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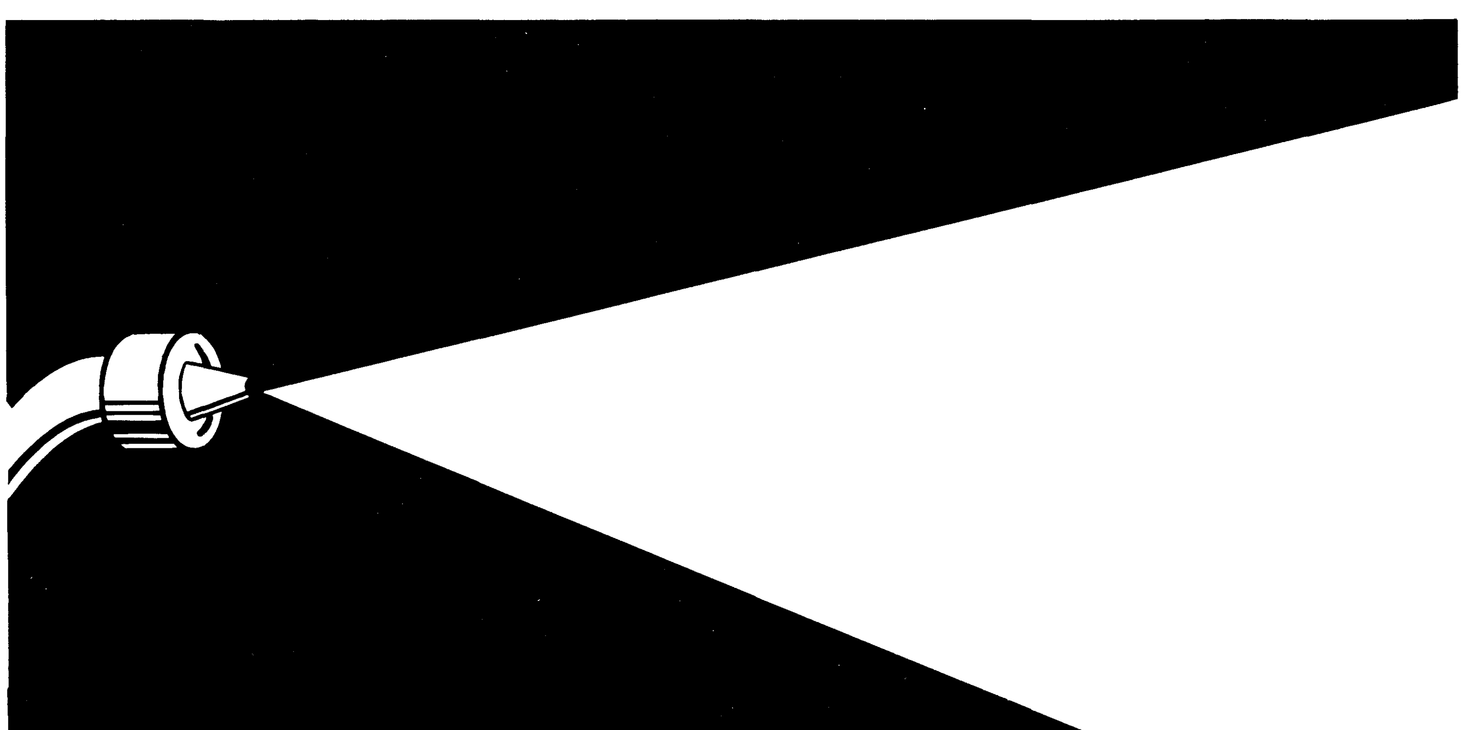
MARYLAND PESTICIDE APPLICATOR TRAINING SERIES

AGRICULTURAL MANUAL



ACKNOWLEDGMENTS

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Illustrations of insects and equipment were taken from the following sources: "Field and Forage Crop Pests", MEP 310, Maryland Cooperative Extension Service (CES); "Control of Insects and Diseases in Home Vegetable Gardens", Bulletin 252, Maryland CES; "Pesticide Applicator Training Manual Category 1", New York CES; Pesticide Applicator Training Manual", Colorado CES; and "Field Crop Insects, NHE Series Entomology Fact Sheets", Illinois CES and Illinois Natural History Survey. Weed illustrations were provided through the courtesy of: Agricultural Research Service, U.S. Department of Agriculture, Jim Converse and O.M. Scott and Sons.

CONTENTS

INSTRUCTIONS FOR USE OF THIS MANUAL

This manual contains specific information that you will need to know about pests, pesticides and application equipment in order to apply pesticides safely and effectively in your operations.

Private Applicators

Private applicators in Maryland who wish to use restricted use pesticides must become certified in one specialty area. This is the training manual for private applicators in the specialty areas of Field and Forage Crop Pest Control, Fruit Pest Control, Tobacco Pest Control, and Vegetable Pest Control. To prepare for the certification examination, you should study and understand your core manual, and Chapter 1 plus one of the other chapters in this manual, depending on your main operation. Study Chapter 2 if you grow field or forage crops; Chapter 3 if you have an orchard, a vineyard or other fruit crops; Chapter 4 if you grow tobacco; or Chapter 5 if you are a vegetable producer.

Commercial Applicators

Commercial applicators must become certified in at least one category. This is the Maryland training manual for commercial applicators in Category 1, Agricultural Pest Control. If you study and understand your core manual and all of the chapters in this manual, you will be prepared for the Maryland pesticide applicator certification examination in this category.

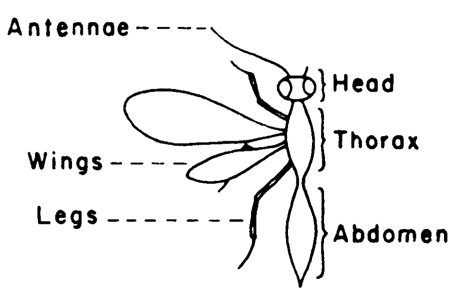
CHAPTER 1

GENERAL PRINCIPLES

In this chapter, typical life cycles and characteristics of pests will be discussed, as well as principles involved in their control by pesticides. Important pests and their control by various methods are discussed in later chapters. Consult those chapters and available Extension materials for more specific information.

Insects and Mites

Insects and mites thrive in many different environments and can become pests of many plants and animals. They may cause economic injury to crops or livestock, unacceptable aesthetic damage to ornamentals and turf, or considerable annoyance to people. Some insects are capable of transmitting diseases to plants, animals and humans.

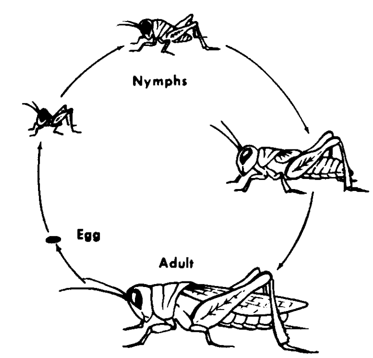


Characteristics

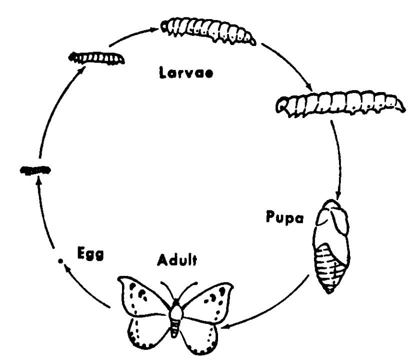
Insects and mites are distantly related and, therefore, share some similarities. They usually have jointed legs and a tough outer skin during one or more life stages. They must shed their skins several times in order to grow and become adults. Insects and mites can be distinguished by the number of body regions, legs, wings and antennae each possesses. Adult insects usually have three body regions (head, thorax and abdomen), three pairs of legs and one or two pairs of wings on the thorax, and one pair of antennae on the head. Scale insects are a notable exception to this body plan. Adult mites usually have one conspicuous body region, four pairs of legs, no wings and no antennae.

Life Cycles

Metamorphosis, defined as a change in form, is a characteristic of insect and mite life cycles. Because of this change in form, immatures may not resemble adults of the same species, and may not feed in the same manner or on the same food. In order to find the weakest link in such a pest's life cycle, the pest manager should be familiar with the appearance and habits of all stages of a pest's life cycle. There are two general types of metamorphosis—gradual and complete.



Gradual metamorphosis. Newly hatched insects (nymphs) resemble the adult insect but are smaller, and the wings are not obvious. These insects change shape gradually. Each time they shed their skins they grow and enlarge their wings. Nymphs and adults usually feed on the same food source. Mite development is similar, but legs are added instead of wings.



Complete metamorphosis. Newly hatched insects do not resemble the adults. They have worm-like bodies with no external sign of wings and are called larvae. Like nymphs, larvae must also shed their skins to grow. Each larva changes into a pupa before it can change into an adult. Wings usually are visible on the resting pupal stage, which does not feed and usually remains hidden. Adults eventually emerge from the pupal skins.

Principles of Insecticide/Miticide Use

Insecticidal 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 are less mobile than the adults and therefore are confined to a given area. 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, 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.

Types of Insecticides/Miticides

Stomach poisons must be eaten in order to kill the pest. These materials must be applied to the insect's or mite's food source.

Contact pesticides kill pests that merely touch them. These pesticides must be applied to a place that the insect or mite will contact in its normal habits. The advantages of contact insecticides include the following:

- they are effective against both small and large chewing and sucking insects,
- they remain on the surface of the leaves and thus are susceptible to being broken down by exposure to sunlight and to washing off, and
- they generally are effective for 2 to 3 days, depending on weather.

Systemics are chemicals that are moved throughout the tissues of the plant or animal to which they are applied. When a pest feeds on the treated plant or animal, the systemic insecticide or miticide is ingested, and the pest dies. Some systemics are to be applied to the outside of the plant or animal to be protected; these will be absorbed through the skin of the animals or the outer covering of the plants. Others are formulated for direct injection into plants.

The systemic insecticides have several advantages and disadvantages when compared with the contact insecticides. Advantages of systemic insecticides are that they

- enter the tissue and are not lost through exposure to sunlight or by washing off,
- move in the tissue to a greater or lesser extent toward the growing point,
- give a day or two longer effective control, and
- are very effective against small sucking insects such as aphids and leafhoppers.

The disadvantage is that systemic insecticides generally are not effective against large chewing insects.

Broad spectrum materials are those that control a wide variety of insects and/or mites. These materials may be desirable when more than one type of insect is causing damage. However, broad spectrum materials are likely to kill beneficial insects as well as pests.

Factors to Consider

Residual effectiveness. Insecticides and miticides vary in how long they last as killing agents. Some break down into nontoxic byproducts almost immediately. These *short-term* chemicals are very good in situations where the pests do not return or where long-term exposure could injure nontarget plants or animals. For example, in homes where people and pets might be exposed to the chemical, short-term pesticides often are preferred for use. Other pesticides remain active killers for a fairly long time. These residual pesticides are very useful when the pests are a constant control problem and where they will not be an environmental hazard. For example, residuals often are chosen for fly control in livestock buildings or for termite control around wooden structures.

Type of foliage. Plants have characteristic foliage. 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.

Leaf surface. Another factor to consider is the leaf surface. Some plants have a very waxy leaf surface, making 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 ease 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.

Spray coverage. There are several ways the applicator can check for thorough coverage. These include checking for the white residue of wettable powders after the application has dried on the foliage and using paper cards or other indicators placed at the site in the foliage where coverage is most difficult. Remember that coverage must be obtained where the insects live and feed, their microhabitat. Obviously, if the proper coverage is not being obtained, corrective adjustments must be made. You may need to adjust as follows:

- increase the gallonage,
- change the nozzles,
- fly higher or lower in the case of aerial application,
- use drop-nozzles,
- use more nozzles, or
- change the type of spraying equipment.

Time of application. An important factor to consider is the time of day you make the application. For maximum effectiveness, the insecticide must be at a lethal level at the time the insects are active.

Plant Diseases

Causes

The causes of plant disease may be divided into two basic groups—biotic and abiotic. Nonparasitic or *abiotic* diseases are caused by some condition unfavorable for plant growth, such as too little or too much water or fertilizer, improper light, temperature extremes, mechanical injury (such as hail and blowing sand), air pollution and other damaging chemicals. Included in the parasitic or *biotic* group are diseases caused by fungi, bacteria, nematodes, viruses and parasitic higher plants. These parasitic organisms can be found inside or on the surface of the plant.

The severity of a disease will depend on many factors, especially the degree of susceptibility of the plant and the weather conditions that either favor or inhibit infection of the plant by the parasite. Some diseases are worse during cool, wet weather while others are most severe in hot, dry weather.

The disease organisms must be able to survive during periods when the host plant is not growing, such as over the winter. Many plant parasites form resistant resting structures which remain in soil or plant parts. Some plant parasites survive inside insect, mite or nematode *vectors* (organisms capable of transmitting diseases). Others may persist in seed or in weeds. Whatever the system, the life cycles of these parasitic organisms must be understood in order to choose an effective control practice.

Fungi. Some fungi attack plants and cause disease. Almost all crops may be damaged by some fungal diseases. In severe cases a fungus may cause crop failure. Most plant parasitic fungi are not so devastating, but still cause damage to crops and require the use of controls including fungicide treatments to produce a salable crop.

Fungi reproduce by structures called spores. Fungal spores may be dispersed by air currents, insects or splashing water. Some fungi produce swimming spores called zoospores that swim in water. Spores are very small in size, but they may be so plentiful that they are seen as masses of fine powder. Spores may be white or brightly colored (usually orange or yellow), or they may be dark. Spores may be contained in larger fungal structures. For example, a mushroom is a reproductive fungal structure that produces many microscopic spores on the gills. Each fungus needs specific environmental conditions of moisture and temperature before it can attack the plant and cause disease.

Bacteria. A small number of kinds of bacteria cause diseases of plants. Bacteria may be spread in a variety of ways including splashing rain, water, soil movement, insects or infected seeds and plants. Some bacterial plant pathogens can thrive on plant debris and in soil, but most require a living plant. Bacteria may enter the plant through wounds or through natural openings such as plant stomates. Bacteria can multiply rapidly inside plants where they may kill plant cells causing spots, blights and rots, or cause abnormal tumor-like growths, or block the water-conducting tissues producing wilt. Bacteria often move throughout the plant becoming systemic.

The "yellows" diseases are caused by *Mycoplasma*, unusual bacteria that lack a rigid cell wall. For a long time these "yellows" diseases were thought to be caused by viruses because the *Mycoplasma* is difficult to see. Aster yellows is a common vegetable disease caused by a *Mycoplasma*.

