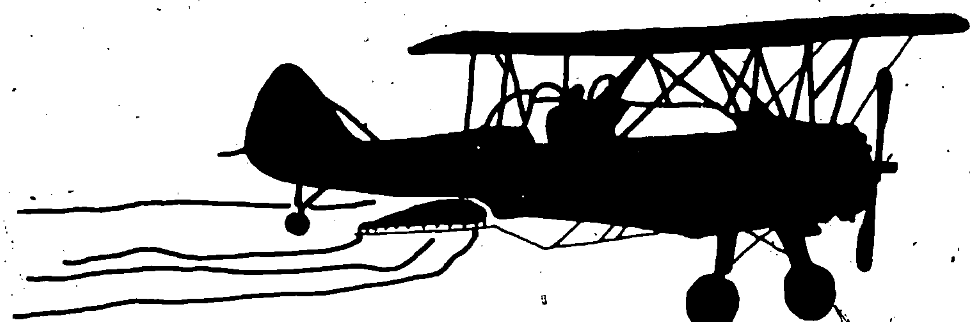

# SAFE, EFFECTIVE USE OF PESTICIDES
## A MANUAL FOR COMMERCIAL APPLICATORS

# PREFACE

This manual is intended to assist pesticide applicators in vegetable crops prepare for certification under the Michigan Pesticide Control Act of 1976. The manual was prepared by Drs. D. Cress, F. Laemmlen, and M. Erdmann of Michigan State University.

A list of self-help questions and instructions for completing the questions are at the end of each section. If you encounter difficulties in using the manual, please consult your county agricultural extension agent or representative of the Michigan Department of Agriculture for assistance.

Some suggestions on studying the manual are:

1. Find a place and time for study where you will not be disturbed.
2. Read the entire manual through once to understand the scope and form of presentation of the material.
3. Then study one section of the manual at a time. You may want to underline important points in the manual or take written notes as you study the section.
4. Answer, in writing, the self-help questions at the end of each section. Instructions on how to use the self-help questions in your study are included with the questions. These questions are intended to aid you in your study and to help you evaluate your knowledge of the subject. As such, they are an important part of your study.
5. Reread the entire manual once again when you have finished studying all of its nine sections. Review with care any sections that you feel you do not fully understand.

This manual is intended to help you use pesticides effectively and safely when they are needed. We hope that you will review it occasionally to keep the material fresh in your mind.

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INSECT PESTS OF VEGETABLE CROPS

Insect control programs ideally should be aimed at the most susceptible or vulnerable stage of development of the insect pest. Generally this is the immature stage. The immatures: (1) are less mobile than the adults and are therefore confined to a given area; (2) immature stages cause damage through their feeding, therefore, to prevent the damage, the immature stages must be controlled; and (3) immature stages do not reproduce—only the adults reproduce. By controlling the immatures, there are fewer adults to reproduce.

Under field conditions, there are many instances where the insect pests have two or more generations per year. Hence, if the crop is a full season crop (onions, potatoes), it will be attacked repeatedly. In these cases, it may be possible to control the second generation adults—especially in cases where the immatures live in the soil.

Type of Foliage: The various vegetable crops have characteristic foliage. In the case of lettuce, cabbage and spinach, the foliage is rather erect and stiff with relatively few leaves. On the other hand, potatoes, cucumbers, and tomatoes lie flat on the ground with a large number of small leaves. Between these two extremes are crops such as celery, peppers, carrots and other crops which grow erect with many leaves. The more leaves there are, the more dense the foliage becomes. The denser the foliage, the more difficult it becomes to achieve thorough and adequate coverage of the lower portions of the plants. Early season applications, when there is relatively little foliage, may be adequately and thoroughly made with 3 to 5 gallons of spray per acre. However, it stands to reason that by midseason and later as the amount of foliage and the density increase drastically, the amount of spray (gallons per acre) must likewise be increased to maintain thorough and adequate coverage of all the additional foliage.

Another factor to consider concerns the leaf surface. Some crops such as cabbage and onions have a very waxy leaf surface. This makes it difficult to keep the spray material on the leaves. In these cases, additional spreader-sticker or wetting agent may be helpful. The applicator must keep in mind, however, that leaf surfaces are highly variable in case of wetting. Hence, in some cases additional wetting agent or spreader may cause the spray to run off the leaf which results in less spray deposit on the leaf than would have been present if no additional wetting-spreading agent had been used.

<u>Insect Pests and Damage:</u> Insects can be separated into three groups depending on their mouth parts. The three kinds of mouth parts are: (1) chewing, (2) sucking, and (3) rasping. The type of mouth parts determines the type of damage caused by a given insect.

Examples of insects with chewing mouth parts are Colorado potato beetles (adults and larvae), cabbage loopers, cutworms, cucumber beetles, asparagus beetles, maggots and bean beetles. The damage consists of holes in the leaves and/or whole leaves and roots and stems being consumed. Insects with chewing mouth parts generally do not transmit plant diseases—with the exception of the cucumber beetles which transmits bacterial wilt of cucumbers.

Examples of insects with sucking mouth parts include aphids, leafhoppers and tarnished plant bugs. These insects pierce the leaf surface (like a mosquito pierces your skin) and suck out the plant juices. This results in the stunting of the plants and/or curling and wilting of the leaves. Also, in some cases there is plant reaction to the insect's saliva. Examples of this type of plant reaction are leafhopper "burn" in snap beans and potatoes. There is a yellow to yellowish-brown spot each place where the insects pierce the leaves. Another example is "black joint" of celery which is caused by the tarnished plant bug.

In addition to the feeding damage, insects with sucking mouth parts—namely the green peach aphid and aster leafhopper—transmit several plant diseases.

These diseases include leaf roll in potato, aster yellows in celery, lettuce, carrot and onion, and mosaic in peppers.

Insects with rasping mouth parts are thrips. Thrips rasp or scratch a small hole in the surface of the leaves and then suck up the juice as it runs out. In cabbage, these small holes heal over and turn brown and later black. In onions, tiny white streaks result, and as damage continues, the photosynthetic ability of the leaves decreases. No plant diseases are transmitted by thrips.

Insect Reproduction: Insects reproduce in two ways. One way is by sexual reproduction and the vast majority of insects reproduce in this manner. This method is somewhat limited in that only (roughly) half of the population deposits eggs, which incubate for several days before hatching. This results in 1 to 5 generations per year (depending on the specific insect).

The other method of reproduction is by parthenogenesis. All aphids reproduce by this method. There are only females, which means that every individual is capable of adding individuals to the population. Furthermore, young aphids are born alive so there is no loss of time in egg incubation. The net result is that aphids can pass through a generation in 5 to 7 days and increase up to tenfold in 10 days. There are 16 to 18 generations per year.

Method of reproduction and number of generations per year is extremely important in any insect control program.

Insect Microhabitats: One kind of insect may only be found in potato fields, another kind only in onion fields or cabbage fields. However, to effectively control the given insect you must know its microhabitat. This is where the insect actually lives on the plant. Some insects such as Colorado potato beetles, leafhoppers and flea beetles live and feed on the upper leaves. On the other hand, aphids prefer the undersides of the lower leaves. Other insect forms such as maggots, wireworms and white grubs live in the soil. These are examples of microhabitats.

To control the pest, the insecticide must be either originally placed in the microhabitat or in the case of the soil systemics it translocates (moves) through the roots and stems to the microhabitats of the foliage feeding insects.

Nonsystemic insecticides and foliar systemic insecticides do not translocate. Hence, they must be originally applied to the microhabitat or in the case of the foliar systemics, to or slightly below the microhabitat.

D. Ultimate Use of Crop: The commercial applicator should be sure that he knows the ultimate use of the crop he is treating. He should keep records of those crops that will be used for fresh market, those that will be processed directly out of the field and those that will go into storage for a period of time. The ultimate use of the crop is important in terms of when the crop will be harvested and enter the channels of commerce. This is important information in the selection of the chemical and the cut-off days before harvest.

Generally, those crops which go for fresh market (for example, lettuce, celery, some cabbage, potatoes, etc.) must be the most insect-damage free. This requires that the applicator properly apply the correct chemical in such a way as to control the pest before damage occurs and yet not have excessive residues.