Viruses. There are many viral diseases of plants. A particular virus is very specific in the type of host it infects; viruses that cause plant diseases are not known to infect animals. Once the virus is inside a host cell it takes control of the cell, and directs the cell to produce material to make more viruses. This disturbs the normal operation of the cell, producing a variety of symptoms.

Symptoms produced include mosaics, where leaf tissues show patterns of light and dark green color; distorted plant parts such as wrinkled leaves or stunted plants; ring spots; yellowed leaf veins and others. Often plants can be infected with one or more types of virus and yet show no symptoms. Once the plant is infected, it cannot be cured.

Viruses may remain from season to season in perennial weeds, inside insects and nematodes, and in seed. Thus controlling insects, nematodes and weeds should reduce the severity of many virus diseases on crops.

Nematodes. All nematodes that attack plants are small, ranging in size from 1/50 to 1/8 of an inch long. These colorless worms feed by using a rigid spear-like structure (the stylet) to pierce plant cells. The stylet and other nematode body features can be seen only with a microscope. Many different nematodes may be found associated with plants, and most are not damaging to plants. The only way to determine if nematodes are the cause of plant disease symptoms is to extract the nematodes from plant and soil, identify and count them.

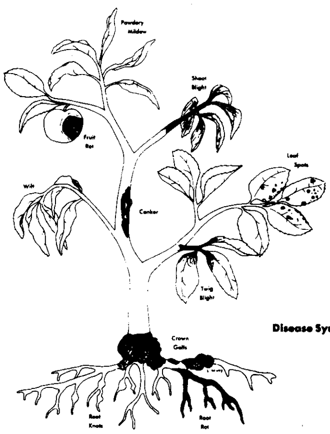
A few nematodes feed on leaves and shoots causing leaf spots, blights, malformed growth or wilts. Most plant parasitic nematodes feed on plant roots and are found in soil near plants. The plant's symptoms may be vague such as not growing well, failing to respond to fertilizer and having poor color. Close examination of roots may reveal browned areas in roots, swelling on the roots or a greatly reduced root system.

The damage caused to crops by nematodes is determined by the number of nematodes, weather factors and the susceptibility of the crop to each kind of nematode. If nematode populations are low, damage will be slight.

Parasitic seed plants. A variety of higher plants have evolved as parasites of other plants. Familiar examples of parasitic plants include mistletoes on oak trees, and dodder on some vegetables and foliage plants. Parasitic plants attach to the host plant and extract nutrients from its roots or stem.

Diagnosis

A plant disease may be defined as any change from normal plant growth. These changes from normal growth are called



Disease Symptoms

symptoms. Symptoms caused by biotic agents usually appear slowly and gradually become worse. Biotic agents causing plant diseases are usually microscopic in size, but many produce larger structures, called signs by plant pathologists.

Since symptoms are the most obvious feature of plant diseases, we may group diseases together by the types of symptoms observed. Effective control methods depend on an accurate diagnosis of the cause of disease symptoms. Symptoms and signs can be useful in identifying the cause of a plant problem, when combined with other information about the sick plant. Unfortunately, many different causal agents produce similar symptoms. Signs are much more useful in determining the exact cause of the disease. The following is a list of disease symptoms and signs with advice on other clues to look for to help in diagnosing the problem.

Wilt. When shoots and leaves are not getting enough water they become soft and wilt. Eventually wilted plants will begin to die from the tips and edges inward. Wilts may be caused by anything that interrupts the flow of water up from the roots: dry soil, excessive heat, root disease, physical damage to roots or stems, a girdling canker or a vascular wilt disease. Look for evidence of damage to roots and bark. Look for discoloration in plant tissues just under the bark by cutting into the bark and peeling back a small part. A brown or olive green discoloration may indicate a bacterial or fungal vascular wilt disease.

Root rot. Plants with root rot diseases grow poorly. Foliage may be off color and smaller than normal. When most of the roots are dead, the entire plant will die. Diseased roots are usually darkened and decayed. Woody roots may become spongy. Many root rots of trees are caused by fungi that produce large fruiting structures, such as mushrooms and shelf fungi on or near the base of the tree.

Leaf spots. Most of the leaf is normal but spots or blotches appear on portions, and may cause affected leaves to yellow and drop. Leaf spots may be caused by insect or mite feeding as well as by fungi and bacteria. Many fungal leaf spots have small fungal fruiting bodies that look like little dark lumps or blobs about the size of the head of a pin, and can be seen scattered in the browned leaf tissue. Some fungal leaf spots produce a target pattern of concentric rings. The rust fungi often produce leaf spots with bright yellow or orange powdery spore masses. Bacterial leaf spots may have a water-soaked yellow margin around the spot. When very young leaves have many leaf spots, the leaf may be distorted and fail to expand properly. Spotted leaves often turn yellow and drop prematurely.

Cankers. Both woody and herbaceous plants may develop canker diseases. A canker is a sunken diseased part of a stem or branch. Often fungal cankers have fruiting bodies scattered uniformly in the dead area. Bacteria may also cause cankers. Bacterial cankers often have a sticky ooze at the edge of the canker. Damage by some insects that bore and tunnel under bark may be confused with canker diseases. Insects usually make tunnels and leave sawdust in the canker.

Galls and other excessive growths. Galls are enlarged lumps of plant tissue. Most galls caused by fungi or bacteria (such as crown gall) are somewhat disorganized looking on the surface and may produce fungal spores erupting from the surface. Insects and mites may produce galls on leaves, twigs or stems. Most insect and mite galls have a more organized appearance. Cut into the gall and look for the insect or mites inside. Nematodes may cause galls or swellings on roots and other parts of plants.

Principles of Disease Control

Breeding crop varieties for resistance to important diseases is a common method of disease control. Most of the preliminary work is done in laboratories and test plots, and by seed increase organizations. The finished product is then sold to the grower.

Chemical control is quicker and more flexible. The chemicals used most frequently are fungicides, although a few bactericides and virusides are available.

Changing cultural practices is a practical method of disease control. Continuous culture with the same crop can result in a rapid buildup of a disease organism. Rotation with other crops slows down this buildup. The environment can favor an organism and hence result in more disease. Poor drainage and soil compaction favor certain soil-borne fungi. Improving soil drainage along with aeration and improving soil structure with proper tillage and organic matter can reduce injury from soil-borne fungi.

Fungicides

All fungicides work through contact with the fungus; therefore, most fungicides are applied over a large surface area to ensure direct contact of every individual. Some fungicides are systemic and are designed to be fed or injected into the plant. The systemic fungicide is then transported throughout the plant, killing the fungi. There are important differences between the two main types of fungicides that the pest manager must understand in order to choose a chemical that will be effective in any given situation.

Protectants. These sprays are applied before infection occurs. They set up a chemical barrier between the susceptible plant tissue and the germinating spores. Since new surface is exposed during constant growth, repeat application is often necessary. These fungicides are useful when a particular disease or group of diseases is likely to attack a plant under certain known conditions. This method is not economical when there is a low gross per acre except in special circumstances. 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.

Eradicants. These sprays may be applied for a certain time after infection occurs and still destroy the pathogen and prevent damage. Eradicants often are used when protectants are not available, were not applied in time, or are too expensive. They also are useful for diseases that appear unexpectedly. Eradicant compounds should be used at the full recommended rate since lesser rates may reduce or negate effectiveness. To use these materials effectively, the grower must understand and record the progress of disease development and the concurrent weather conditions. The eradicant must be applied regardless of the weather to achieve control. 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.

Seed treatment is an important method of disease control with fungicides. An effective fungicide intercepts the transfer of a fungus from one crop to the next via the seed. Fungicides can be applied during seed treatment to protect the young seedling and reduce seed decay from organisms, which are in the soil. The liquid form may be a true solution, a wettable powder mixed with water, or a flowable form applied with slurry treater. The dry or dust application is a mechanical mixing; the dry fungicide is applied to the seed in the drill box or planter box. Dry methods can result in imperfect control because of incomplete coverage of the seed.

Tolerance to fungicides. Development of tolerance to fungicides 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.

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 fungicide or closely related fungicides 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. Rather, classes with different modes of action should be rotated.

Nematicides

To kill nematodes, nematicides must enter their bodies. Penetration may occur through skin or body openings, or by ingestion. Some nematicides reduce nematode activity by suppressing feeding and/or reproduction rather than by killing them. Nematicides may be brought into contact with nematodes by mechanical dispersal through the infested soil, watering them in, or gaseous diffusion of a nematicidal fumigant through the pore spaces of the soil.

Complete eradication of soil-borne parasitic nematodes through soil application of nematicides is impractical for field conditions. Instead, the objective of treatment is the reduction of nematode populations to a level where serious damage will be prevented. Complete eradication is possible, however, in limited volumes of soil, such as in greenhouses and seedling production.

Nematicides generally are used as a preventive measure. Likelihood of damage often can be predicted in field situations where good records of pest damage have been kept. Control procedures usually are based on preplant or time of planting application.

Soil fumigants are used to reduce infestations of soil-borne nematodes, fungi, insects and weed seeds. Most soil fumigants are injected into the soil as liquids. They then volatilize to a gas, diffusing through the soil. Immediately following application the soil must be sealed using a drag, roller, water or polyethylene tarp to maximize the effectiveness of the treatment. Soil porosity, soil moisture, temperature and organic content of the soil affect control results.

Contact nematicides must be applied, mixed into or carried by water into contact with the nematodes. They may be applied before or at the time of planting. When such chemicals are used, care must be taken to place the seeds into the treated portion of the soil. Label directions must be followed carefully to prevent injury to germinating seeds or seedlings. Chemically, contact nematicides are generally either organophosphates or carbamates.

Weeds

Identification

A weed is defined as a plant out of place. Weeds have been responsible for huge expenditures of money and energy. They may be problems because land use is less efficient, product quality may be reduced, crop yields may be reduced, beauty of turf and ornamental plantings may be affected, rights-of-way may be obstructed, and enjoyment of outdoor recreation may be diminished.

Weed names. The pest manager must be able to identify weeds by these common names in order to choose the correct herbicide for the job.

Life Cycles

Weeds can be grouped according to the length and timing of their cycles.

Annual weeds grow from seed, mature and produce seed for the next generation in 1 year or less. Whether they are grasses or broadleaf weeds, annuals are easiest to control when young. Herbicides, if necessary for control, should be applied early in the growing season not only to kill existing annuals, but also to prevent seed formation.

- Summer annuals are plants that result from seeds germinating in the spring. They grow, mature, produce seed and die before winter each year.
- Winter annuals grow from seeds that germinate in the fall. They grow, mature, produce seed and die before summer each year.

Biennials. These plants require 2 years to complete their life cycle. They grow from seed that germinates in the spring. Biennials develop a heavy root and a compact rosette, or cluster of leaves, the first summer, then remain dormant through the first winter. In the second winter they mature, produce seed, and die before winter.

Perennials. These plants may grow from seed, but many produce tubers, bulbs, rhizomes (below-ground stems), and stolons (aboveground stems). The aboveground portions of these plants may die back each winter, but new aboveground parts develop each spring.

- Creeping perennials produce rhizomes as well as seeds.
- Simple perennials produce seeds each year as their normal means of reproduction. In some instances, root pieces may produce new plants following mechanical injury during cultivation.
- Bulbous perennials produce seed and bulbs. They may form aboveground bulbs like wild garlic, or below-ground bulbs like wild onions.

Principles of Herbicide Use

Types of Herbicides

Selective herbicides kill some plants but cause little or no injury to others. Usually they kill either most broadleaf plants or most grasses. Some very selective herbicides kill only certain plants in a group. The degree of selectivity is affected by plant age, rate of growth, stage of the plant and physiology.

Nonselective herbicides are toxic to all plants. They are usually used in areas where any living plants are undesirable. Some nonselective herbicides may be made selective by varying the dosage, directing the spray or using spray additives such as wetting agents. Selective herbicides may be made nonselective by manipulating the same factors.

Soil sterilants are nonselective herbicides that kill all plants and prevent reestablishment of weeds for a relatively long period.

Contact herbicides kill the plant parts on which the herbicides are deposited. These herbicides destroy only the aboveground parts of plants. They are effective against annual weeds.

Translocated herbicides may be absorbed by leaves, stems and/or roots. Once absorbed, they are moved throughout the plant. Root absorption and translocation occurs in the water-conducting tissues (xylem), whereas leaf or stem absorption and translocation occurs primarily in the food-conducting tissues (phloem).

Plant growth regulators increase or decrease the normal rate of growth or reproduction of a plant. Some growth regulators are used to either hasten or delay the normal harvest date. Others are used to obtain better quality and/or yield.

Defoliants and desiccants are often used to make plants easier to harvest. Defoliants cause the leaves of a plant to drop off prematurely. Desiccants draw moisture out of the plant, causing it to wither and die.

Preplant herbicides are applied before the crop is planted. These chemicals may be used in seed beds or incorporated into soil prior to planting.

Preemergence herbicides are applied before both the crop and the weeds appear, or after the crop is up but before the weeds appear. The label directions will state "preemergence to the crop", "preemergence to weeds" or "preemergence to both crop and weeds".

Postemergence herbicides are applied after the weeds appear. These applications must be very selective, as they must control the weeds but leave the crop unharmed. Often these chemicals are applied postemergent to the crop, but preemergent to the weeds.

Methods of Application

Broadcast applications are made over an entire area of foliage or soil.

Band applications are applied in a strip along plant rows.

Directed applications are aimed at the base of plants and are kept off of foliage.

Spot treatments are applications to small areas or to clumps of weeds made with hand sprayers.

Factors Affecting Herbicide Application Results

Many factors affect the movement of a herbicide to the site of action. A knowledge of these factors is helpful in obtaining more consistent responses.

Application rate. Very small amounts of herbicide can inhibit plant growth. However, sufficiently high rates must be used to compensate for the amount bound to soil or otherwise made unavailable for uptake by the plants. Rates must not be high enough to cause crop injury or excess residues.

Uniformity of distribution. Nozzles must have a uniform delivery, a uniform spray pattern, even spacing and proper height to give uniform coverage. Uniformity of concentration and delivery rate is essential. Therefore, correct nozzles, sprayer speed, agitation, pressure and dilution are important. Granulars present a greater problem with regard to obtaining uniformity.

Soil interception. An even, uniform surface, free of clods, manure, plant litter and other debris will help ensure 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 on uneven surfaces.

Interception by leaves. The angle formed between the leaf and stem, degree of hairiness, expansion, and the ratio of leaf area to dry weight vary. In annuals, the greatest leaf area to dry weight ratio occurs in the seedling stage. In perennials, the greatest ratio occurs later, so treatment should be delayed until considerable growth has developed. Depending on the situation, a canopy of leaves can be either 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. The type of leaf surface, such as waxy coating, hairiness or roughness will affect retention. Use of wetting agents and other materials that will lower surface tension, nonpolar formulations (esters), low spray volumes, and will increase retention.

Weather conditions. Runoff can result if rain occurs during or shortly after application. For many herbicides, 1 to 2 hours without rain is enough time for penetration and absorption. Herbicides can volatilize from leaf surfaces when exposed to high temperatures.

Physical movement. Wind and water (excessive rainfall) cause runoff or movement from treated areas. Movement is toward 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 the 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 ¼ to ½ 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 gases plays a part if the herbicide is quite volatile. The 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 microorganisms 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 microorganisms will speed breakdown.

Adsorption. A great deal of variability exists in the amount of herbicide adsorbed by soil since soils differ in organic matter and inorganic soil colloids. Soil that is high in organic matter adsorbs herbicides more strongly and thereby greatly reduces the amount of chemical available and also retards movement of herbicides through the soil.

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

Translocation. Herbicides tend to move to regions of high activity such as buds, young leaves, seeds, storage sites , and growing points. Excessive application rates or contact injury can reduce translocation and should be considered before combining herbicides in one application. Movement of some herbicides out through the plant roots has been demonstrated. This will reduce the amount available to the plant, and the response will be altered accordingly.

Activation and deactivation. Some herbicides are activated by an enzyme system after entering the plant, while others are deactivated by being broken down within the plant. The rate or degree of degradation is influenced by conditions affecting plant growth such as temperature, sunlight and moisture.

Accumulation. The rates of absorption and translocation affect accumulation.

Cellular sensitivity. The ultimate response of a plant to an herbicide is at the cellular level. Susceptibility varies through the season and the year. Maturing plants develop varying degrees of tolerance. Mature or less active tissues may show little response to a dose that would have caused injury at an earlier stage of the plant.

Decontamination of Application Equipment

When you are using only preemergence 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 2 hours. Drain it out through the boom and nozzles, and rinse the sprayer with water. Do not let spray solutions stay in the tank overnight. Do not allow solutions to run into streams or other water sources.

Application Equipment

Multipurpose Sprayers

Multipurpose sprayers are designed to handle most spraying needs. The sprayers have plunger- or piston-type pumps that deliver 3 to 8 gallons per minute at pressures up to 800 pounds. Tanks range in size from 50 to 800 gallons. The spray material is mechanically agitated.

Skid-mounted models are powered by an auxiliary engine. Wheel-mounted models may be powered by an auxiliary engine or by the tractor's power takeoff.

Hand gun and hose are standard equipment; field booms, usually 20 to 35 feet in length, are available as optional equipment.

Sprayer booms are commercially available in lengths of 15 to 60 feet. The most common boom length is between 20 and 35 feet. Even with a 20-foot boom, it is essential to have some means of protecting the boom from damage if a tree or other obstacle is encountered. The most common boom is made in three sections—one rigid section in the middle of the machine and a folding section extending out on each side. These outer sections are hinged at their inner ends and are supported from the center of the machine by a rope or light chain. This type of construction gives a 20- to 35-foot boom adequate support, and provides the versatility necessary in irregularly shaped areas and the mobility required when moving the sprayer through narrow gateways.

The height of the sprayer boom must be easily adjustable so the nozzles can deliver the chemical uniformly. Boom supports should be made so the boom can be set at any height from 12 to 48 inches above the surface being sprayed.

Boomless sprayers have a central nozzle or nozzles that are designed to produce a very wide spray pattern resulting in a wide swath similar to that laid down by a boom type sprayer. They may be calibrated to spraying a known acreage with water and refilling.

There are four variables that you can adjust to govern the amount of spray delivered by boom sprayers. These are:

- nozzle spacing on the boom
- nozzle tip orifice size
- pressure
- ground speed of the sprayer

Usually your equipment will already be set up to meet your local needs, so you will make minor changes in spray delivery by changing the speed and/or pressure, and major changes by using larger or smaller nozzle tips. Routine checks of your sprayer should be made to make sure that the nozzles are not badly worn and have uniform output, uniform appearance of spray pattern and equal fan angle. Replace any nozzle tips having a flow of 10 percent more or less than required or having obviously different fan angles or patterns.

Nozzle bodies. A complete nozzle assembly consists of the body, screen, cap and tip or orifice (opening) plate. The function of the nozzle body is to attach the screen and tip to the boom. Several different nozzle body designs are available. All designs perform adequately, but each design has advantages for specific spraying jobs.

Nozzle screens. The screen is placed behind the nozzle tip and in the nozzle body to help eliminate, or at least reduce, the frequency with which the nozzle orifice becomes plugged. The size of the nozzle opening and/or the type of chemical being sprayed dictate the size and type of nozzle screen that should be used. For most general herbicide spraying, a 100-mesh monel or stainless steel nozzle screen can be used. When wettable powder suspensions are being applied, a 50-mesh monel or stainless steel nozzle screen should be used.

When the boom must be turned off frequently, nozzle "dribble" may be a serious problem. A nozzle screen with a check valve in it will help eliminate dribble and will not affect the operation of the sprayer. Some care must be taken to make certain that the ball bearing does not become glued to its seat or that dirt or chemical particles do not hold the ball bearing off its seat.

Nozzle tips. A nozzle is an atomizing device that spreads the liquid droplets in a definite direction to form the spray pattern. Nozzles are made to accommodate a variety of replaceable tips or discs to meet different spraying requirements. Manufacturers of sprayer nozzles can supply data sheets for the delivery rate (usually in gallons per minute at different pressures for their nozzles). The application rate cannot be specified on these data sheets unless the forward speed of the sprayer and the spraying pressure are specified. Never operate nozzles at high pressures to compensate for selecting the wrong nozzle size. Unnecessarily high pressures increase the rate of nozzle wear and increase the drift hazard.

Nozzle tips and discs are made of aluminum, brass, ceramic, plastic, stainless steel or tungsten carbide. Tungsten carbide discs and stainless steel tips are more resistant to abrasive wettable powders, but they are more expensive than steel discs and brass tips. No single material is the least expensive, most corrosion resistant, and most durable for spraying all agricultural chemicals.

Fan or flat pattern nozzles. The spray droplets are arranged in a fan shape as they leave the nozzle. The orifice in this type of nozzle is elliptical. Herbicides are best applied with this type of nozzle because:

- when a series of these nozzles is properly mounted on a boom, the spray material is more evenly distributed than it would be with any other type of nozzle; and
- at 30 to 60 pounds per square inch, the flat-pattern nozzle delivers small to medium droplets that do not drift excessively.

The most commonly used flat-pattern nozzles have a spray angle of 65, 73 or 80 degrees; the most commonly used pressure is 40 pounds per square inch.

For most herbicide spraying done with a relatively short boom (20 to 35 feet), the 80-degree flat-pattern nozzle is best. It is possible to keep the boom relatively low to reduce the drift hazard, and give a uniform distribution of spray material over the entire length of the boom.

The flat-pattern nozzle is available in brass, plastic, stainless steel and hardened stainless steel. The brass nozzle is inexpensive and satisfactory for spraying chemicals in solution. The hardened stainless steel nozzle is the most durable, but it is not as corrosion resistant. When using any wettable powders, it is essential to calibrate the sprayer frequently, because as a nozzle wears, the quantity of the spray material delivered increases.

Broadcast or boomless nozzles. The broadcast nozzle is made of one or more nozzles in a cluster. These nozzles deliver a flat fan-like pattern that covers a swath up to 70 feet wide. The spray droplets range in size from very small to very large. Broadcast nozzles are convenient for spraying areas in which a uniform distribution of spray material is not essential. Never use a broadcast type of nozzle when there is any breeze.

Flooding fan. This is a broadcast-type nozzle that has been modified to be mounted on a boom. The nozzle spacing usually used is 40 to 80 inches. The small- to large-sized spray droplets are not distributed as uniformly as the droplets from a flat-pattern nozzle. The flooding-fan nozzle is available in brass or stainless steel. Its main use is for surface application of herbicides that are immediately incorporated into the soil.

Full cone and hollow cone. These two types of nozzles deliver circular patterns. The hollow cone nozzle delivers most of the material to the outside of the circle; the full cone nozzle delivers material to the entire area of the circle. The circular opening in the stainless steel, hardened stainless steel or tungsten carbide disc resists the abrasive action of wettable powders relatively well. The droplets are small or very small and are not distributed uniformly when the nozzles are mounted on a boom. The major use for these nozzles is in the application of insecticides or fungicides to field crops where complete coverage of the leaf surfaces is extremely important and where spray drift will not cause a problem. In cone nozzles the number of holes in the whirl plate affects the output rate. Be sure to check the whirl plate as well as the nozzle tips in calibrating a sprayer.

Calibration. Manuals usually come with the sprayers. If a manual is not available, the equipment can be calibrated to deliver the amount of spray desired. Follow these steps.

1. Measure the distance traveled, in feet, in 1 minute at the speed you will use in applying the pesticide; use this value for L in step 5.
2. Measure the width, in feet, of the swath that will be covered by the pesticide (measure the width from end to end even though the pesticide will be applied only in narrow bands across this width); use this value for W in step 5.
3. Count the number of nozzles that will be used; use this value for N in step 5.
4. Collect and measure the spray, in liquid ounces, delivered in 1 minute from several nozzles at the approximate settings that you will use, or use equation 1 to determine this. Determine the average amount delivered in one minute from these nozzles and use this value for A in step 5.
5. Determine the gallons per acre delivered by a sprayer using the following equation:

$$\text{Gallons per acre} = \frac{340\,\text{NA}}{\text{WL}}$$

(340 is a constant that will convert ounces per square foot to gallons per acre.)

Example:

Tractor speed (L) is 176 feet per minute

Eight 36-inch rows covered (W = 24 feet)

Eight nozzles used (N = 8)

Twenty liquid ounces of spray per nozzle per minute (A = 20)

$$\text{Gallons per acre} = \frac{340 \times 8 \times 20}{24 \times 176} = 12.88$$

Airblast Sprayers

Airblast sprayers are now in general use for treating tree fruits and are increasing in use for the spraying of row and field crops. They may be used to apply sprays ranging from dilute to highly concentrated. All use air to transport pesticides to the crop. Most use nozzles under pressure to provide initial breakup of the liquid, but some rely on airblast to shear the liquid into fine droplets. The volume and velocity of the airstream and the shape and arrangement of the air outlets vary depending on the purpose for which the machine was designed. It is essential that the airblast be sufficient to distribute the spray droplets throughout the swath to be covered.

Airblast machines are classified as follows:

1. Dilute spray (high gallonage) 301 or more gallons per acre.
2. Semi-concentrate (moderate gallonage) 101 to 300 gallons per acre.
3. Concentrate (low gallonage) 20 to 100 gallons per acre.
4. High concentrate (very low gallonage) 1 to 19 gallons per acre.
5. Ultra high concentrate (ultra low volume) less than 1 gallon per acre.

Many machines may be modified to make applications in more than one classification. However, because of airblast and pump limitations, machines designed for low volume usually cannot be used for applying dilute sprays. Likewise, high volume machines are not efficient for use in applying low volume since the airblast and pump capacities would be excessive.

The principles for adjusting and calibrating airblast machines for treating fruit trees are the same regardless of the volume of water to be used.

Calibration procedures for trees.

1. Make sure that the fan and pump are operating at speed indicated in the operator's manual and that all strainers, nozzles and similar equipment are clean and in good condition.
2. Check the liquid pressure at the nozzle position on the discharge manifold. Pressures must be within limits set in your operator's manual and/or nozzle performance table.
3. Determine the effective airblast. Effective airblast is that part of the airblast actually used in covering the trees in question.
4. Make a diagram of the air outlet and liquid manifold. Indicate the effective airblast, nozzle positions and upper one-third of effective airblast.
5. Determine:
   a. Gallons per acre to be applied
   b. Distance between rows
   c. Speed at which the sprayer is to be operated
6. Use a calibration slide rule provided by the manufacturer or the formula given below to calculate gallons to be discharged from one side of the machine.

Gal/min (per side) =

$$\frac{\text{gals/acre} \times \text{miles per hour (mph)} \times \text{distance between rows (ft)}}{1{,}000}$$

For example, if one selects 200 gals/acre and 2 mph in an orchard with 25 ft row spacing:

$$10 \text{ gals/min} = \frac{200 \times 2 \times 25}{1{,}000}$$

7. Divide gals/min per side by 3. In the case cited above this would mean $10 \div 3 = 3.33$. Two-thirds of this volume or 6.7 gallons should be discharged through the upper ⅓ of the effective airblast and ⅓ of the volume or 3.3 gallons should be discharged through the lower two-thirds.

   Now consult a manufacturer's chart which matches the nozzles and nozzle pressure which you are using and select the appropriate sizes to give the desired rate of delivery for each position on the manifold. Spray coverage will be more satisfactory if nozzle sizes are selected which will give a gradual decrease in volume from the top to the bottom of the effective airblast, still maintaining the pattern of ⅔ of the liquid being discharged in the upper ⅓ of the airstream.
8. Install the desired nozzles in their appropriate positions. Unused nozzle positions above the effective airblast should be shut off but may be fitted with intermediate size nozzles for use during poor spraying conditions or for covering trees larger than those for which the sprayer was calibrated.
9. Fill the tank at least ¼ full. Turn on the newly nozzled side and check the time it takes to empty the tank. Calculate the gallons discharged per minute. The example given in Step 6 indicated 10 gallons per minute as the desired delivery rate. At this rate the tank should empty in 5 minutes if ¼ full is 50 gallons. Your allowable error should not be greater than 5 percent or 15 seconds. This means that a range from 4 minutes, 45 seconds to 5 minutes and 15 seconds is within desired limits. If the delivery rate falls within this range, nozzle up the other side and go to work. If not, go back over your calculations to find the error. If there is no error in your calculations the problem may be a faulty pressure gauge, wrong nozzle size, or obstructions that may have developed in strainers or other parts of the liquid system.