Generally, processing crops can tolerate some insect damage because this damage will be "masked" in processing. However, crops that go into storage can break down in storage due to rot organisms entering through insect damage. Therefore, knowing the ultimate use of the crop can be very important in selection of the insecticide as well as knowing how much damage can be tolerated and still provide a marketable crop.

E. Timing—Seasonal and Time of Day: No insecticides, or other pesticides, can perform miracles! They must be applied at the right time to coincide with the appearance of the pest—and before the damage has been done. Most insects appear at about the same time each year. However, due to weather conditions they may vary 10 to 15 days in initial appearance from year to year. The commercial applicator should be knowledgeable of the approximate time of initial appearance as well when second, third and additional generations emerge during the season. To aid in "keeping tabs" on a given season's activity, commercial applicators should stay in close touch with their county Extension office as well as receiving the "Insect, Disease and Nematode ALERTS" issued by Michigan State University.

Another important factor concerning timing the application for maximum effect is the time of day when the application is made. To be most effective, the insecticide must be at present at a lethal level when the insects are active. Most foliage feeding insects are active between 65°F. and 85°F. Below or above these temperatures, control will be somewhat reduced.

Generally, insecticides should be applied in the late afternoon, evening, night, or very early morning. As a rule of thumb, application between 9:00 a.m. and 4:00 p.m. is not advisable because temperature and wind are too high. In addition, sunlight breaks down most insecticides so they are not available when the temperature returns to conditions for insect activity.

The foliar systemic insecticides are generally absorbed best when the plant stomates are open. Hence, they should be applied at temperatures between 65°F. and 80° to 85°F. This also corresponds to the insect activity range.

Types of Chemicals: The systemic insecticides have several advantages and disadvantages when compared to the contact (nonsystemic) insecticides. Advantages of systemic insecticides are that they: (1) enter the tissue and are not exposed to sunlight, washing off, etc: (2) move in the tissue to a greater or lesser extent toward the growing point: (3) give a day or two longer effective control because of 1 and 2: and (4) are very effective against small sucking insects (aphids, leafhoppers, etc.). The disadvantage is that systemic insecticides are not generally effective against large chewing insects.

The advantages of contact (nonsystemic) insecticides include: (1) they are effective against both small and large chewing (and sucking) insects: and (2) they are widely available and registered on most crops. The disadvantages include: (1) they are not absorbed into the tissue and so they mandate thorough coverage of all leaf and stem surfaces: (2) they remain on the surface of the leaves and thus are exposed to sunlight, washing off, etc.: and (3) they are generally effective for 2 to 3 days (depending on weather, etc.).

Applicator Responsibility: The commercial applicator must fully realize that he is responsible for proper application, using only registered chemicals and disposal of "empty" containers and excessive spray material.

Days to harvest, tolerances and residues: All pesticides which are registered for use on vegetables (and other food crops) must have a tolerance (established by U.S. Food and Drug Administration). To meet the tolerance level, residue samples are taken during the development of the chemical to determine the "cut-off days before harvest." The cut-off days before harvest vary from crop to crop for a given chemical. This variation concerns leaf surface properties, plant growth habits, and chemical properties of the given insecticide as it reacts on the plant surface. The commercial applicator must be aware and READ THE LABEL EVERY TIME he applies the chemical to be sure the cut-off days before harvest will not be violated.

Spray coverage: There are several ways the applicator can check to see whether thorough coverage is being obtained. These include: (1) checking for the white residue of wettable powders after the application has dried on the foliage and (2) use of paper cards or other indicators placed at the site in the foliage where coverage is most difficult. REMEMBER—coverage must be obtained where the insects live and feed (microhabitat). Obviously, if the coverage is not being properly obtained, corrective adjustments must be made. These adjustments may include: (1) increasing the gallonage, (2) changing the nozzles, (3) flying higher or lower, (4) use of drop-nozzles, (5) using more nozzles, and (6) changing the type of spraying equipment altogether.

Environmental factors: Environmental factors such as temperature, sunlight, and relative humidity function together to shorten (breakdown) the residual time of pesticides. Wind is another important factor because of drift. Drift is undesirable because the drifting chemical is "lost" into the surrounding environment and thus it is not available in the target foliage to control the pest. Furthermore, drift can contaminate adjacent crops and/or livestock, homes, water, etc. Hence, the commercial applicator must be especially aware of drift and its potential problems.

Pesticide compatibility: Pesticide compatibility refers to the mixing of two or more pesticides in the tank at the same time. Some of these compatibilities and incompatibilities are given in the various Cooperative Extension Service publications. Additional information is given on the label and/or from the various companies.

"Gross" chemical compatibility can be checked by mixing a small amount of the chemicals in the proper amounts and allowing them to stand for at least one-half hour to see whether they precipitate or heat up when mixed. However, you should be aware that subtle chemical changes can take place which will not appear in the gross check but nonetheless will render the combination less effective or (worse yet) ineffective.

Another type of incompatibility results in plant phytotoxicity. This can happen even though the chemicals are chemically compatible. To check for phytotoxicity, a small area (few plants) should be treated. If no plant injury is apparent in 1 to 2 days after application you can be reasonably sure that the remainder of the crop can be treated without phytotoxicity occurring.

Little is actually known about compatibility-incompatibility due to the vast number of possible combinations, formulations, crops and weather conditions. For these reasons you should always be very cautious when mixing pesticides. It is ALWAYS better to be safe than sorry!

## SELF-HELP QUESTIONS

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. At which stage is an insect generally most vulnerable?

2. How does a waxy leaf surface affect the retention abilities of a pesticide?

3. Explain what kind of damage results from insects with (a) chewing mouthparts; (b) sucking mouthparts; (c) rasping mouthparts.

4. What is parthenogenicity?

5. Is it necessary to know the microhabitat of a pest in order to control it effectively?

6. How does knowing the ultimate use of a crop affect the selection of an insecticide?

7. In general, at what time of day should insecticides be applied?

8. Are systemics generally effective against small sucking insects?

9. Is the commercial applicator responsible for disposal of empty pesticide containers?

10. Should a commercial applicator read the label every time a chemical is applied in order to be sure the cut-off days before harvest will not be violated?

11. List five ways to adjust the rate of pesticide application.

12. Why is pesticide drift undesirable?

13. How can you check for gross chemical compatibility?

# WEED PESTS OF VEGETABLE CROPS

## Why Control Weeds?

WEEDS REDUCE VEGETABLE CROP YIELDS by competing for water, nutrients and light. Some weeds release toxins that inhibit crop growth, and others may harbor insects, diseases, or nematodes that attack crops. Weeds may interfere with harvesting operations, and in some instances, contamination with weed seeds or other plant parts may render a crop unfit for market. It is obvious that profitable crop production depends on effective weed control.

You should never attempt to establish a vegetable crop in a field that is badly infested with perennial weeds such as quackgrass, yellow nutsedge, or Canada thistle. Herbicides and tillage should be used to control these pests at least one year in advance.

Usually, effective weed control in vegetable crops requires a combination of management techniques. You may need to use a combination of different herbicides or alternative methods. In some cases, minimizing tillage can effectively reduce weed populations. Growing the same crop year after year, and using the same weed control techniques will encourage the development of problem weeds. Rotation of crops, herbicide or tillage methods can help solve this problem. Whenever you see a small infestation of a problem perennial weed invading a field, it should be eradicated immediately. Wherever possible, weeds should be prevented from producing seed. One plant can produce thousands of seeds, and these seeds will live in the soil for many years.

Types of weed pests: Weeds may be classified according to their life cycles, habits of growth, or general appearance of their leaves and stems.

Annual weeds are plants which complete their life cycle from seed to seed in one year. If they germinate in the spring, grow mature, and produce seed that summer they are called summer annuals. Examples are large crabgrass and redroot pigweed. Plants that germinate in late summer, overwinter, and produce seed the next spring are called winter annuals. Examples of winter annuals are common chickweed and shepherdspurse.

Annual weeds reproduce primarily by seed. Single plants of some species may produce hundreds of thousands of seeds per year. Only a small percentage of these seeds germinate the next season but many more seeds can remain viable in the soil for a period of several years.