Most of the effort to calibrate and adjust a sprayer is lost unless it is operated at the right speed. Travel speed may be checked with a special speedometer, an engine tachometer (if proper adjustment is made for tire slippage) or by finding the number of trees you should pass per minute at the desired mph. Use the formula:

$$\text{trees passed/min} = \frac{\text{mph} \times 88^*}{\text{tree spacing in feet}}$$

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* 1 mph = 88 feet per minute

If your trees are planted 25 feet apart and you plan to travel at 2 miles per hour, then using this above formula you should spray 7 trees per minute.

$$7 \text{ trees/min} = \frac{2 \text{ mph} \times 88}{25 \text{ ft}}$$

If you are spraying more than 7 trees per minute you are traveling too fast; less than 7 trees per minute, too slow. Adjust your speed accordingly.

After the newly calibrated sprayer is operating satisfactorily periodic maintenance checks should be made to assure continued high performance. This should include checking the engine or PTO rpm, wear on the nozzles, strainers, pressure, and possible partial clogging of pipes and/or the hose lines and nozzles.

Calibration procedures for row crops. Airblast sprayers for treating row and field crops should be calibrated using the same general procedure followed for those used to treat fruit trees. Slight variations in the procedure are as follows:

1. The swath width in row crop spraying is the distance between passes made across the field. The formula to calculate gallons to be discharged from one side of the machine then becomes:

$$\text{gals/min} = \frac{\text{gals/acre} \times \text{mph} \times \text{swath width in feet}}{500}$$

2. The most effective liquid discharge pattern within the airstream varies from one machine to another. In most cases it is necessary to discharge a large part of the liquid in the upper part of the airstream to assure proper

deposits at the more distant parts of the swath. See manufacturer's operation manual for suggested nozzle sizes and arrangement.

3. You can check your speed by measuring the distance your sprayer travels in one minute and dividing by 88 (feet per minute traveled at one mph). Suppose you travel 176 feet in one minute:

   $$2 \text{ mph} = 176 \div 88$$

Broadcast Applicators for Granules

These applicators may be of the full width hopper type with sliding gate openings or augers, or those using air, or spinning disks to cover swaths much wider than the machines.

With the full width sliding gate and auger types one should check the evenness of distribution from all the openings by setting the gate at a particular opening, turning the drive mechanism and comparing the output over a given time from each opening. Use the actual pesticide to be applied and a preliminary setting as recommended by the equipment operator's manual for the pounds per acre desired.

For the air and spinning disk types, select a preliminary setting as recommended by the operator's manual for the application rate desired. Select and determine your actual travel speed, then check the distribution pattern in the field. Containers deep enough to keep the granules from bouncing out should be placed on two foot centers across the swath at several intervals along the first pass. Then by vision, volume, or weight, compare the output at each station. This will alert you to any correction needed and allow you to select the best swath width.

Calibration. To check the application rate, fill the hopper, settle the material in the hopper, then refill. Treat a known acreage using at least 10 percent of hopper contents and determine the pounds of granules required to refill. Then:

$$\text{pounds per acre} = \frac{\text{amount used (in pounds)}}{\text{acres covered}}$$

If the pounds per acre used are within 10 percent of that desired, treat another acreage and recheck the delivery rate, then make minor adjustments to correct the rate to within 5 percent and frequently recheck the delivery rate during application.

If the amount used is more than 10 percent in error, then change the applicator's rate settings and recalibrate. Keep calibrating until the rate is correct to within 5 percent.

Remember most units require that speed be held almost constant to keep the application rate constant. Also weather conditions can markedly affect granular flow rates so be alert to such changes.

Band or Row Applicators for Granules

These applicators should have tubes to the spreader which are not too long nor too shallow. Some use a flexible metal hose to carry granules from the hopper to the ground. The hose must not be too long for even flow or the application rate will vary along the row. Careful adjustment of the hose position or length may be necessary to provide uniform flow.

Banders should spread the bank evenly even when on 10 or 15 percent slopes. Chain drives should use sprockets of eight teeth or more to keep the drive speed uniform. Design should be such that the flow of granules stops when the drive stops even when the outlets remain open. The drive should be strong enough to turn and not break when restarted after road travel even when the hopper is full of granules.

Care must be taken to ensure the placement of the granules over the row or in the row as the pesticide label directs. Proper placement in some cases is as important as proper calibration.

Calibration. Band applicators should be calibrated in the field just like broadcast granular applicators, after first calibrating in a manner similar to row or directed sprayers (outlined below).

1. Set each individual applicator to apply the desired amount per acre as suggested in the equipment operator's manual.
2. Fill hoppers at least half full, turn on applicators and run until all begin feeding.
3. Disconnect nozzle of spreader and attach container under each tube.
4. Travel a measured distance (at least ⅛ of a mile or 660 feet) at the speed you wish to apply in the field.
5. Weigh the amount recovered for each band separately and record. Use an accurate scale such as a postal or kitchen scale.
6. Calculate the application rate for each unit using Equations 1 and 2 where the band width (in feet) is the swath width.

Equation 1:

$$\text{acres covered} = \frac{\text{distance traveled (ft)} \times \text{swath width (ft)}}{43{,}560\ (\text{ft}^2/\text{acre})}$$

Equation 2:

$$\text{application rate (lb/acre)} = \frac{\text{amount used (lb)}}{\text{acres covered}}$$

- This is the broadcast rate per acre and the rate the pest is subjected to in the banded area. The amount used per crop acre will be reduced by the ratio of band width to distance between rows.
- For some pesticides such as soil insecticides the recommended rate is in pounds per crop acre in which case use row spacing (in feet) for swath width in Equation 1 and your answer will be in pounds per crop acre directly.
- If the recommendation is in pounds per 1,000 feet. or row, then:

$$\text{lb/1,000 ft of row} = \frac{\text{lb collected} \times 1{,}000\text{ ft}}{\text{distance traveled (ft)}}$$

7. If the delivery rate is not within 5 percent of that recommended on any unit, adjust it accordingly and repeat steps 3 to 6 until it falls within the 5 percent.
8. Use the method described for broadcast application during the first part of each application to check the delivery rate. Adjust the settings accordingly.

Soil Fumigation Equipment

Equipment used for applying liquids or fumigants to the soil varies considerably, but all such equipment uses one of two basic methods of metering out the liquid fumigant. The method of metering does not affect the efficiency of the material. Preferences of metering equipment usually are based on cost, simplicity, accuracy, practicality and the specific needs of the applicator. There are two methods of metering.

Orifice size is selected to restrict flow from a system that maintains constant pressure at the orifice. Constant speed is necessary to maintain uniform application rates. Pressure regulation varies with the equipment but usually is one of three types.

- Constant head gravity flow. These units use a closed drum or tank with a special breather to establish a constant head of about ½ to ¼ pounds per square inch, depending on height differences between breather inlets to tank and the vented orifice. Needle valves, orifice plates and capillary coils are used to control flow rate. Capillary coils can vary in both length and diameter, but for any one application must be all the same length and diameter for equal pressure and delivery at the outlet.
- Pump and pressure regulator. Gear, roller, diaphragm or similar pump units use either a power takeoff or other power source. They generally operate at low to moderate pressures (5 to 20 pounds per square inch).
- Gas pressure. This method generally is used with highly volatile fumigants such as methyl bromide. Pressure approved storage tanks and pressurized nitrogen cylinders are used and a constant pressure in the fumigant tank is maintained with one of a variety of pressure regulation devices operating at 5 to 35 pounds per square inch depending on the fumigant and metering system used.

Metering pumps are driven from a ground wheel and are geared to the pump. Full output of the pump or pumps is forced out of the orifices. Changes in output are adjusted by changing the gear ratios and/or the length of the pump stroke. Uniform output is independent of tractor speed. Piston pumps are most common but gear, roller, diaphragm or similar pumps can be used.

Principal methods used for soil treatment are:

Injection systems. These are used for fumigants but can be used for other liquid soil pesticides.

- Chisel cultivators, blades or shanks with volatile materials may be 8 inches or more apart; with non-volatile materials, banding or 1- to 2-inch spacing between chisels is necessary.
- Sweep-type cultivator shovels.
- Planter shoe.
- Plow.
- Transplant water.

Surface treatment and soil incorporation. This method is used mostly for low or nonvolatile materials. Mixing usually is shallow, 5 inches or less. The simplest method is to spray soil, turn it in with disks and compact with a drag, float or cultipacker. Rotary hoes or weeders also are used. Nonvolatiles sometimes are applied as granules.

Drenching and flooding. These methods usually are used before prior to planting, but material also may be applied by irrigation water.

Calibration. This equipment can all be calibrated in the same manner as boom broadcast and band sprayers. However, fumigant labels usually specify the desired flow rate as fluid ounces per 100 or 1,000 feet of travel, or as feet traveled per pint of fumigant. A simpler technique is described below:

1. Establish the speed to be used in application by setting the equipment at depth to be used, and then, leaving fumigant valves turned off, drive across a tilled field at a rate that allows a constant travel speed. This speed is determined in feet per minute and converted to feet per second by dividing by 60. If the tractor has a speedometer, its speed per second can be calculated by multiplying miles per hour by 1.45.
2. Determine collecting time:

$$\text{collecting time (sec)} = \frac{\text{distance suggested on label (ft)}}{\text{speed in ft/sec}}$$

For example, if the label lists "X" ounces to apply per 1,000 feet and speed is 8 feet/second, then:

$$\frac{1{,}000\text{ ft}}{8\text{ ft/sec}} = 125 \text{ seconds necessary to apply "X" ounces}$$

3. With the orifice pressurized and constant speed units, keep the unit stationary and with pump or pressure system operating at some preliminary setting:
   a. Collect the output for the collection time calculated in step 2.
   b. If the amount is more than 5 percent above or below the ounces per 100 or 1,000 feet recommended on the label, change the pressure or orifices until the right amount is collected.

   There are tables available that approximate the output for each fumigant over a range of pressures and orifice sizes.
4. With ground-wheel-driven metering pump units:
   a. Determine the circumference in feet of the tire on the ground-driven wheel.
   b. Divide the calibration distance by the circumference to obtain the number of turns needed for that distance.
   c. Turn the wheel the calculated number of turns while collecting the output from one or more of the outlets. If the amount is not right, change the gears or sprockets in the drive or change the length of the piston stroke

and then recheck the delivery until it is within 5 percent of the amount recommended on the label.

5. Once field application is started, check the application rate immediately and often thereafter by comparing the amount used and the acreage covered.

Note: Row treatment rates and calibration can be kept less confusing by remembering that flow rates per outlet usually are the same as for broadcast fumigation.

Care of Application Equipment

Operating precautions for pesticide equipment

- Never use a pin, knife or other metal object to unplug a nozzle. Use compressed air, an old toothbrush, or a brush with soft bristles. Never blow into a nozzle to clean it.
- Never allow dirty water or debris to enter the tank.
- Control spray drift by:
  - using the largest nozzles and the lowest pressure that will apply the pesticide properly;
  - keeping the boom as low as permissible; and
  - spraying on days without wind or breeze.
- Do not use corrosive fertilizer solutions in an ordinary weed sprayer. Parts made of brass, copper, steel, aluminum or even galvanized materials may be severely damaged, unless the sprayer is cleaned carefully.
- Never operate a sprayer with any of the screens or filters removed. If the screen constantly becomes plugged, replace it with a screen of the proper mesh and capacity.
- Never fasten a power takeoff driven pump solidly to the tractor. The chain provided will keep most sprayer pumps from rotating. Fastening the pump with a bar usually causes rapid bearing wear.
- Never allow any sprayer pump to run without water, even for a short time; pump seals, bearings and other working parts may be severely damaged.
- Always pump a large amount of clean water through the sprayer at the end of the day or when changing from one pesticide to another. Clean all nozzle tips and screens at the same time. This helps reduce the gummy deposits or the accumulation of wettable powders in the sprayer.
- Airblast or mist sprayers are designed to apply insecticides and/or fungicides. They should never be used to apply herbicides.

Cleaning the sprayer. There is no satisfactory way to completely remove all traces of an herbicide from a sprayer. Traces of chemicals in solution cannot be completely removed from porous tanks, or from hoses, pressure regulators, selector valves, or screens. If an herbicide sprayer must be used to apply an insecticide or fungicide, do not apply the insecticide or fungicide to plants that may be damaged by the herbicide. Chemicals in suspension may not be as difficult to remove from the sprayer, but traces may still be present unless all parts are thoroughly cleaned.

At the end of the day or whenever wind or weather conditions force you to stop spraying, clean the sprayer to prevent gum or powder deposits in the pressure regulator, selector valve, nozzle tips and screens.

Follow these steps:

1. Rinse the inside and outside of the tank three times with clean water.
2. Put in a moderate amount of clean water and spray it out. A small amount of liquid detergent added to the water will help clean the inside of the sprayer system.
3. Clean the nozzles, nozzle screens, and suction screens with compressed air or a soft brush. Replace the screens and nozzles.

Caution: Never clean a sprayer near susceptible plants or where the rinse water could contaminate sewers, ponds, streams, or other supplies of water.

Storing the sprayer. When you store your sprayer properly, you add years to its useful life.

1. Clean the sprayer thoroughly.
2. Completely lubricate all moving parts according to the manufacturer's recommendations.
3. Make a list of all faulty parts and order the new ones to be ready for the following spring.
4. Fill the tank with water and add the recommended quantity and type of rust inhibitor or new light oil (see your instruction manual). Drain the tank. Leave all tank openings uncovered for ventilation, but screen them to keep out dust debris, insects and animals.
5. Clean all nozzle tips and screens with compressed air or a soft brush and kerosene. Store the tips and screens in a jar of new light oil or kerosene.
6. Take the weight off of any tires.
7. Remove, clean and drain the pump. Fill it with the light oil, antifreeze or rust inhibitor recommended by the pump manufacturer. Seal all pump openings to keep out dust, dirt, insects and animals.

Note: Make sure that no water is left in the pressure regulator, selector valve or boom. These parts will be severely damaged if water freezes in them.

Pesticides

In this section you will find specific information on some of the pesticides commonly used by pesticide applicators in this category of pest control work. For more information, consult the pesticide label or your local Extension Service.

Restricted Use Pesticides

Pesticides are classified for restricted use if there is reason to believe they may cause harm to people or the environment even when used according to label directions. Understanding why pesticides that you use are classified for restricted use will help you avoid endangering yourself, others or the environment. Some common reasons include acute or chronic toxicity to humans, effects on wildlife, or potential for ground water contamination. In the Appendix you will find a list of

Common Sprayer Troubles

Problem	Cause	Remedy
Loss of pressure	1. Pressure regulator improperly adjusted or stuck open. 2. Suction screen plugged. 3. Suction hose cracked or porous. 4. Pump worn.	1. Adjust pressure regulator. 2. Clean screen thoroughly. 3. Replace hose. 4. Replace or recondition pump according to manufacturer's instructions.
Excessive pressure	1. Pressure regulator improperly adjusted or stuck closed. 2. Bypass hose plugged or too small. 3. Gauge faulty.	1. Adjust pressure regulator. 2. Unplug the hose or replace it with a larger one. 3. Replace gauge.
Pressure gauge needle jumps excessively	1. Gauge too sensitive. 2. Air cushion for the surges in liquid flow is gone (surge tank is waterlogged).	1. Replace gauge or mount a flow restrictor or needle valve. 2. Admit air into the pump's air chamber, or install an air chamber on the pressure side of the pump.
Plugged nozzles	1. Nozzle screen too coarse. 2. Water, chemical, or tank not clean. 3. Nozzles too small. 4. Boom plugged.	1. Replace with the proper mesh screen. 2. Drain tank and clean thoroughly; check suction screen for holes. 3. Replace with the proper nozzles for the chemical being used. 4. Remove the plugs in the ends of the boom section to clean the boom.

restricted pesticides often used in various agricultural operations and the reason each was restricted. This information is included as a reference to help you choose and apply these pesticides carefully.

Triazine Resistance

The following herbicides are all in the triazine chemical family. They should be avoided if weed resistance to triazines is of concern.

atrazine (Aatrex)
cyanazine (Bladex)
metribuzin (Lexone, Sencor)
simazine (Princep)

Cholinesterase Testing

Organophosphate and carbamate insecticides are *cholinesterase inhibitors*; that is, they reduce the amount of cholinesterase available for the body's use. Cholinesterase is an enzyme made by the body and is necessary for the body to work properly. When the available amount of this important enzyme is reduced below a critical level, nerve impulses to the muscles can no longer be controlled, and death may occur. Depression below the critical level may occur from a single large exposure, such as spilling the insecticide on your clothing and not washing it off immediately, or from a series of small exposures over a long period, such as applying these insecticides according to label directions throughout the season. Some applicators may exhibit some of the symptoms of overexposure within 48 hours of an application, after which the symptoms may disappear until the next exposure. Symptoms include headaches, dizziness, blurred vision, sweating, nausea and vomiting, stomach cramps, diarrhea, excessive salivation (drooling), tightness of the chest, muscle twitching and pinpoint pupils.

Applicators who work with organophosphates and carbamates should ask their physicians about having regular cholinesterase testing done. This consists of monitoring the level of cholinesterase available in the blood throughout the application season. Since the amount that is normal varies from person to person and also changes from time to time, somewhat like a blood pressure reading, it is essential to have a baseline cholinesterase level established before exposure; that is, you should have a cholinesterase test before you begin applying these insecticides each year. Your physician can then compare later cholinesterase tests taken throughout the season to your baseline value and determine whether the level of cholinesterase has dropped significantly. If it has, you must not use any organophosphate or carbamate insecticides until your cholinesterase level has returned to normal.

Following label directions, wearing clean protective clothing, and showering after each application will help keep your exposure low. Since some people have a low baseline amount of cholinesterase available, cholinesterase monitoring throughout the season is strongly recommended for those who use organophosphates and/or carbamates frequently.

The following list includes some organophosphate and carbamate insecticides that may be used by applicators in this category. Insecticides are listed by common name followed by familiar trade names in parentheses.

Organophosphates

acephate (Orthene)
azinphos-methyl (Guthion)
carbophenothion (Trithion)
chlorphenvinphos (Birlane, Supona)
chlorpyrifos (Lorsban)
demeton (Systox)
diazinon
dimethoate (Cygon)
dioxathion (Delnav)
disulfoton (Di-Syston)
EPN
ethion
ethoprop (Mocap)
fenitrothion (Sumithion, Nuvinol)
fonofos (Dyfonate)
malathion
methamidophos (Monitor)
methidathion (Supracide)
methyl parathion (Penncap-M)
mevinphos (Phosdrin)
monocrotophos (Azodrin)
naled (Dibrom)
oxydemeton-methyl (MetaSystox- R)
parathion
phorate (Thimet)
phosalone (Zolone)
phosmet (Imidan, Prolate)
phosphamidon (Dimecron)
terbufos (Counter)
trichlorfon (Dylox, Proxol, Dipterex, Neguvon)

Carbamates

aldicarb (Temik)
carbaryl (Sevin)
carbofuran (Furadan)
methiocarb (Mesurol)
methomyl (Lannate, Nudrin)
oxamyl (Vydate)
pirimicarb (pirimor)

CHAPTER 2

FIELD AND FORAGE CROPS

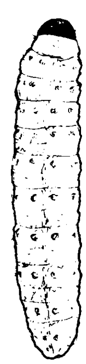
If you are a commercial applicator, you should study this section if you wish to become certified in Category 1, Agricultural Pest Control. If you are a private applicator, you should study this section if you wish to become certified in the Field and Forage Crops specialty.

Insect and Mite Pests of Field and Forage Crops

There are a large number of species of insects and mites that can damage field crops. Only a few of them, however, appear in damaging numbers in some fields each year, and even fewer of them are pests in large acreages of the state.

Nearly all stages of all field crops are subject to insect attack. Examples of pests that can attack different crops at different stages follow. As noted, the insects usually are scattered and sporadic in their appearance in damaging numbers. Their actual appearance is difficult to predict. They tend to be more abundant under some conditions than under others and these conditions are noted for each insect. Their control depends strongly on their biology. Also, some important biological features that affect control are noted. More specific information on control can be found in the Pest Management Guidelines and Control Recommendations available from the Maryland Cooperative Extension Service.

Pests of Corn



Larva

European corn borer. This pest has two annual generations in western and central Maryland and usually three generations in southern Maryland and on the Eastern Shore. Mature larvae overwinter in corn stalks and stubble. In the spring, these overwintered larvae transform into the pupal stage. On the Eastern Shore, pupation usually starts the first of April and ends the third week of May. After 10 to 14 days, the new adult moths emerge, mate and begin to lay eggs on the early planted corn. Eggs are laid in masses of 15 to 35 on the underside of leaves and hatch in 6 to 8 days. Egg-laying normally begins around early May and peaks the last week of May on the Eastern Shore. First brood activity normally lags about 10 to 14 days behind in areas of western and central Maryland.

Young borer larvae less than ⅛ of an inch in length feed on the surface of leaves for several days. As they get older, larvae move into the whorl zone and bore through the leaves. Feeding results in shot-hole injury, particularly visible as the whorl leaves unroll. Somewhat larger larvae will bore into the midribs of leaves causing them to break. When about half grown, the first generation larvae will begin to bore into tassels and the stalk itself. Once borers are inside, all chances for chemical control are lost.

First generation borers continue to feed in stalks for 10 to 14 days, causing tunneling and weakening of stalks. Under severe attack early in the season, corn becomes stunted and yields are reduced because of the inability of the plant to absorb water and nutrients through the damaged stalk. Also, with persistent autumn winds and dry weather, tunneling in the ear shanks increases dropped-ear losses. Losses increase the longer harvest is delayed. Mature borers pupate in their tunnels or elsewhere on the plant, and, after 10 to 16 days, moths emerge to mate and begin laying eggs for the second generation.

The midsummer brood of moths usually seeks the latest planted corn. As a result of varying lengths of development, this brood emerges and lays eggs over an extended period. Second generation borers normally concentrate their attack in the ear zone, roughly the middle third of the plant. Leaf collar feeding may reduce the amount of grain produced. Stalks may be riddled with tunnels causing them to break over and lodge. Ears may drop to the ground as a result of shank damage. Second and third generation borers normally overwinter in corn stalks and become the source of infestation the following year.

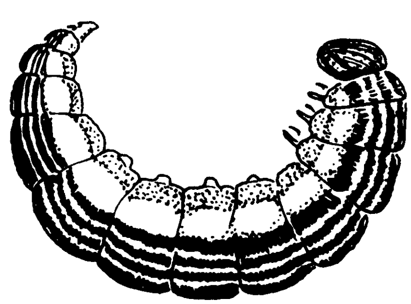
Corn borer damage is present each year but large-scale outbreaks of economic status usually occur in 1 out of every 6 years. Populations are affected by many factors such as the size of the overwintering population, weather conditions, cultural practices, natural enemies and the corn hybrid.

Corn should be checked each week for larval feeding in the whorl leaves following significant moth flights and when the plants reach 18 to 24 inches in height. Examine 20 consecutive plants for fresh whorl feeding in five different areas of the field. Newly hatched larvae feed on the leaves, causing a characteristic "window box" appearance or "shot-hole" injury that is readily visible as the whorl unrolls. Pull the whorl from five infested plants per sample site and carefully unroll the leaves while counting the number of live borers. Also, note the location of the larvae in the whorl or stalk. When sampling is completed, multiply the percentage of plants infested by the average number of live larvae per infested plant to obtain an estimate of the potential number of larvae per plant.

Sampling for the second generation is difficult because of the extended egg laying and larger corn plants. Furthermore, late season control using foliar insecticides on corn that is beyond the tasseling stage is not economically feasible in most cases. However, corn planted late can be significantly damaged if the optimal plant growth stage for egg laying coincides with the second brood of moths. Any late planting in the whorl stage during July should be monitored using the same sampling procedures described above for the first generation.

Whorl infestations can reduce yields by as much as 5 percent for every corn borer per plant that survives to bore into the stalk. Foliar treatment of insecticides directed in the whorl leaves is the most effective method of control. Except under very heavy infestations, one treatment usually is sufficient if applied while the larvae are feeding in the whorl and are relatively exposed.

As a general guideline, treatment of corn grown under average management conditions is suggested only if 80 percent or more of the plants have fresh whorl feeding with live larvae and before borers tunnel too deep in the whorl or stalk. For high management corn, treatment is suggested if 50 percent or more of the plants have fresh whorl feeding with live larvae. The best time to treat is around the first 2 weeks of June—approximately 5 to 7 days after peak egg laying.



Larva

Black cutworm. This species is the most important cutworm attacking corn, although it destroys a wide variety of field and vegetable crops. Moths begin appearing during the first warm evenings of March, suggesting that the insect overwinters as a mature larva/pupa or that it is blown into the area on southerly winds. The first flight of moths peaks in April when females deposit eggs on surface trash and the low dense growth of weeds, usually where there is high soil moisture.

Eggs require 14 days to hatch at a temperature of 50°F. and the larvae mature in 55 to 60 days at the same temperature. As the season progresses, soil temperatures rise and larval development is more rapid; 33 days are spent in larval development at 68°F. At this temperature, 14 days are spent in the first four larval instars (stages) when feeding is of little importance and 19 days are spent in the destructive fifth, sixth, and seventh instars. The larvae pupate in the soil and adults emerge in about 2 weeks. A second flight of moths peaks in late June and a third flight occurs in August and September. Summer larvae do not damage corn significantly.

The black cutworm is light gray to black with a narrow, lighter stripe down the middle of its back. Its skin surface is firm, roughened with granules, and has a greasy appearance. Full-grown larvae can reach 1¾ inches in length. The adult is a large moth with wings that are dark on the basal two-thirds and much paler on the outer third. There is a distinct black "dagger" mark on the outer edge of a large spot on the forewing.

Young cutworms feed aboveground, usually on corn foliage and weeds until they reach about ½ of an inch in length. Older worms feed through the stem at ground level or below to completely sever the plant. One cutworm is capable of cutting 4 to 5 plants during its larval development. The more mature a plant is when severed, the greater the loss in productivity. Complete plant failure occurs when 10-inch plants (extended leaf height) are cut; in this case, the growing tip is cut off at ground level. Cutworms also can burrow into the base of larger plants and cause death.

Cutworm outbreaks on corn generally are sporadic and difficult to predict. However, the following field characteristics seem to be associated with cutworm infestations: (1) Most fields damaged by cutworms are minimum or no-till corn following corn or no-till corn in soybean stubble. Female moths are attracted to the surface trash and weeds associated with no-tillage. Also, larval survival increases as tillage of the soil decreases. (2) Fields in poorly drained soil are most susceptible because the egg laying moths are attracted to moist soil surfaces. (3) The single characteristic that is common in most infested fields is the presence of weeds prior to spring tillage or planting. Early spring weeds such as chickweed, dock, yellow rocket, and coarse grasses provide attractive egg laying sites and food for young cutworms before corn is planted. When the weeds are killed by tillage or herbicides if no-till, the cutworms turn their attention to corn plants. (4) Fields that are tilled and planted later in the spring are more susceptible because the weed cover prior to that time is afforded a greater opportunity to support cutworm population.

Early detection is necessary to reduce crop losses and achieve successful control. Corn fields exhibiting one or more of the four characteristics listed should be sampled beginning in May and continued weekly into June. Follow the procedures detailed in the Pest Management Guidelines.

The decision whether or not to apply a rescue treatment is difficult because most infestations consist of different sized cutworms. Also, the long length of the last instar complicates control decisions because it is hard to know if the worms are just beginning to cut plants or are close to pupation.

The potential for yield loss caused by cutworm damage varies, depending on the insect population and the stage of corn development. Regrowth studies have shown that when 10 percent of 5-inch plants (extended leaf height) are severed, the final yield loss is about 3 percent. At 9 inches of height, a 10 percent severance results in a 7.5 percent yield loss.

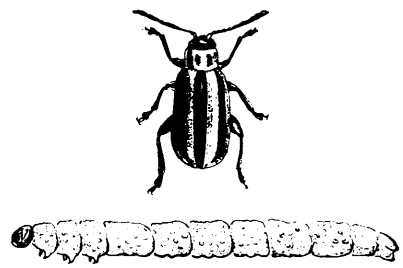
Preplant or at-planting treatments are not recommended except in high-risk fields. Such fields still should be watched closely because a rescue treatment may be necessary in spite of the preventative treatment. Rescue treatments generally are more effective and can be applied when an actual economic population is present. Also, infestations are frequently localized enough to allow spot treatment, thus saving treatment of the entire field.

As a general guideline, a rescue treatment should be applied at the 1- to 2-leaf stage when more than 10 percent of the plants show fresh leaf feeding. At the 3- to 4-leaf stage, treatment should be applied if 5 percent of the plants are cut and there are 4 or more cutworms per 100 plants. A stand count should be taken to help determine the amount of cutting that can be tolerated. Stands at or below the desired plant population cannot tolerate any loss of plants, whereas fields with high plant populations can be watched for a few days before making a decision.