Annual weeds reproduce primarily by seed. Single plants of some species may produce hundreds of thousands of seeds per year. Only a small percentage of these seeds germinate the next season but many more seeds can remain viable in the soil for a period of several years. Annual weeds should be controlled when they are small and whenever possible, seed production should be prevented.

Biennials are plants which complete their life cycle in two years. They typically have a juvenile stage the first season and then produce a seed stalk the second year. Examples of biennials are white cockle and wild carrot.

Perennials are plants which live for more than two seasons. They are often grouped into two categories according to their reproductive mechanisms. (1) "Simple" perennials reproduce primarily by seed and may possess thick fleshy roots capable of regenerating a plant; however, unless they are mechanically cut or disturbed they do not generally reproduce from roots. Plantain and common dandelion are examples of this group. (2) "Creeping" perennials are those which commonly reproduce from creeping vegetative organs. These may be aboveground (stolons) or underground (rhizomes) rootstocks as in quackgrass and field bindweed. Perennials such as nutsedge and Jerusalem artichoke also reproduce by tubers (underground swollen stems) whereas wild garlic can reproduce by bulbs in the soil and small bulblets produced on top of the plant.

Creeping perennials and those possessing tubers are the most difficult perennial weeds to control. Cultivation and other mechanical means of control can result in increased populations due to propagation by these vegetative organs. More details on perennial weeds including color pictures and descriptions of 40 common species are available in Extension Bulletin 791.

Weeds may also be designated as broadleaved species or grasses. This is usually done because herbicides are often toxic to one type and not the other. Weeds which have succulent stems are called herbaceous weeds. Those with hard stems that resemble vines, trees or shrubs are classified as woody plants. Poison ivy, Virginia creeper and dewberries are examples of woody perennial weeds.

Principles of herbicide use: Herbicides are used either on the foliage of weeds or through the soil to kill germinating weed seeds. Some chemicals have both foliar and soil activity.

Foliage applications: These treatments are made to leaves of growing plants, usually as liquid sprays. They kill plants by two methods—contact or translocation.

Contact treatment kills only the plant parts actually contacted by the herbicide. However, the noncontacted parts (i.e., roots) may die because they are deprived of the leaves. Adequate distribution of the herbicide over the foliage is essential. Selectivity may depend upon arrangement and angle of leaves, differential wetting, location of growing points, or upon spray placement. Contact herbicides are most useful to control seedlings. An example of a nonselective contact herbicide is paraquat.

Translocation kills the entire plant because the herbicide moves within the plant. For example, when applied to the leaves the herbicide is translocated to the roots. It may also move from older leaves to young growing points. Therefore, herbicides of this type are used on perennial plants as well as annuals. For example, 2,4-D is a translocated herbicide that is widely used to kill emerged broadleaved weeds in corn.

With foliar herbicides, many factors influence the movement into the plant and the responses can vary. More consistent results are obtained and variability may be explained if these factors are known.

Proper application: Rate and concentration of herbicides are important and therefore uniform application and proper choice of gallonage is necessary. Although uniform distribution of systemic-type herbicides is not as critical as for soil applications, too high a rate can cause decreased long-term kill.

Uniformity of concentration and delivery rate is essential; therefore, correct nozzles, sprayer speed, agitation, pressure and dilution are important.

Interception by leaves: Leaf angle, degree of hairiness, expansion, and leaf area-dry weight ratio influence response. In annuals, greatest concentration per unit area of dry weight is obtained in seedling stage. In perennials, the greatest ratio occurs later so treatment should be delayed until considerable growth has developed. A canopy of leaves can be a deterrent to effective control or a safeguard against injury. Wetting conditions will affect interception by changing leaf orientation and reducing leaf area.

Retention: Keeping spray droplets on the leaf is an important consideration once contact with the leaf has been made. Type of leaf surface such as waxy coating, pubescence, and roughness affect retention. Retention can be increased by use of wetting agents and other materials that lower surface tension, nonpolar formulations (esters) and low spray volumes.

Rainfall will cause run-off if it occurs shortly after or during application. With many herbicides, one to two hours after application without rain will allow for penetration. Herbicides also volatilize from leaf surfaces when exposed to high temperatures.

Absorption: This phenomenon varies with each herbicide, formulation, plant species, and environmental factor. Thickness of the cuticle (waxy coating) has a direct relationship. Uniform leaf coverage is essential for maximum penetration. Penetration may be both an active and a passive process. High humidity, high soil moisture and conditions that favor rapid growth increase absorption. Stomata that are open may be an avenue of entry for volatile herbicides and those of low surface tension.

Translocation: Downward movement is through the phloem (living tissue) and is favored by production of assimilatory material and growth processes. Herbicides tend to move to regions of activity such as buds, young leaves, seed, storage organs and meristematic areas. Excessive application rates or contact injury reduce translocation and are factors to consider in herbicide combination. In a few cases, herbicides have recycled in a plant. Movement out of the plant roots or excretion of herbicides have been shown under certain conditions. This will reduce the amount available to the plant and plant responses will be altered accordingly.

Activation and deactivation: Some herbicides (2,4-DB) are activated by an enzyme system after entering the plant (B-oxidation) while others (atrazine in corn) are deactivated by being metabolized or complexed with cell constituents such that they are not available to exert phytotoxicity. The rate or degree of degradation is influenced by conditions affecting plant growth, i.e., temperature, sunlight, soil moisture.

Accumulation: The rate of absorption and translocation affect accumulation. Accumulation at the sites of action, generally meristematic regions, varies with species and rate of degradation at these sites. Environmental factors that influence metabolism and other mechanisms at the site of action will influence plant response.

Cellular sensitivity: Ultimate response of a plant to a herbicide is at the cellular level. Susceptibility varies during the season and with the season. Maturing plants develop varying levels of tolerance. Mature tissues or those of low metabolic activity will show little response to a concentration that would have been injurious at an earlier stage of growth.

Soil applications: These treatments are usually applied to the surface of the soil but may also be incorporated into the soil by cultivation, or injected below the soil surface.

Timing of the application in relation to the growth stage of the weeds and crop is important. The application may be made preplant, preemergence or postemergence as related to the growth stage of the crop plant.

Surface moisture must follow surface treatment for most soil-applied herbicides to be effective; you will obtain best results when these herbicides are carried into the soil by rainfall, or overhead irrigation..

The tolerance of vegetable crops to soil soil-applied herbicides depends to some extent on keeping the herbicide placed in the surface half-inch of soil. If there is excessive leaching of the herbicide into the termination zone, injury can result. For this reason, less herbicide should be used on coarse-textured sandy soils that are low in organic matter or clay content. It also takes less herbicide to control weeds on these soils because they are not readily tied up.

Before using a herbicide, be familiar with its residual life in the soil. Some herbicides may persist in the soil for extended periods, which will influence other cropping plans the same season or the next season.

Herbicide applications may be further defined based on the area treated. Applications may be further defined based on the area treated. Applications over an entire area of foliage or soil are termed broadcast applications. In contrast, applications in a strip along a row of plants are called band applications. Sprays that are aimed at the base of plants and kept off the foliage are called directed sprays. When localized weeds or clumps of weeds are sprayed with a hand sprayer this is termed "spot" spraying.

Many factors may have an effect on how well soil-applied herbicides move to the site of action. A knowledge of these factors involved in the transfer of a herbicide from applicator, through the soil, and to the plant is helpful in obtaining more consistent responses or in explaining some of the variability.

Proper application: The use of the correct rate of application is essential. Very small amounts are necessary to inhibit plant growth. However, sufficiently high rates must be used to compensate for the amount bound to the soil or otherwise made unavailable for uptake by the plants. Rates must not be of the magnitude to cause crop injury or soil residues.

Uniformity of distribution over the sprayed surface is important. Nozzles must have a uniform delivery, a uniform spray pattern, even spacing and proper height to give uniform coverage. Water volume is not important if there is a constant concentration and uniform distribution. Constant pressure and speed are necessary. Granulars present a greater problem in obtaining uniformity.

Soil interception: An even, uniform surface, free of clods, manure, plant litter and other debris will help insure a good distribution pattern. Spray droplets cover the upper surfaces of clods, but not beneath, while granulars fall in depressions. Granular formulations again present a greater problem or uneven surfaces.