Effective rescue treatment depends on the proper chemical and application technique for particular soil and weather conditions. If the top 2 inches of the soil are dry, effective treatment is not possible because larvae are feeding below the soil surface. If only the top inch of soil is dry, rotary hoeing after treatment can improve control results. If the surface is moist but not wet, use baits or sprayable insecticides. If the soil surface is wet, sprayable treatments directed at the base of the plants are the most effective.

Insecticide baits can be used for very localized infestations but these products are hard to apply and to obtain from local dealers. Pyrethroids are more effective at cooler temperatures and have slightly longer residual action than the organophosphates. Thus, they have the advantage if temperatures for 2 to 3 days after treatment are expected to be below 70°F. However, pyrethroids tie up rapidly in the soil and thus they are more effective in no-till fields with heavy organic matter on the surface. Most organophosphates that are labeled for cutworms tie up in organic matter, so these products work better in fields with bare ground or light surface trash. All of these chemicals are relatively insoluble in water; light rains after application will not be a problem.

Northern and western corn rootworm. Corn rootworms may damage the corn plant in either the larval or adult stage. Lodging of corn or "goosenecking" resulting from larval root feeding is a typical symptom of damage caused by rootworms. Roots of corn may be severely damaged from June to August. Newly hatched larvae feed primarily on the root hairs and outer root tissue. As larvae become older they may burrow into the inner core of tissues containing the vascular bundles. Larval damage usually is most severe after the secondary root system is well established and brace roots are developing. The entire root system may be destroyed under heavy population pressure. Root tips appear brown and often are tunneled and chewed back to the base of the plant. Larvae may be found tunneling in larger roots and occasionally in the plant crown. After emerging, corn rootworm beetles may feed on green silks or pollen, depending on the state of development of the corn. However, the Western species also will feed on the green epidermal layer of the corn leaves whereas the Northern will not. This injury is similar to that of the cereal leaf beetle on small grain. Unless the adults are unusually abundant, only scattered plants are damaged. Such damage does not justify spraying to control beetles but is indicative of large, adult populations.



Larva

Severe silk pruning by adults may result in a yield reduction resulting from poor pollination, but this seldom occurs unless beetles are especially numerous in the early green silk stage (Stage 5) as silking is commencing. Insecticide treatments to control beetles are not needed after pollination is completed and the silks are brown. Occasional ears may be singled out by the beetles for feeding on developing grain, but this damage usually is not significant.

Both rootworms have only one generation per year. The life histories of the two are very similar, but several biological differences can be noted.

Eggs of both species are deposited in the soil in mid- to late-summer by female beetles and pass the winter in this stage. Eggs usually are concentrated in the top 6 inches but female beetles will follow soil cracks to depths of 10 to 12 inches to deposit eggs. Plowing and subsequent soil tillage practices disperse the eggs both vertically and horizontally.

Egg-hatch may begin as early as mid-May, depending on soil temperatures. Most egg-hatch occurs in June but may be spread out from mid-May to mid-August. Considerable variation in hatching dates is encountered from place to place because of the differences in latitude, elevation, seasonal variations in soil temperature, depth of eggs in the soil, sex and species.

After egg-hatch, the small (less than ⅛ of an inch) first instar larvae move to corn roots and begin to feed. Rootworm larvae can move at least 20 inches to a food source (corn roots). Three distinct larval stages or instars are observed in normal development. After about 3 weeks in the larval stage, the larva stops feeding and constructs a small cell in the soil to transform to the pupal stage. The transformation from pupa to adult requires 5 to 10 days, depending on the temperature.

Males usually are the first to emerge; female emergence begins about a week later. In general, western corn rootworms emerge earlier than northern corn rootworms. Since larvae hatch at different times and develop at different rates, beetles continue to emerge from about the first week in July through August. Peak emergence of beetles usually is from mid-July to early-August, but this varies from season to season.

After emergence and mating, about 14 days elapse before the females begin egg laying. Rootworm beetles may deposit up to 1,000 eggs; an average of 500 per female is probably common. Most egg-laying occurs after August 1.

Soil types can also influence the degree of rootworm infestations. Rootworms are not a problem on muck soils. Rootworms are usually not a significant problem where corn is grown on sandy soil under nonirrigated conditions. Soil texture affects both adults and larvae. Adults prefer sites composed of large soil particles with cracks and moisture for oviposition. Soil moisture affects both quantity and location of egg-laying. More eggs will be deposited in moist soil than in dry soil.

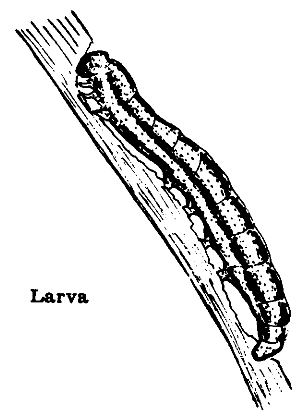
No consistently reliable and accurate method is available to monitor for corn rootworm larvae. Newly hatched larvae are especially difficult to detect. Because of this, an accurate sampling method would require a great amount of time and many samples. However, the presence or absence of rootworm beetles in a cornfield is an excellent indicator of future rootworm problems. The potential for rootworm damage can be estimated for the following season by counting beetles between mid-July and August (about July 20 to August 25). Corn growers can determine the potential for rootworm larval damage for the following year using the system detailed in the Pest Management Guidelines.

Instances of rootworm damage to first year corn after soybeans, alfalfa, small grain, and grain sorghum are rare. Exceptions have occurred where corn followed soybeans with heavy infestations of volunteer corn and other weeds or after small grain with a weed infestation. Treatment of first year corn for rootworms is rarely required, unless substantial beetle populations were observed in the fields the year before. Crop rotation is still the most effective method of control.

Pests of Corn and Small Grains

Armyworms are distributed throughout Maryland; however, the most serious outbreaks occur in no-till cornfields having a dense spring stand of rye or other grassy cover crops. In most years, a grower could have an 80 percent probability of encountering armyworms follow a rye cover crop.

ARMYWORM



There are three generations each year in Maryland. The first generation causes the most serious damage to corn and small grains. This species overwinters in the soil and emerges in the spring (April and May) to lay eggs. Although parasites and other natural controls suppress the second and third generations, our native population frequently is supplemented with migrations of moths from the South.

Armyworms cause occasional loss in conventional tilled corn and may cause severe damage in minimum or no-tilled corn. The worms chew the leaves of small grains and grasses. They may confine their feeding to leaf margins or in some instances totally strip corn plants. In moderate infestations, the corn will recover if the plant has not been damaged below the growing point. If infestations are severe and plants are eaten below the growing point, entire fields can be lost. There are two distinct problems with armyworms in corn. If corn is planted in reduced tillage situations and these areas have grasses or other crops used for pasture, hay or cover crops, moths lay eggs in the grasses before the corn is planted. The plants with young larvae are killed with herbicides, leaving only corn for armyworm food. This occurs from early May into June. The second problem occurs when moths lay their eggs in small grains in May and June and the larvae develop in the small grain fields. As small grain matures, armyworms migrate (in tremendous numbers) to nearby fields. Large numbers of larvae can, within a matter of a day or two, destroy the field.

It is important to detect armyworms when they are still small because they are easier to control and have not begun to clip grain heads. There are two reasons why armyworms escape early detection: 1) larvae do most of their feeding at night and hide during the day under debris on the ground, and 2) larvae do not feed much until the last instar when they begin to eat voraciously. Sample according to procedures detailed in the Pest Management Guidelines.

Spot treatments may be warranted if infestations are confined to small areas. Control for armyworms in *corn* is recommended if 35 percent or more of the plants are infested and 50 percent or more defoliation is seen on the damaged plants, provided that larvae average less than ¾ of an inch long. Worms greater than 1¼ inches in length have completed most of their feeding.

As a general guideline, *barley* should be treated if the number of armyworms exceeds one per linear foot between rows and most of the worms are less than ¾ of an inch long. Fields with mixed infestations of armyworms and sawfly caterpillars may need treatment even if worm counts of each pest do not exceed threshold levels.

Since armyworms tend to nibble on the tips of *wheat* kernels rather than clip heads, populations around 2 to 3 worms per linear foot between rows are required to justify control in wheat. In high management fields with 4-inch rows, treatment is recommended when armyworm levels exceed 3 to 5 per square foot of surface area.

If the grain crop is close to harvest or the majority of armyworms are longer than 1½ inches and no head clipping has occurred, control may not be needed. Control also depends on the amount of subcanopy vegetation available for the worms to feed on and on the expected value of the crop. More worms can be tolerated in fields with plenty of green vegetation for them to complete their development. Lower populations are needed to justify treatment in high management fields with greater yield potentials.

Stalk borers attack many species of crop and weed plants. In conventional tillage, stalk borer damage usually is confined to the field margins and corn plants along grassy waterways and terraces. Eggs laid on grassy weeds in the field would be destroyed by plowing.

Stalk borers can cause damage throughout a field where reduced tillage is practiced. When grass plants are not turned under by plowing, stalk borer eggs may be present throughout the field and subsequent damage would not be limited to field margins.

The larvae are recognized easily by the prominent longitudinal white stripes at both ends of the body. The stripes are interrupted by a dark purple area on the third thoracic segment and the first three segments of the abdomen. Full grown larvae are 1½ inches long. The last larval instar does not have the prominent white stripes and dark purple area. It is dirty gray in color and is more difficult to recognize. The larvae pupate in late July, usually just below the soil surface, but sometimes they will transform to the pupal state inside the stem of the host plant.

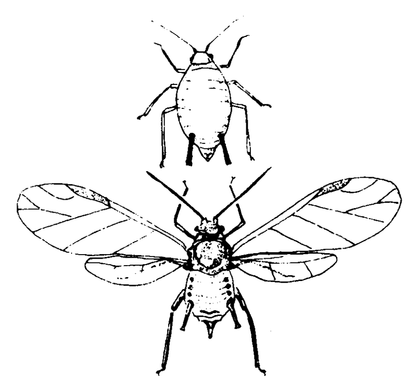
Eggs usually are laid in the creases of rolled or folded leaves in late August until frost appears on grasses and weeds. The eggs hatch in May and the larvae bore into the stems of nearby weeds or crop plants. Larval stages are found throughout the summer, and pupation occurs in August.

Corn plants attacked by this insect will show irregular rows of holes through the unfolded leaves. Many plants will have an unnatural growth and display a twisted or bent-over, stunted appearance. Many infested plants will not produce an ear. Larval damage occurs from May to August. The larvae may enter corn and other plants at the side of the stem and burrow upward causing the heart of the plant to die. They also may enter small corn plants from the whorl and work downward, causing part of the plant to wilt and die.

Survey field edges that border small grains or large grassy areas for damaged plants. If stalk borer damage is seen, examine 20 plants at each of five locations within the field and record the percentage of damaged plants, the average larval size, and the severity of injury. If slug injury is suspected, turn over clods of dirt and surface trash around five plants at each location and determine the average number of slugs associated with each plant.

Spot treatments may be warranted if infestations are confined to small areas. Treatment is suggested if more than 4, 6 and 10 percent of the plants are initially damaged at the 2-, 3- and 4-leaf stages and the worms have not bored into the stalks. Good weed control eliminates egg laying sites. Increased seeding rates should be used in high risk fields.

Pests of Small Grains



Wingless and winged aphids

Aphids. The four species of aphids that injure small grains in Maryland (in order of abundance) are the English grain aphid, apple-grain aphid, corn leaf aphid, and greenbug. These aphids overwinter in grain fields as partially or fully grown females. In the spring when the weather turns warm, the females give birth to live young that may or may not develop wings. Aphids multiply rapidly and feed on small grains by sucking sap from the leaves, stems and grain heads. Plant tissue often becomes discolored, and dead areas appear in the field as a result of toxic saliva injected by the aphids when feeding.

The most serious damage results when large numbers of aphids feed on the grain head causing the grain to shrivel or fail to fill. Also, some species have been linked to the transmission of barley yellow dwarf; however, this disease has not been a major problem to small grain production in Maryland. After the harvest of small grains, aphids migrate to wild or cultivated grasses where they continue to cycle through numerous generations throughout the summer. In the fall, they go back to newly planted winter grains where they overwinter.

It is not as important to identify all four grain aphids as it is to recognize an infestation of aphids and their natural enemies. In general, grain aphids are small pear-shaped insects with bright green or bluish-green bodies and black legs and antennae. Both winged and wingless forms are found together in small grains. Since greenbug injury is more serious than feeding caused by the other three species, this particular aphid should be identified if present when diagnosing an aphid infestation. The adult greenbug is pale green with a dark green longitudinal stripe running down the back of its body.

Natural enemies of aphids include lady beetles, syrphid fly maggots, lacewings and tiny parasitic wasps. *Lady beetles* are easily identified but their larvae are quite different in appearance and sometimes mistaken for pests. Larvae are ⅓ of an inch in length, bluish-black with orange markings, and their legs are stretched outward on the sides. *Syrphid fly maggots* have brown worm-like bodies with a tapered head and a blunt rear end. They have no hard head capsule or legs. They characteristically hold their hind ends in place and move their heads about in search for aphids. This maggot is the major predator of aphids on small grains, yet frequently it is mistaken as a pest. *Lacewing larvae* are light brown, about ⅓ of an inch in length, and resemble tiny alligators in general body appearance. They have a pair of piercing mandibles that they use to spear and suck the body juices from aphids. *Parasitic wasps* insert eggs into aphids causing them to die and turn brown.

Small grain fields should be checked once a week starting the first week of April or earlier if damage symptoms are evident. Occasionally, infestations begin to build up in the fall, especially in the earliest planted fields that are under high management practices.

To determine aphid activity on tillering grain, 10 to 20 sites should be examined throughout the field. Each site should consist of 5 linear feet of row. More sites may be necessary in large fields. You should first examine areas in the field that are showing plant stress symptoms, but do not bias your sampling to these areas. Aphids should be counted on a few plants and then estimated proportionately over the entire area at each sampling site. Record the average number of aphids per linear foot of row and note what proportion of the population consists of the greenbug.

To determine aphid activity on tillering grain, 10 to 20 sites should be examined throughout the field. Each site should consist of 5 linear feet of row. More sites may be necessary in large fields. You should first examine areas in the field that are showing plant stress symptoms, but do not bias your sampling to these areas. Aphids should be counted on a few plants and then estimated proportionately over the entire area at each sampling site. Record the average number of aphids per linear foot of row and note what proportion of the population consists of the greenbug.

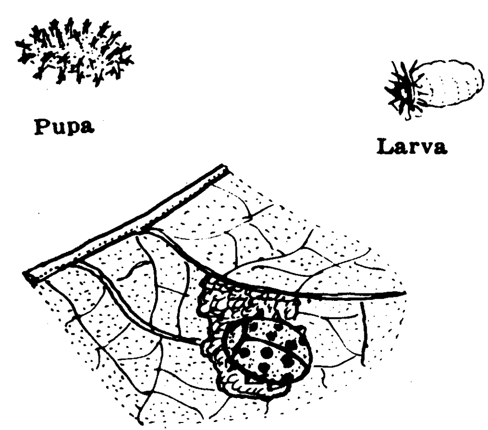
To determine aphid activity on small grains in the head stage, 50 to 100 heads should be examined throughout the field. Do not bias your sampling by checking a few heads along the field margins where populations are normally higher. Heads should be examined at 10 to 20 paces starting well into the field. It is important to check for natural enemies at the same time that aphids are being counted. But be careful not to confuse these natural enemies with other pests. Aphids normally are clustered as colonies among bracts of the grain head and do not move when disturbed. Anything that moves when disturbed is probably a predator. Record the average number of aphids per grain head and note the ratio of predators to aphids.

Control is rarely needed during the tillering stage. However, treatment is suggested if aphid counts exceed 150 per linear foot of row throughout the field and plant stress is apparent, especially if the greenbug is the predominate species.

The decision to treat depends primarily on the number of aphids, plant maturity and the presence of natural enemies. As a general rule, control is suggested if aphid numbers exceed more than 25 per head, especially if the crop is late and the natural enemy population is low. Control is not advised if the crop is approaching the hard dough stage or if there is good predator/parasite activity. Ratios of one or more predators to every 50 to 100 aphids are sufficient to achieve biological control. Spraying too early kills off the natural controls. Remember that 98 percent of the time, aphids are controlled by natural enemies.

Soybean Pests

Mexican bean beetle. Two or more overlapping generations develop in Maryland each year. At least one stage of the beetle may be present in a soybean field during the entire



Adult and damage

season, and all four life stages (egg, larva, pupa and adult) can be found simultaneously.

The third and fourth instar larvae and adults consume most of the foliage. Populations usually do not reach economic proportions until August because soybean growth during June and July compensates for damage and Mexican bean beetle densities usually are not high enough to warrant concern until late in the growing season. Early planted fields generally attract more colonizing adults than do later fields and tend to suffer greater damage, but double crop soybeans may develop high Mexican bean beetle populations late in the season when adults leave mature beans in search of more favorable food sources.

Larvae typically are more damaging. Larvae strip away the top layer of leaf tissue between the veins, giving the leaves a skeletonized appearance. Adults consume all leaf tissue between major veins producing a distinctive lacy appearance to the foliage. The leaf veins remaining after Mexican bean beetle feedings often drop away from the leaves because of wind or rain action, resulting in large, ragged holes in the foliage.

Late in the season when the leaves become less attractive and begin to yellow, Mexican bean beetles may feed on stems and developing pods. Damage to the pods usually is characterized by skeletonized outer tissue; if the beetle chews a hole into the pods, it seldom extends all the way through to the seeds. Though stem and pod feeding may be damaging in some situations, yield reductions usually result only from the beetle's feeding on the foliage of soybean plants.

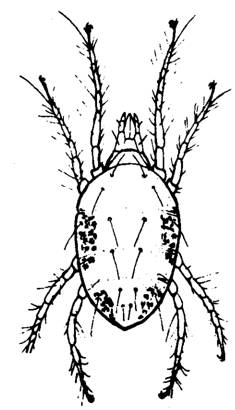
Mexican bean beetles can appear on soybeans from crop emergence until senescence. However, scouting is more justified during August through September and should be continued in fields until 50 percent of the leaves are yellow. Sample according to procedures detailed in the Pest Management Guidelines.

- Before the first true leaf stage, treat if six or more beetles per row foot are feeding and reducing stands to levels less than 75 percent of the plant density recommended for the given row width. For seedling soybeans after the second trifoliate stage, control is recommended when leaf loss approaches 35 percent and 5 to 10 beetles and/or larvae per plant are present.

- During pod-fill, treatment is recommended if defoliation exceed 15 percent and more than 5 to 10 larvae and/or adults per rowfoot are actively feeding. If eggs and pupae are the predominant stages, wait until hatch or adult emergence to treat. If more than 30 percent of the larvae are mummified (parasitized) then population may soon be brought under control.

Spider mites. Although a number of species of mites injure soybeans, it is not as important to identify species as it is to recognize an infestation.

Mites are dispersed by wind or they may crawl from adjacent weed or other crop hosts into soybean fields. Consequently, many infestations originate at field edges where plants in bordering areas provide mite reservoirs. After dispersing, females settle on a suitable plant. They begin to feed and lay eggs within a few hours. As the population increases, young females disperse from the parent host plant by producing silk—a "swarming" phenomenon that results in bridging the distance between adjacent plants with silk and allowing individuals to be blown across by the wind.



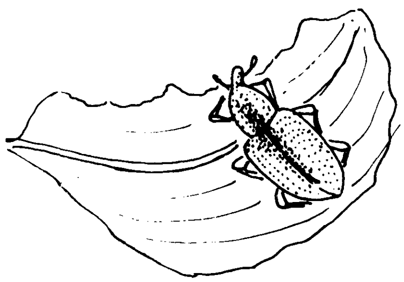
Mite injury and outbreaks usually are associated with hot, dry weather that accelerates the reproductive and development rates. High humidity and field moisture may adversely affect spider mite populations but high temperatures can nullify these effects. Another important factor contributing to outbreaks is the availability of a physiologically suitable host plant. Not all stages of soybean growth are nutritionally adequate to support the high reproductive rate necessary for an outbreak. Thus, outbreaks are most often associated with the blooming or pod development stages rather than the vegetative growth stages.

Spider mites injure soybeans by feeding on the green foliage. They have needle-like mouthparts that are used to puncture individual leaf tissue cells and consume the contents. The presence of numerous empty cells results in the yellow or white stipples characteristic of mite-injured leaves. Generally, these feeding signs are first noticed at the base of the leaf when 20 to 30 mites are present on the underside. Extensive feeding by a large number of mites (300 to 600 per leaf) causes the leaves to turn yellow or brown on the margins, and eventually die and drop from the plant.

Scouting should begin during early July and continue through early September, especially during a hot, dry season. Particular attention should be given to border areas showing dry weather injury, mineral deficiencies, and herbicide injury since these symptoms are similar to mite damage. Concentrate on the field borders and look for the early signs of white stippling or the sand-blasted appearance at the base of the leaves.

If isolated spots of mite activity are confined to the field edges, spot treatment with a miticide using ground equipment is recommended to prevent further spread of mites into the field. If the infestation is widespread, aerial application of the entire field may be justified. Procedures for sampling and deciding on control strategies have been carefully worked out and are based on years of research. These procedures are detailed in the Pest Management Guidelines.

Alfalfa Pests



Alfalfa weevil. This insect is primarily a pest of first-growth alfalfa, but some minor damage can be observed throughout the summer. Most of the leaf feeding damage is caused by the larvae. The youngest larvae feed inside the tight bud tips and as the larvae grow larger, they move out onto the open leaflets and skeletonize the tissue. Severe damage causes the leaves to dry, turn gray and appear "frosted". Mature larvae also can feed on the new second growth (stubble growth) and prevent the typical "green up" normally observed 3-4 days after harvest.

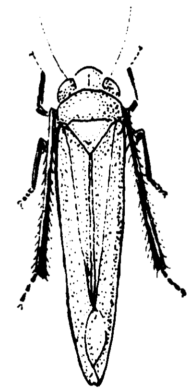
The adults cause less damage. They usually chew long slits from the leaf margin, often eat the skin of the stems, and also feed on the new second growth shoots.

If a stand is recommended to be cut early because of the heavy larval feeding, scouts should check the regrowth for the presence of feeding larvae and new adult weevils. These newly emerged adults themselves may seriously damage the regrowth and prevent the normal "green up" 3 to 4 days after cutting.

Alfalfa weevils generally have one generation per year. A partial second generation is possible, but this may represent only 1 to 5 percent of the weevil population. Egg laying occurs in the fall and spring in Maryland but the spring population is the most serious. Usually 90 percent of the eggs are laid in the spring. The female deposits about 10 eggs inside the fresh alfalfa stem or the stubble plants. Depending on temperature the eggs begin to hatch in late March to mid-April in central Maryland. Larvae feed for 3 to 4 weeks, then spin a loose, silk cocoon and pupate inside. Adults emerge in 1 to 2 weeks and remain active for a week or two when they leave the field to estivate (hibernate for the summer). These adults again return to the field in the fall.

Currently, six species of wasps have established themselves in the northeast states as natural enemies. Their success in suppressing the alfalfa weevil reached record highs in the last 5 years. Today, 90 to 95 percent of the alfalfa grown in the northeast United States is not sprayed for weevils and these wasps are given most of the credit for the control.

Procedures for sampling and deciding on control strategies have been carefully worked out and are based on years of research. These procedures are detailed in the Pest Management Guidelines.



Potato leafhopper damage may occur in the second and third alfalfa cuttings in Maryland, but rarely the fourth. First symptoms of feeding may appear in early to mid-June. Both the nymphs and adults feed by piercing and sucking plant tissues, causing a blockage of the plant vascular tissue, usually along the midvein. In a short time, the typical triangle-shaped yellowing of the leaf tips results, eventually spreading to the entire leaf. These plants in turn become yellowed ("hopper burn"), stunted and fail to grow again until the crop is harvested. Hay from injured alfalfa has less proteins and a large reduction in vitamin A. Stands that suffered severe "hopper burn" frequently have excessive winterkill the following year.

Generally, alfalfa is most susceptible to damage during the new growth period such as on a spring planted stand and during the regrowth period after cuttings on established stands. In general, the shorter the plants at the time of attack, the greater potential damage to the stand. Remember, hopper feeding can stunt alfalfa growth even at the 2- to 3-inch height. Peak damage can occur at any time between mid-June to late August throughout Maryland.

This species does not overwinter in Maryland but migrates northward each year from the Gulf of Mexico. The first pale lime-green, wedge shaped, ⅛-inch-long adults arrive in Maryland in late May or early June and sometimes as late as mid-July. This species may attack a wide range of crops and wild plants throughout the summer.

Eggs are laid in alfalfa stems, leaf petioles and along the midleaf vein. Eggs hatch in 4 to 5 days. The nymphs characteristically move very quickly. Frequently they move sideways when disturbed. The period from egg to adult usually is 3 weeks under favorable conditions. Cool night temperatures or excessively high temperatures about 95°F retard development times. Thus several generations can occur during the summer.

Since this species migrates into Maryland each year, the preventative control approach is not recommended because the potato leafhopper may not arrive in Maryland until mid-July when sprays are being applied in June. Scouting is the best method for determining when to treat. Rescue treatments only are recommended for established alfalfa stands. Follow procedures detailed in the Pest Management Guidelines for sampling and control decisions.

Note: If insecticide treatment is warranted, avoid spraying alfalfa having flowering weeds, in order to protect bees.

Diseases of Field and Forage Crops

Several diseases in field crops are discussed to illustrate types of diseases or methods of control for some of the more important diseases.

Fungal Diseases

Loose smut in wheat is caused by a fungus whose related forms attack either barley or spelt. The fungus multiplies and produces black spores that completely replace the grains in the head. At blossoming time, these spores disperse to healthy flowers where each spore can germinate and penetrate the growing embryo. Here the fungus remains dormant until the healthy looking seed is planted. The fungus "reawakens" and spreads in the plant until it reaches the flower head where it again produces its mass of spores. Most fungicides applied to diseased seed would not penetrate the embryo to kill the fungus. However, a systemic fungicide can penetrate the seed to inactivate the fungus thus rendering the seed safe for planting.

Loose smut in oats is quite different from loose smut in wheat because the black spores lodge on the outside of the seed. Here the fungus remains dormant until the seed is planted in the spring. Germination of spores is rapid and the young oat plant is invaded followed by rapid advancement of the fungus up the plant until the head is reached. Here the seed is replaced with a mass of fungus spores. During threshing, the enveloping sac is broken and the spores scattered to healthy grains. Since it is on the surface of the seed, this fungus is easier to control with fungicides. Several varieties of oats have considerable field tolerance to loose smut.

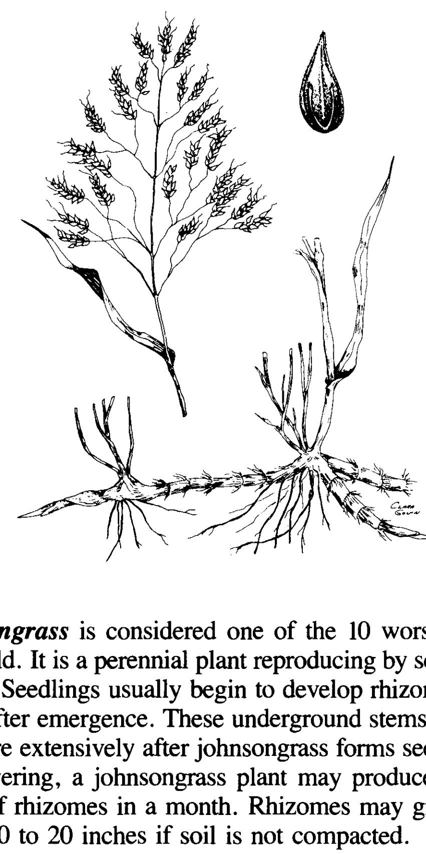
Bacterial Diseases

Bacterial blight of beans is a collective term used to describe the symptoms of several diseases caused by bacteria. These bacteria are carried in the bean seed from crop to crop. Individual infected seeds produce a diseased plant from which surrounding plants may be infected by bacteria spread on equipment, or by rain and wind. Blossoms and later pods become infected and contaminated seeds are then produced. The only sure way to produce blight-free beans is to use certified seed that has been produced under dry, disease-free conditions.

Weeds in Field and Forage Crops

Examples of weeds that are common in Maryland field crops follow. More information on the control of these weeds can be obtained from the Maryland Cooperative Extension Service.