Physical movement: Wind and water (excessive rainfall) cause run-off or movement from treated area. Movement is to depressions, causing increased concentrations in these areas. Some leaching into the soil is necessary for effective control. Incorporation into the soil will benefit some herbicides but distribution may be uneven or placement too deep. Band applications are lost when untreated soil is moved in by the cultivator.

Volatility: This is a major form of loss for certain herbicides. High soil temperatures and air movement increases volatility losses. Damp or wet soil at time of application can cause additional losses through water vapor distillation or by keeping the herbicide concentrated in the exposed surface layer as water moves to the surface. Incorporation reduces volatility losses.

Photodecomposition: Many herbicides are broken down by exposure to sunlight. Losses occur when herbicides remain on the soil surface for extended periods.

Solubility: Movement into the soil is related to solubility; therefore, salts will move more readily than wettable powders. Additional rainfall is needed to get wettable powders into the upper one-fourth to one-half inch of soil.

Movement in soil: Water transport provides for the greatest amount of herbicide movement in the soil. This occurs primarily when there is sufficient water to exceed field capacity. Diffusion in soil water is important only in the vicinity of roots. Diffusion in soil gasses plays a part if the herbicide is quite volatile. Greatest movement is downward; however, some lateral and some upward movement occurs. Movement varies greatly in different soil types.

Degradation: Breakdown of the chemical is by chemical and biological processes. Temperature, aeration, pH and other soil factors will affect chemical processes such as hydrolysis and oxidation. The degradation by micro-organisms is one of the major means of herbicide loss from soil. Organisms may be specific for a particular herbicide and their numbers will increase when repeated applications are made. Conditions that favor growth of micro-organisms will speed breakdown.

Adsorption: A great deal of variability exists in the amount of herbicide adsorbed by soil since soils vary in organic matter and inorganic soil colloids. Organic matter adsorbs more strongly and thereby greatly reduces the amount of chemical available and also retards movement in soil. Randox (CDAA) is an exception in that it is more effective in high organic matter soils.

Absorption: This is the means of entry into the plant and it is favored by conditions that favor high transpiration rates. The amount of root system exposed is important since amount of herbicide absorbed is generally proportional. A heavy plant population may reduce amount absorbed by any one plant as well as concentration of herbicide in soil.

Translocation: Upward movement is primarily in the xylem (nonliving tissue) and concentration is in areas of most rapid water loss. Rather high concentration is in areas of most rapid water loss. Rather high concentrations of herbicide can be moved since living tissue is not involved once the chemical reaches the vascular system.

Activation and deactivation: Some herbicides (2,4-DB, Sesone) require activation either in the soil or plant. Other herbicides may be deactivated in the plant by metabolism or modification. Active and inactive metabolites or complexes may be formed. Selectivity may be obtained by these processes.

Accumulation: There is a threshold concentration for phytotoxicity. Amount taken in must be greater than the amount degraded or eliminated. Conditions that affect absorption, translocation or degradation will reduce the accumulation of toxic concentrations.

Cellular sensitivity: Plant response is due to sensitivity to a certain concentration of chemical. Species vary greatly in tissue structure. Environmental conditions and tissues' maturity play an important role. Mature tissue generally shows less activity and older plants are less likely to be killed.

## Preventing Herbicide Injury

Although herbicides offer an effective and economical means of control, certain risks are inherent in their usel Plant injury is one of these risks. No plant is completely resistant to herbicide injury, but any plant tolerates certain dosages. Selectivity, or the ability of a herbicide to kill weeds without harming plants, may be partially lost under adverse environmental conditions. Careless application can also result in injury to a customer's plants or those of a neighbor. Injury can range from complete destruction of plants to slight stunting or discoloration which often has no long-term adverse effect. More details on prevention and diagnosis of herbicide injury can be found in Extension Bulletin 809.

Make sure spray equipment is designed and operated properly: Faulty application equipment or improper use of equipment can lead to overdosing which causes crop injury or underdosing which gives poor weed control. Herbicide sprayers are designed to apply chemicals uniformly over a given surface area. Application rates are determined by the speed, pressure, nozzle size and the amount of chemical added to the diluent (usually water). Nozzles designed specifically for herbicide application (flat fan or even spray) should be used rather than cone-type nozzles used for other pesticides. Improper spacing of nozzles can cause overlapping and result in a banded injury pattern.

Equipment should be calibrated periodically to assure that the desired gallonage is being delivered. When nozzles become worn (particularly by abrasive wettable powders) the flow rate can increase and result in overdosing or uneven application.

Frequent checks on tractor speeds and line pressure during application will insure uniform application rates. Injury occurring on slopes could result from overdosing if the sprayer were slowed down as it climbs the hill.

Proper agitation in the spray tank is essential if uniform distribution is to be obtained. Failure of the agitation system can cause settling of the spray material, and overdosing may result in the areas that are first sprayed.

Sprayer calibration: One of the most important factors in effective weed spraying is accurate calibration—determining the amount of spray material applied per acre. A range of 20 to 60 gallons per acre, at a pressure of 20 to 60 pounds per square inch, is satisfactory.

Adjust the boom height so that the spray overlaps about a third at ground level. For overall spraying, using 80 degree nozzles, this places the nozzles about 18 to 20 inches apart on the boom and 18 to 20 inches from the sprayed surface.

A good way to calibrate a sprayer is to:

1. Fill the spray tank with water only.
2. Spray a measured area, in a field if possible, at a fixed tractor speed and pressure gauge setting. Be sure to allow for partial coverage if bands are used.
3. Measure the amount of water needed to refill the tank.
4. Divide this amount by the fraction of an acre sprayed to get the gallons applied per acre.
5. Mix the amount of chemical desired per acre with water to give this much spray material.

For example, if 10 gallons were applied on one-fourth acre, the volume of spray material applied would be 40 gallons per acre. If you change the tractor speed or gear pressure setting, nozzle size, or number of nozzles, the amount of liquid applied per acre will be different and recalibration will be necessary.

Cleaning weed control sprayers: It is important to keep weed control sprayers clean. This is especially true if you use them to spray more than one crop or to apply fungicides and insecticides.

Do not use a sprayer to apply either insecticides or fungicides if the sprayer has contained 2,4-D type herbicides.

When cleaning a sprayer, thoroughly rinse the whole sprayer with water, inside and out, including boom, hoses and nozzles, both before and after cleaning. Partially fill the sprayer with water before you add the cleaning agent. Keep the pump running so that the cleaning solution will circulate throughout the sprayer. Do not leave corrosive cleaning agents in the tank or spray system more than two hours.

When you are using only pre-emergence sprays, a good rinsing with water is enough. For other spraying purposes, remove weed killers from sprayers by adding 1 gallon of household ammonia or 5 pounds of sal soda to 100 gallons of water. Allow this solution to stand in the sprayer for at least two hours. Drain it out through the boom and nozzles, and rinse the sprayer with water. Do not let spray solutions stand in the tank overnight. Do not allow solutions to run into streams or other water sources.

SELF-HELP QUESTIONS

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. Can minimizing tillage effectively reduce weed populations in some cases?

2. Explain difference between simple and creeping perennials.

3. What stage of plant are contact herbicides most useful in controlling?

4. Are translocated herbicides effective against both annuals and perennials?

5. What can result from too high a rate of herbicide?

6. List four factors influencing herbicide interception by leaves.

7. How can retention be increased?

8. Does thickness of the cuticle affect absorption?

9. Do translocated herbicides tend to move to the roots?

10. List three factors affecting the rate or degree of degradation of herbicides.

11. Does the rate of absorption affect accumulation?

12. What are band applications?

13. Does water volume affect proper application if there is a constant concentration and uniform distribution?

14. Is some leaching into the soil necessary for effective control when using soil applied herbicides?

15. What is photo-decomposition?

16. Does any lateral movement of herbicides occur in the soil?

17. How does organic matter affect adsorption?

18. Can some herbicides be deactivated in the plant?

19. How do mature plants differ from young plants in sensitivity to herbicides?

20. What is herbicide selectivity?

# CAUSES OF VEGETABLE DISEASES

Diseases of vegetable crops are caused by organisms (biotic agents) which derive their nutrients by feeding on other plants. Some diseases are also caused by adverse environmental factors (abiotic factors) which cause the vegetable plant to malfunction. Fungi, bacteria, viruses, nematodes and mycoplasma are the living organisms which can cause plant disease. Toxic chemicals, low or high nutrient levels, adverse temperatures and too much or too little water are some of the environmental factors which can also cause plant disorders. Both cultural and chemical methods are used to control plant diseases. In the following discussion biotic agents as the cause of plant disease and chemical pesticides as control agents will be primarily discussed.

## Disease Cycles

All vegetable diseases caused by biotic agents have a disease cycle, i.e., a pattern or sequence of development. Usually control measures must be applied at specific stages in the disease cycle if they are to be effective. If the disease is wrongly identified, or control measures poorly timed or misapplied, disease control will be disappointing, at best. Improper timing of sprays is one of the most common reasons for poor disease control.

Disease cycles are of two kinds: primary and secondary. The primary cycle is initiated by the biotic agent (pathogen*) after a period of dormancy or inactivity. In Michigan this occurs usually in spring after the winter rest period.

* A microorganism capable of causing a plant disease

Secondary cycles occur as a result of pathogen propagules (inoculum) produced during the primary cycle of disease development. During a growing season a pathogen may have several secondary cycles, but only one primary cycle.

During a disease cycle, the pathogen passes through several stages, and knowledge of any or all stages may be necessary to effect satisfactory control. These stages may be listed as: (a) dormancy, (b) primary dispersal, and (b2) innoculation, (c) incubation, (d) multiplication, and (e) secondary dispersal after which stages b2, c, d, and e may be repeated several times during the growing season. The length of each stage varies with the environment, the pathogen and the condition of the host plant.

Dormancy stage: During dormancy the pathogen is inactive. The inactivity may be temperature or moisture induced or may be induced by the absence of a satisfactory host. Fusarium wilt of vegetables is a warm temperature disease and the organism cannot become fully active until soil temperatures are sufficiently high. The sclerotia of *Sclerotinia sclerotiorum* will not germinate to produce the sexual stage. When temperatures are no longer limiting many pathogens still will not initiate growth unless a suitable host is present. Some fungus structures, nematode eggs, etc., will not develop unless growing plant exudates are present.

Primary dispersal and inoculation: Some pathogens wait for the host to come to them, others break dormancy and produce propagules which are liberated and dispersed by wind, water, insects, or man. Usually this activity is temperature induced and coincides with a particular stage in the development of the potential host. The primary dispersal stage ends when the propagule is deposited on a suitable host.

The act of inoculation consists of placing the pathogen in a location on the host (the infection court) where further development can occur. The terminal point of dispersal may be inoculation if the pathogen has been deposited in the right location on a suitable host.

Sources of inoculum (propagules of the pathogen) may be diseased crop refuse, living plant parts (seeds, transplants, fruit, leaves, etc.) or contaminated tools and equipment. Infection courts are such areas as wounds, healthy plant surfaces (leaves, fruit) or natural openings in the plant (stomata, nectaries, lenticels).

Incubation stage: This stage in the disease cycle is the time between inoculation and the first expression of disease symptoms. The length of this stage is determined by three interrelated factors: the host, the pathogen and the environment (temperature and moisture, primarily). During this stage the pathogen must infect and establish itself within the host. If conditions are not proper, disease will not occur.

Multiplication stage: After the pathogen has established itself, it grows through the host tissues causing disease which is expressed as wilt, leafspot, fruit rot, cankers, galls, and other symptoms. Eventually the pathogen develops reproductive structures which may not be dispersed until the plant dies and decays, or they may be produced in such a way as to be carried off by wind, water, insects and/or man while the host plant is still partially alive. These reproductive structures are secondary inoculum and when dispersed constitute the secondary dispersal stage of the disease. This latter inoculum may cause secondary disease cycles which usually occur during the summer or growing season of a given crop.

## Examples of Vegetable Disease Cycles

Many vegetable crops are grown in Michigan and each one has one to several diseases affecting it which may cause minor or severe crop losses depending on the growing conditions (environment) during a given year. Most vegetable crops are annual in Michigan, hence severe disease losses during one year do not necessarily mean severe losses in subsequent years, even in the same field.

Many textbooks have been written on the subject of vegetable diseases, hence for the purpose of this manual only a few representative diseases will be discussed in detail. The emphasis will be given to points in the disease cycle where weaknesses occur and control practices can be most judiciously applied. For information on other diseases of vegetables contact your county Extension office or Michigan State University.

Black leg of cabbage: Black leg is caused by a fungus, Phoma lingam. The disease occurs mainly in the temperate zone where ever its cruiferous hosts are found. It is one of the most destructive diseases of cruifers; however, due to effective control measures it is seldom a severe problem anymore.

Symptoms: Plants can be infected during any stage of growth from seedling to maturity. Usually the first symptom is an oval, depressed tan canker near the base of the stem. The canker enlarges until the stem is girdled. Circular tan spots also appear on the leaves and elongate lesions occur on the seed stalks and pods of seed plants. In the cankers, spots and lesions numerous tiny black dots appear. These are fruiting (reproductive) structures of Phoma lingam. The presence of these structures is an important diagnostic sign (a visible structure of the fungus). Badly diseased plants wilt and leaves brown or turn bluish-red at the margins. The stem canker may cause the plant to lean or fall over.

Disease cycle (primary): The fungus can survive in crop residues and soil for up to three years. It also is carried on and in the seed. When infected seed is planted the fungus infests the soil and can attack nearby healthy seed and seedlings. Also, some diseased seed grows allowing direct attack of the seedling produced. And where previous crop residues are present seedlings may also be attacked from this source of inoculum. Lesions and spots produced by this primary inoculum soon produce black fruiting structures (pycnidia), which produce spores.

Disease cycle (secondary): Spores produced in the pycnidia of the primary lesions, etc. are liberated when temperature and moisture conditions are satisfactory. These spores may be dispersed by wind, rain and cultivation tools to new areas on the same plant or other plants where new infections will occur. This secondary spread within a field can occur repeatedly during the growing season.

In this disease the stopping of primary spread (seedborne stage) is critical to disease control.

Tomato and Potato Late Blight

This major and highly destructive disease of potatoes and tomatoes is caused by the fungus Phytophthora infestans. This fungus shares the distinction, along with a few others, of having 'changed' the course of history, because it was directly responsible for the potato famine in Ireland and Europe which caused a large number of these people to immigrate to the United States.

Symptoms: The disease attacks all parts of its hosts. An infection is first evident by the appearance of circular or irregular watersoaked spots on the foliage, usually on the lower leaves. These spots rapidly enlarge destroying the leaves and stems of the plant. During rains spores produced in the spots are washed onto fruits or down the stem into the soil where they can infect the potato tubers.

On tomato fruits dark, olive-green, greasy-appearing spots develop which enlarge to rot the entire fruit. On potato tubers in irregular, purplish-black or brownish blotch appears which becomes firm, dry, and somewhat sunken.

The foliage and fruit symptoms can develop and spread as long as conditions remain moist or until the host is destroyed. Once infected, fruit and tubers will continue to breakdown in storage producing watery putrid mush from which nothing can be salvaged.

Disease cycle: The disease survives as mycelium (vegetative fungus strands) in tubers in storage, in the field, in cull piles or dumps. This is the primary inoculum. In more temperate climates it may survive on cultivated or wild host plants in nature. When infected tubers are used for seed the fungus attacks the tuber sprouts and grows to the aboveground shoots. Under favorable conditions of moisture and humidity the fungus readily produces spores which are windborne or waterborne (initiation of the secondary cycle) to healthy plant tissues. Tomatoes may be infected by this windborne inoculum from potatoes. However, more commonly, the initial infection in tomatoes occurs in seedlings grown in the southern United States and transported to Michigan. From these infected seedlings secondary spread to healthy plants readily occurs.

Temperature and humidity are very important to the development of this fungus. Fungus reproduction or sporulation occurs most abundantly at or near 100 percent relative humidity and at temperatures between 16$^{o}$C. and 22$^{o}$C. The propagules lose their viability in 3-6 hours at relative humidities below 80 percent. On the other hand, the period of time from inoculation of a plant to sporulation (first crop of secondary spores) may be as short as 4 days; thus, inoculum levels can build up to epidemic quantities in a short time. Hence, knowledge and surveillance of these factors are critical to control of this pathogen.

Fusarium Wilt of Vegetables

The genus *Fusarium* has several species of fungi which can cause severe plant and crop losses. In particular, the species *F. oxysporum* contains several variants which affect specific crops. Hence, the fungus *F. oxysporum f. batatas* causes a wilt disease of sweet potato, *F. oxysporum f. pisi* causes a wilt disease in peas, *F. oxysporum f. melonis* causes a wilt disease in muskmelons and cantaloupe and *F. oxysporum f. lycopersici* affects tomatoes. In all instances the process of infection and disease development is similar; hence, for purposes of this discussion, the wilt disease of celery, "Fusarium yellows;" will be discussed.

Fusarium yellows of celery is caused by *F. oxysporum f. apii* which is a soil inhabiting fungus which can remain alive for many years after it is introduced into the soil even if susceptible host plants are not present.

Symptoms: The fungus invades the root system of the plant causing a deterioration of the root system and a malfunction of the vascular elements (water ducts). As a result the affected plant is stunted, pale green ("yellows"), and the tissues are brittle and bitter. If infected as a seedling the plants soon die, older plants, however, may live as long as healthy individuals even though they are dwarfed and pale green. When the stalk is cut longitudinally through the base an internal yellow to red or brown discoloration can be seen extending upward in the vascular tissues.

Disease cycle: Fusarium, once introduced, remains viable in the soil for many years. Usually the initial introduction is made by diseased seedlings, or the soil carried with them (primary spread). Once in the field it may be further dispersed by water, and soil movement and contaminated farm equipment or infected plant parts (secondary spread).

When seedlings are planted the fungus propagules are stimulated to activity and can produce structures which penetrate the root of the seedling directly or through injuries to the roots caused in transplanting. From the roots the fungus grows throughout the plant via the vascular tissues. From the time of inoculation until symptoms are expressed requires about 20 days under normal growing conditions. Since infected plants are not marketable they remain in the field and as they decay add to the fungus inoculum already present.

Soil moisture levels are not critical for Fusarium activity. However, soil temperatures between 68°F. and 90°F. allow maximum fungus activity and favor disease development.

Bacterial Wilt of Cucurbits

This disease caused by the bacterium *Erwinia tracheiphila* can attack several members of the plant family Cucurbitaceae. Cucumbers, muskmelons, pumpkins, squashes, gherkins, white gourds and numerous wild cucurbits are susceptible. Watermelon is rarely infected.

Symptoms: The first symptoms of disease are the drooping (wilt) of one or more leaves on the vine. This mild wilt is quickly followed by the wilting of whole canes and finally the entire plant collapses as the bacterium moves throughout the vascular system. The incubation period for bacterial wilt is usually less than a week and the whole plant is invaded in 12 to 15 days. In less susceptible plants like the squashes the infection sometimes progresses more slowly resulting in a dwarfing of growth along with excessive blossoming and branding. Fruit production is reduced and of inferior quality.

When the tissues of infected plants are cut droplets of bacterial ooze (a creamy, gummy liquid) can often be squeezed out. However this is not always a dependable way to determine the presence of the bacterium.

Disease cycle (primary): The pathogen overwinters in the body of the striped and 12-spotted cucumber beetles. In the spring when the beetles begin to feed, the bacterium is transferred to the feeding wounds on the plant in the fecal matter of the beetle.

The relationship between the beetle and the bacterium is an obligate one as it has been shown that if the bacterium is eradicated the beetle also disappears. Also the bacterium is not able to enter the plant unless introduced into major wounds such as those created by the feeding of the beetles.

Secondary spread (secondary disease cycle) occurs when beetles feed on infected plants and contaminate their mouthparts with the bacterium. Once contaminated in this manner, the beetle is capable of infecting the next 3 to 4 plants on which it feeds.

In this disease knowledge of the beetle (vector) and its relationship to the bacterium is essential to control.

Sclerotinia Diseases

Sclerotinia sclerotiorum is a fungus which has a wide host range in the vegetable crops and causes diseases which have a variety of common names. It is called "white mold" or "cottony soft rot" in beans; it causes "pink rot" and "damping-off" in cauliflower and celery. Sclerotinia disease in soybeans, squash, spinach, sweet potatoes, Swiss chard and tomatoes is called "timber-rot," or "wilt." "Petiole-rot" in parsley, parsnips, onion, and lima beans, "canker" in pumpkin and radish, and "watery soft-rot" in turnip, watermelon, cucumber, carrot and cabbage may all be caused by Sclerotinia sclerotiorum. In Michigan lettuce, carrots, celery, beans, tomatoes, and onions are among the major vegetable crops affected.

Symptoms: The pathogen may attack its host at any stage of development. In seeds and seedlings it causes a damping-off disease and the young plant may be destroyed in less than a day if environmental conditions are favorable to disease development. The pathogen is a soil inhabitant, hence when it does attack a plant it is usually through the roots or stem or a portion of the plant that has contacts with the soil. When roots are attacked the symptoms are a gradual decline of the plant—lower leaves yellow and die, growth is reduced, and wilting may occur. When the stem is attacked the above symptoms are also expressed; however, the affects may be onesided at first, followed by general wilt and decline as the stem is gradually girdled. Whenever an aboveground plant part is attacked symptoms are usually accompanied by a cottony, white fungus growth and the development within this mycelial growth of black, hard structures which may be one-sixteenth to one-half inch in diameter. These structures are called sclerotia and enable the fungus to survive between crops and during unfavorable climatic periods.

<u>Disease cycle</u>: <u>Sclerotinia sclerotiorum</u> survives as sclerotia in the soil or in diseased crop residues. The sclerotia require a period of low temperatures before they will germinate to produce the spore stage of the organism. When this occurs the sclerotium produces a saucer-shaped structure on a stalk, in which many spores are produced. These spores are forcibly liberated from the saucer and are air dispersed. If not subjected to cold, the sclerotium will simply produce mycelium which can grow through the soil to infect susceptible crop tissues which have been planted near it.

Whether spores or mycelium are the primary inoculum, as soon as new host tissue is invaded more sclerotia are produced to aid in the secondary spread of the disease.

## VEGETABLE FUNGICIDES AND BACTERICIDES

Chemically, fungicides may be divided into inorganic and organic types. The inorganic materials, such as sulfur, copper and mercury compounds, were the earliest fungicides used in commercial vegetable production. Many of these early compounds have now been replaced by organic fungicides, which are generally less phytotoxic and more effective than the inorganic compounds.

### Inorganic Fungicides

#### Copper Compounds

Bordeaux mixture has been used for nearly 100 years for disease control. Consisting of soluble copper sulfate mixed with hydrated lime in water, it is used as a spray. The lime safeguards the mixture and improves control by sticking the copper onto the plant.

Bordeaux mixture is seldom used for the control of vegetable diseases due to its phytotoxic properties. It is, however, sometimes used for late blight control in potatoes when severe disease condition exist. In a 2-6-100 Bordeaux, for example, the first figure of the formula is copper sulfate in pounds, the second figure is spray lime in pounds, and the third figure is water in gallons. Homemade Bordeaux is superior to prepared dry mixes.

Bordeaux has many compatibility problems. Before combining with other pesticides, check the compatibility chart and read the label container carefully, especially of the material you wish to add to the Bordeaux. In addition, Bordeaux is often somewhat phytotoxic to fruit and foliage when applied under cool, slow-drying conditions. Damage consists of fruit russetting and some spotting of tender foligage.

The "fixed," or "insoluble," copper compounds are sometimes used in place of Bordeaux mixture for disease control. There are several fixed copper products available, containing either basic copper sulfate, basic copper chlorides, copper oxides, or various other formulations. These formulations are used for the control of downy mildew of cruifers, early and late blight of celery, bacterial blights of beans and cucurbits and anthracnose and other leaf spots of various vegetable crops.

Sulfur Compounds

Sulfur was the first known fungicide and is still used extensively today for the control of certain foliage diseases. Sulfurs are known particularly for their effectiveness in controlling powdery mildews. They are used as dusts or as sprays. Although several formulations of sulfur exist, they fall into three types: wettable sulfur, sulfur paste, and lime-sulfur. The wettable sulfurs are the most common types used today.

Lime-sulfur is seldom used in vegetable production due to its unsightly residue and phytotoxicity problems. However, it still finds a use in powdery mildew control in peas.

Wettable sulfur and sulfur paste: Because of their convenience, the wettable sulfur formulations are generally used. Recommendations are usually based on a 95 percent wettable sulfur formulation. Formulations containing less sulfur should be used at higher rates. Sulfur was once used extensively as a protectant for powdery mildew, but it has generally been replaced by organic materials of the protective-eradicant type which are less phytotoxic.

Mercury Compounds

Mercury, both inorganic and organic forms, was used extensively as a seed protectant fungicide until recent years. Due to their possible contribution to mercury contamination of the environment and their toxicity to humans and animals, mercury compounds have been suspended for use as fungicides. Organic fungicides have essentially replaced the mercuries.

## Organic Fungicides

### Benzene Compounds

There are several fungicides in this chemical class but most of them are relatively specific in the diseases they control or in how they may be used. Dinocap is specific for powdery mildew and is sold under the trade name of Karathane or Mildex. Dichloran or Botran is used for Rhizoctonia and Sclerotinia disease control in lettuce and other crops where PCNB can no longer be used.

Dinocap (dinitro capryl phenyl crotonate) is a 25 percent active wettable powder sold under the trade name Karathane. It is used primarily for the control of powdery mildew. A liquid formulation is also available. It is often used in the summer when high temperatures make the use of sulfur questionable on vegetables. This material may be combined with other fungicides used for disease control but should not be used with liquid insecticides having an organic solvent (kerosene or xylene) base.

Botran (2, 6-dichloro-4-nitroaniline) is a 75 percent yellow, wettable powder for use as a soil drench and basal spray for several vegetables.

Duter (triphenyltin hydroxide) is a 47.5 percent, white, wettable powder used on carrots and potatoes. It is used on a 7 to 10 day schedule for Cercospora and Alternaria leaf spot control in carrots and for early and late blight control in potatoes. Duter has the side benefit of being an effective herbicide against purselane in these crops.

Dyrene (anilazine) is a 50 percent wettable powder or a 5 percent dust used as a foliage fungicide in vegetables and turf. It is used for early and late blight control in celery, potatoes and tomatoes. It also provides effective control for Anthracnose and Alternaria diseases in the cucurbits. Dyrene also works well on several foliage diseases of onion.

New PCNB, Terraclor or Pentachloronitrobenzene, is a 75 percent wettable powder which is highly effective against several soilborne diseases. It was extensively used as a soil drench and basal spray for Rhizoctonia and Sclerotinia rot control in lettuce, celery, beans, and other crops. Due to residue problems, however, its use has recently been confined primarily to the treatment of seed (preplant).

Nabac (Hexachlorophene) is a 25 percent wettable powder or a 13 or 20 percent liquid concentrate which has bactericidal activity. Though not widely used in vegetables it has been effective in the control of angular leaf spot of cucurbits. It is also used for bacterial spot and canker suppression in peppers and tomatoes. For good control early detection and thorough coverage are necessary.

Benzimidazole Compounds

The benzimidazoles are systemic fungicides and include fueridazole, benomyl and thiabendazole (TBZ). These compounds are in the early stages of development commercially. The benzimidarates are primarily effective against the ascomycete fungi, a group that includes a large number of plant pathogens. In this group benomyl is the most widely used and is registered for control for a number of vegetable diseases. Benomyl appears to be active at slightly lower rates than thiabendazole. Because they are systematic they are effective against internal pathogens and less subject to weathering.

There are also two closely related fungicide compounds which are usually considered within this class—thiophanate, also called Topsin or Cercobin, and thiophanate-methyl, also called Topsin M. The spectrum of activity of these compounds resembles that of the benzimidazole compounds. Recent evidence indicates both benomyl and thiophanate-methyl break down into the same fungitoxicant, thus explaining their similar biological activities.

Benomyl (methy 1-(butylcarbamoyl)-2-benzimidazole carbamate) is used for the control of white mold in beans and lettuce, powdery mildew, and gray mold caused by Botrytis, and Cladosporium leaf mold of tomatoes.

Benomyl is particularly effective for the control of white mold in beans. Sprays may be started at early bloom, but before plant close over the row. Applications must not be made closer than 14 (snap beans) to 28 (lima bean) days to harvest.

Because of problems with fungicide tolerance, benomyl should not be used on an exclusive schedule. To avoid tolerance, benomyl is often combined with other fungicides and applied as a mixture.

Thiabendazole (2-(4-thiazolyl) benzimidazole) is used for control of storage rots of potatoes. Thiabendazole is active against Fusarium, Penicillium and Botrytis (bluemold and gray mold) but will not control rots caused by Phytophthora and Pythium. Dip, drench, or spray the harvested tuber with a suspension of the fungicide.

Carbamates

Development of the carbamate fungicides was a major breakthrough in fungicide chemistry. Because of their value to mankind in preserving food and fiber, the discovery of the carbamate fungicides is comparable in importance to the discovery of DDT as an insecticide. These compounds are used throughout the world to control a variety of diseases on many crops.

The carbamate fungicides are all derivatives in dithiocarbamic acid, an organic acid used in vulcanizing rubber. They are classified into three groups: (1) The thiuram disulfides. These are sold under many trade names such as Thiram, Arasan, Tersan, Thylate, etc., and are known by the common name of thiram. On vegetable crops they are used primarily for the control of the seed rots and seedling diseases. (2) The dithiocarbamates. Ferbam and ziram are the important members of this class. Although they are not used as much today as previously, they are still used to some extent for the control of seed, seedbed and seedling diseases. (3) The ethylene bisdithiocarbamates. Nabam, zineb, and maneb are important members of this class. Maneb and certain related compounds are used extensively for the control of several diseases of vegetable crops. Like the dithiocarbamates, each of these chemicals contain a metal such as sodium, zinc, iron, or manganese.

The thiram disulfides: Thiram (tetramethylthiuram disulfide) is sold under the trade names of Thylate and Thiram. Thiram can be used for seed treatment to control damping-off in carrots, beets, lettuce, onions, peas, spinach, tomatoes, eggplant, and peppers.

The dithiocarbamates: Ferbam (ferric dimethyl dithiocarbamate) is formulated as a 76 percent wettable powder. It is used as a protectant for control of drop (Schlerotinia), Botrytis blight and bottom rot in lettuce and other vegetables.

<u>The ethylene bisdithiocarbamates</u>: <u>Maneb</u> (manganese ethylene bisdithiocarbamate) is used on many vegetables for foliage disease control. It has many uses from rust and anthracnose control on beans, and control of corn leaf blights, to downy mildew and cercospora leaf spot control on tomatoes and peppers. It is a broad spectrum fungicide and profitable vegetable production in Michigan would be difficult without it.

<u>Zinc-maneb</u> (Manzate D. or Dithane M-22 Special) is an 80 percent dry wettable formulation of maneb containing zinc as a safener. This formulation is used as an alternate for maneb on some crops.

<u>Mancozeb</u> (Dithane M-45 and Manzate-200) is a coordination product of maneb and zinc ion. It is an 80 percent wettable powder.

These products are used interchangeably on many crops, however, the latter two are somewhat more expensive and are usually only used where sensitive crops or severe disease conditions exist. They have excellent sticking properties.

These products are compatible with most pesticides and can be used in combinations similar to ferbam.

<u>Polyram</u> is sold as an 80 percent wettable powder and is a mixture of 5.2 parts by weight (83.9 percent) of ammoniates of (ethylenebis (dithiocarbamic acid), biomolecular and trimolecular cylic anhydrosulfides, and disulfides. It is used in a protective schedule against anthracnose and alternaria leaf spot diseases of cucurbits and is used against black leg and <u>Fusarium</u> tuber rot in potato seed pieces. Polyram has good retention and redistribution properties. It is a mild eradicant, approximately equivalent to captan.

Polyram like ferbam is compatible with most pesticides and can be used in combinations.

<u>Zineb</u> (zinc ethylene bisdithiocarbamate) is sold as a 75 percent active wettable powder. It has a broad spectrum of activity and is widely used on vegetable crops. Rust control in asparagus and beans as well as Alternaria, downy mildew and black leg on crucifers may be controlled by zineb. Downy mildew, purple blotch, <u>Botrytis</u> leaf blight, and neck rot in onion, and <u>Alternaria</u> leaf spot, downy mildew, anthracnose and <u>Cercospora</u> leafspot on radishes and spinach can be effectively controlled with a regular zineb protective spray schedule. Zineb is also widely used for early and late blight, plus <u>Septoria</u> and <u>Phomopsis</u> blight,

and Anthracnose control on tomatoes, peppers, and eggplant.

Trichloromethylmercapto Compounds

This group includes three closely related fungicides—captan, folpet, and Difolatan. Captan was the first to be developed. It is used for the control of a large number of fungus diseases of many food and ornamental crops. Folpet and Difolatan have similar properties and are used where they are more effective than captan. Difolatan is known for its ability to resist weathering and, thus, gives extended control.

Captan (N-trichloromethylthio-4-cyclohexene-1, 2-dicarboximide) is used for control of seedling diseases and some foliage pathogens in vegetables. It is primarily used along with thiram as a seed treatment compound since mercury compounds have been banned. It is also extensively used to control seedling diseases in the seedbed, potato seed piece treatment for black leg and Fusarium control, and for leaf rot and gray mold control in rhubarb. It is usually marketed as a wettable powder formulation. Several dust formulations and an 80 percent wettable powder formulation are available and should be used at equivalent rates.

Though primarily a protectant fungicide, captan will eradicate some diseases if applied shortly after the beginning of infection. Captan does not have good retention properties and must be applied at 7-10 day intervals during periods of rainy weather.

Difolatan (cis-N-(1, 1, 2, 2-tetrachloroethyl)thio)-4-cyclohexene-1, 2-dicarboximide) is formulated as an emulsifiable solution containing 4 pounds of Difolatan per gallon. It has good fungicidal activity on several pathogens and has excellent retention and redistribution qualities. It is used for anthracnose and Alternaria leaf spot control in cucurbits and controls anthracnose and early, late, Septoria and Phomopsis blights in tomato and pepper.

Human skin sensitization has occurred in some instances where Difolatan was used. Only a small percentage (10 percent) of the population is sensitive. A few farm workers have developed a reaction to the product after exposure to residues of Difolatan on the leaves and fruit. People who may come in contact with it must be warned of the possibility of this allergic reaction.

## Antibiotics

Antibiotics are chemical substances produced by micro-organisms which are toxic to other micro-organisms. Penicillin, produced by the fungus Penicillium notatum, is an example of an antibiotic widely used in human medicine. Certain others are used for control of plant diseases caused by either bacteria or fungi.

Streptomycin, an antibiotic produced by a soil micro-organism, is used for the control of bacterial diseases. It is used against bacterial spot and bacterial canker in tomatoes and peppers. It can be quite effective if sprays are well timed and thorough. It is ineffective against diseases caused by *Xanthamonas sp.* bacteria, however.

## Fungicides, the Disease Cycle, and Control

Much goes into the planning of an economical and effective spray program. A successful disease control schedule must be based on knowledge of:

1. the life history of the important diseases likely to be encountered on a given crop;
2. the characteristics of the various fungicides and bactericides available, and their proper use, and
3. susceptibility of the different kinds of varieties of vegetables to disease and spray injury.

The following information relates the control of disease to the characteristics of several fungicides. It is an example of how to put together a control program. It should be remembered that these are generalized approaches which will have to be adapted to the specific requirements of the crop involved. Several general approaches are described.

1. Protectant spray program—Protectant sprays are applied before infection occurs. They set up a chemical barrier between the susceptible plant tissue and the germinating spore. All fungicides may be used effectively as protectants and in vegetable production most materials are recommended for application

in a protective spray schedule. The success of a protective spray program depends on the frequency of application, the ability of the compounds to resist the weathering action of sunlight, rainfall and dew, and the growth rate of the plant.

The use of the carbamate fungicides for foliage disease control and the use of captan-thiram for seed treatment are good examples of the use of fungicides in a protective treatment. Septoria leafspot of celery controlled by Bravo or purple blotch of onions prevented by the use of copper oxide are also examples of protective spray programs.

2. Eradicant spray program—Eradicant sprays or chemicals that have the ability to eradicate an infection may be applied for a certain time after infection occurs and still destroy the pathogen and prevent crop damage. Eradicant compounds should be used at the full recommended rate since lesser rates may reduce or negate their eradicant ability. To use these materials effectively, the grower must understand and record the progress of disease development and the concurrent weather conditions, because excessive delay in application of the eradicant spray may allow the pathogen to become established in its host beyond the period where the eradicant can confine and eliminate disease development. Also weather plays an important role, for the eradicant must be applied regardless of the weather if control is to be achieved. The systemic fungicides such as benomyl and thiabendazole have eradicant properties for the control of powdery mildew, Fusarium, anthracnose and Cladosporium leaf mold diseases.

3. Protectant-eradicant programs—Several spray programs used in modern vegetable production use a combination of protectant and eradicant fungicides for successful crop production. Due to the high cost of many fungicides it is often most economical to use protectant materials during the initial stages of crop development and apply eradicant materials only when weather and disease conditions necessitate.

4. Tank mixture programs—Applying two or more fungicides simultaneously in the same spray has been practiced for several years to achieve increased protection or eradicant action against one or more diseases, and to reduce application costs.

Occasionally, manufacturers will sell fungicides in mixed form, thereby eliminating the need for the grower to mix compounds on his own.

Because of problems with fungicide tolerance there is increased interest in mixing fungicides with different modes of action, thereby delaying or preventing the buildup of tolerant strains of disease organisms.

Tolerance to Vegetable Fungicides

Development of tolerance in fungi to the fungicides used to control them has been rare under field conditions. However, recent experience with some of the new organic fungicides (especially those with systemic action) with selective action on fungi indicates fungicide tolerance can be a problem.

Tolerance problems on vegetables in Michigan have not become a major problem as yet. However, benomyl-tolerant Botrytis blight and powdery mildew are known in several crops other than vegetables.

Although it is seldom possible to determine the source of tolerant fungal strains, the pattern of fungicide application has a marked effect on where tolerance problems will occur. High and continuous selection pressure, such as from using one or closely related fungicides repeatedly year after year, tends to enhance the tolerant population. Thus, detectable populations of benomyl-tolerant fungi have been found primarily where benomyl was used regularly and exclusively for several years.

In order to reduce the emergence of fungicide tolerance in the field, specific classes of fungicides should not be used exclusively through the growing season or year after year.

## SELF-HELP QUESTIONS

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. List, in order, the stages a pathogen passes through during a disease cycle.

2. Is the pathogen active during dormancy?

3. What is the infection court?

4. When do secondary disease cycles usually occur in Michigan?

5. What is the first symptom of black leg of cabbage?

6. How does the pathogen causing late blight of potato and tomato overwinter?

7. What is the range of soil temperature most favorable for Fusarium wilt developmen

8. How is bacterial wilt of cucurbits transmitted to the plant?

9. List at least five diseases caused by Sclerotinia sclerotiorum.

10. Why is Bordeaux mixture not commonly used for the control of vegetable diseases?

11. What are the three types that sulfur formulations can be classified as?

12. Can dinocap be combined with other fungicides?

13. Is Nabac a fungicide?

14. What diseases can benomyl be used to control?

15. What is the main use of thiram on vegetables?

16. Is Maneb compatible with most pesticides?

17. Is Polyram an eradicant or a protectant?

18. Do both captan and Difolatan have good retention qualities?

19. What are antibiotics?

20. At what stage in the disease cycle are protectant sprays applied?

21. Must eradicant compounds be used at the full recommended rate?

22. What are the benefits of applying two or more fungicides simultaneously?

23. What can be done to reduce the possibility of developing a fungicide tolerance in the field?

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