Grass Weeds



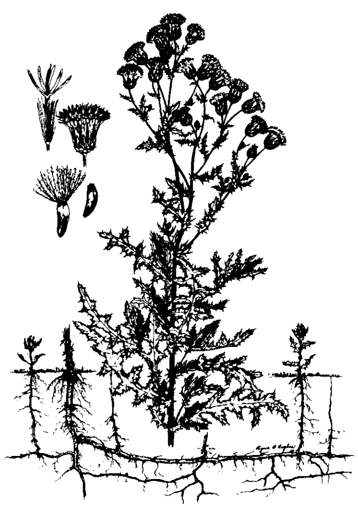
Johnsongrass is considered one of the 10 worst weeds in the world. It is a perennial plant reproducing by seeds and rhizomes. Seedlings usually begin to develop rhizomes 3 to 4 weeks after emergence. These underground stems are produced more extensively after johnsongrass forms seedheads. After flowering, a johnsongrass plant may produce 200 to 300 feet of rhizomes in a month. Rhizomes may grow to a depth of 10 to 20 inches if soil is not compacted.

Rhizomes can overwinter in the soil and produce new plants at each node of the rhizome. Even a small rhizome fragment with a single node may sprout to produce a new plant the following year. Seeds may remain viable in the soil many years before germinating. Since the seeds may remain dormant many years in the soil, spraying for seedling control is necessary even after several years of good johnsongrass control.

Johnsongrass also is the overwintering host for maize dwarf mosaic virus. The virus lives in the tissue of the johnsongrass rhizome. In the spring the virus spreads into the new shoots and becomes available for transfer to corn. The corn leaf aphid feeds on johnsongrass and on corn, so the transfer of the virus from emerging johnsongrass to nearby corn seedlings is accomplished readily as the aphids move about and feed. One means of practical control of maize dwarf mosaic virus is to remove the source of the disease virus by johnsongrass control.

Control of johnsongrass is best achieved in conventional plantings. A number of management programs are available. See Agronomy Mimeo No. 61, published by the Agronomy Department, The University of Maryland, for further details.

Broadleaf Weeds



Canada thistle is a perennial weed that causes serious problems throughout the northern half of the United States and Canada. This weed reproduces either by seed or by its extensive horizontal and vertical root system. Single plants may spread from 10 to 15 feet through the soil by root growth in one season and may reach a depth of 6 to 10 feet. In the spring new shoots emerge from the root system. These new shoots become fully developed plants, with flowers, in 7 to 8 weeks. When the underground roots are cut or broken into pieces through plowing, discing, or cultivating, each root piece is capable of developing a new plant.

The flowers of Canada thistle can produce nearly 50 viable seeds per head. Most plants bear purple to rose colored flowers although white flowered plants are found occasionally. The flower heads are ¾ of an inch or less in diameter. They form in clusters at the end of branches that arise from the leaf axils (the joining of the leaf and stem). Thus, a single plant may produce thousands of seeds. When the seeds are mature they are brownish in color and each seed is attached to a small tuft of hairs or plume, which allows it to be carried long distances by the wind. The seeds mature quickly after the flowers open and are capable of germinating in 8 to 10 days.

Once it is established, Canada thistle is very difficult to control and eradicate. The best control program depends on the size, age and location of the patch as well as the crops grown and available labor. Choose the control measures that interfere least with your normal crop production, but give the greatest economic return. The program you choose may have to be implemented for at least 2 to 3 successive years. Plan your eradication program and adhere to it until control is complete. For additional information, consult Agronomy Mimeo No. 60, published by the Agronomy Department, The University of Maryland.

Special Problems

Triazine-resistant weeds. The triazine herbicides have been used widely in corn production for many years. Continuous usage of these materials has resulted in the development of triazine-resistant weeds. In Maryland, five triazine-resistant weeds have been reported: barnyard grass, common lambsquarters, giant foxtail, smooth pigweed and velvetleaf. Triazine-resistant smooth pigweed is widespread, having been identified in most counties in Maryland. The other four resistant weeds have localized infestations in the Piedmont area of the state.

In general, triazine-resistant weeds have developed in areas that: a) continuously grow corn; b) use only triazine herbicides; c) do not use cultivation or postemergence herbicides to control escaped weeds; d) use minimum or no-tillage farming practices; and e) spread manure on the land.

To manage and help prevent the spread of triazine-resistant weeds consider the following: 1) rotate crops; 2) rotate herbicides, especially between families of herbicides; 3) cultivate or use postemergence herbicides for weed escapes; and 4) consider primary tillage before planting in severely infested areas.

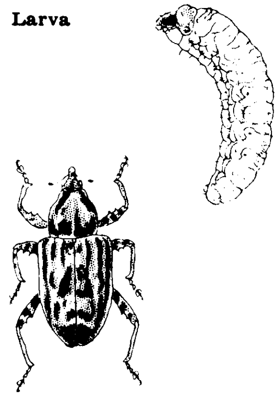
CHAPTER 3

FRUIT

If you are a commercial applicator, you should study this section if you wish to become certified in Category 1, Agricultural Pest Control. If you are a private applicator, you should study this section if you wish to become certified in the Fruit specialty.

Insect and Mite Pests in Fruit Crops

Pests that Cause Direct Damage



Plum curculio. The adults are dark brown snout beetles, about ¼ of an inch long, with four humps on their wing covers. Larvae are white, legless, curved-bodied with small brown head capsules, and about ⅓ inch long in the last instar.

Adult beetles overwinter in sheltered areas, usually near the orchard. Emergence is temperature-dependent and begins during or just after bloom. Both sexes feed on developing fruit, and females deposit eggs under the skin of apples. Growing larvae feed on the flesh, seeds and core of the apples, which frequently drop from the tree. Full grown larvae then burrow into the soil and pupate. In August, adults emerge, feed briefly, then seek cover in debris on the ground to overwinter.

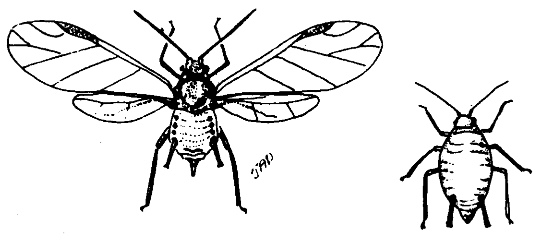
Feeding injury appears as small round holes, often undercut because of the sickle-shaped nature of the adult plum curculio mouthparts. Feeding holes usually are seen in association with egg-laying injury. The oviposition (egg-laying) injury that appears as a distinctive crescent-shaped cut usually is more damaging than the actual feeding scars. As the apple swells, both types of injury enlarge and become corky in appearance.

If eggs fail to hatch or larvae die, egglaying scars appear on fruit at harvest as crescent-shaped corky areas resembling the letter "D". Evidence of the oviposition hole sometimes is distinguishable as a slightly raised and darkened lip on the straight side of the scar. Early season feeding injury often appears on harvested fruit as raised, rounded, corky blemishes on the skin.

Given that plum curculio populations are capable of 100 percent fruit damage if unchecked and that there are no effective predators or parasites of plum curculio adults, the only acceptable control measure available is application of a recommended insecticide. Application should be made when injury to fruit is first detected. A second cover spray may be needed 7 to 10 days later.

Grape berry moth. The adult is a grayish-purple moth with a ½-inch wingspan. The larva is ⅓ to ½ of an inch long, greenish-gray with a brown head. Adults emerge just before bloom and lay their eggs on the cluster stems and young berries. Young larvae feed on clusters during early bloom. Look for webbing where the dried calyptra (caps covering the grape flowers) are embedded. Berry damage appears as a small hole in the side of the fruit which, on blue or red grape cultivars, may be surrounded by a ring of red or purple tissue. These fruits usually shrivel and drop to the ground. A second flight of the moths begins in mid- to late-July. Berry moth larvae feed for a time inside one berry, then tunnel into another and, sometimes, a third before they mature. Infested berries are filled with insect frass (excrement). Isolated vineyards may escape berry moth damage for several years, but once established this pest becomes a regular problem.

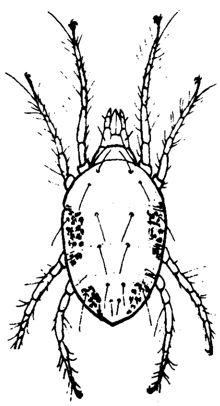
Where needed, apply an insecticide just before and just after bloom, then continue at 2-week intervals. A light to moderate grape berry moth infestation can lead to even greater



Wingless and winged aphids

losses near harvest when damaged berries become infected with the Botrytis rot fungus.

Pests that Damage Fruit Crops Indirectly



Aphids. Several species of aphids feed on apple and strawberry crops. The *rosy apple aphid* is purple or rosy in color when nearing maturity. The *apple aphid* and *apple grain aphid* are yellow, pale green or gray. All feed on the underside of leaves. Rosy apple aphid nymphs and adults cause curling of leaves and stunted, deformed fruit. They feed on apple in the spring, migrate to cover crops during the summer, and return to trees to lay eggs in the fall. Apple and apple grain aphids cause little or no damage to trees. It is important to identify the aphid correctly, because rosy apple aphids may warrant treatment with an insecticide.

Aphids feeding on strawberries cause plants to yellow and become stunted. One species feeds on the roots. These aphids should be controlled to prevent them from introducing and spreading viral diseases.

Aphids that attack tree fruits and strawberries usually are controlled by a large complex of natural enemies. These natural enemies include such readily recognized beneficials as ladybird beetles and aphidlions (green lacewings). Other aphid enemies include several types of tiny parasitic wasps and fly larvae that feed on the aphids. Aphid populations do not survive for long without being found by one or more types of these natural enemies, especially where insecticide sprays have not been frequently used.

Mites. European red mite is the major mite pest. The adult is bright to brownish red, and unspotted in color. The eggs also are red. Two-spotted mites are yellow to orange in color with two dark spots on the back. The eggs are white. These mites cause bronzing of foliage and cause a reduction in fruit size. If damage occurs before June, fruit set for the following year's crop will be reduced. European red mites overwinter as eggs on twigs of apple trees. These eggs hatch about bloom time, and nymphs feed on foliage. Two-spotted mites overwinter as adults in debris on the orchard floor and migrate to the trees in spring and summer. Average length of the life cycle is about 21 days, with 4 to 8 generations per year.

Predaceous mites (those that feed on other mites) are very important in controlling European red mites, two-spotted spider mites, and other pest mites in orchards throughout the world. The tiny beneficial mites have large appetites and are efficient in controlling the pest species. In some locations, these predatory species have even developed resistance to standard orchard insecticides, and are not adversely affected by a normal insect control program.

A monitoring technique is used specifically to detect the presence and relative numbers of mite pests in leaf sampling and brushing. A sample of leaves (50 or 100) is picked from trees throughout an orchard. The leaves are then passed through a mite-brushing machine where mites on the surface of the leaf are brushed onto a sticky plate. The mites on a predetermined area of the plate are counted and the average number of mites per leaf calculated. This technique is not only useful in detecting pest mites but also reveals the presence of predator mites and is an important tool in integrated mite control.

Diseases of Fruit Crops

Descriptions of several important diseases found in fruit follow to illustrate types of diseases or methods of control. More specific information on fruit diseases and their control is available from the Maryland Cooperative Extension Service.

Fungal Diseases

Apple scab occurs on the leaves, petioles, blossoms and fruit. The most striking symptoms are on the leaves and fruit.

Leaf infections usually appear first on the flower bud leaves. Lesions develop primarily on the undersurface of the leaf, the side exposed when the fruit buds first open. Once the entire leaf has unfolded, both sides may be infected. Diseased leaves often are distorted. Severe infection also can dwarf leaves and cause defoliation. Trees severely defoliated 2 or 3 years in a row are weakened and susceptible to low temperature damage.

Lesions develop as velvety brown to olive spots that turn black with age. At first, the edges of the lesion are feathery and indefinite, but later distinct limits are evident.

Fruit infections resemble leaf infections when young, but with age become brown and corky. Early scab infection results in uneven growth of the fruit and cracking of the skin and flesh. Lesions (pinpoint scabs) often develop around the blossom end of the fruit early in storage. These lesions usually are small and vary in size from specks to spots ¼ of an inch in diameter.

The fungus overwinters in leaves on the orchard floor. In late fall and early spring, microscopic, black pimple-like structures, called perithecia, are produced in these dead leaves. Within each perithecium are ascospores (reproductive structures), which produce the first or primary infections of the new growth.

Perithecial development is favored by alternating periods of wetness and dryness in late winter and early spring. In years with good snow cover and no deep frost, the fallen leaves are well protected and perithecia mature early. Ascospore production begins during mild days in February. Spores develop gradually at first, but much faster as the temperature increases to about 65°F. Perithecial development is reduced and spore production delayed in dry springs.

Normally, some perithecia have mature ascospores at the silver tip stage of bud development. When the leaves on the orchard floor become wet, spores are ejected. Air currents carry them to the emerging tissues where infection takes place. Maximum spore discharge occurs within 30 minutes of wetting; complete discharge requires about 2 hours. Maturation and discharge of ascospores usually lasts 5 to 9 weeks.

Lesions are not visible until several days after the fungus first infects the leaf or fruit. The average temperature after penetration is important for determining the time required for lesion development. About 9 to 17 days are required from inoculation to the appearance of the olive-green, velvety scab lesions. Within the lesion are secondary spores (conidia) for perpetuating the disease in summer.

Secondary infections are initiated by conidia produced in primary lesions. Since conidia may develop as soon as 7 to 9 days after infection, secondary infection, if not controlled, may be initiated if sufficient wetting occurs during bloom. This is particularly true when ascospores infect the tips of sepals and leaves at the silver tip stage of bud development.

Conidial formation is favored by high humidity and moderate temperatures. Wetting is not required for spore formation. Spores are disseminated by splashing rain and wind. Conidia germinate and infection occurs under about the same conditions as for ascospores.

Secondary infection of fruit can occur in the fall but may not show up until the fruit has been stored for several months. The disease can also build up on the leaves. Since the fungus overwinters in these leaves, perithecia may be present in quantity to start the new season even though a good spray program was followed the previous year.

Timing of eradicant schedules for primary apple scab is based on wetting and prevailing air temperatures. Eradicants are applied after the length of wetting is sufficient for infection to occur. Germination begins as soon as a spore lands on new, green leaves or fruit, if a film of moisture is present. The number of hours of wetting required for infection varies with prevailing temperatures. Growers should record the beginning of rainfall and average temperatures, to determine how long it will take for infection to occur. For example, at an average temperature of 58°F, primary infection occurs 10 hours after the start of the rain. After 22 hours of wetting, the degree of infection will be severe. This simple calculation is useful in deciding when to use fungicide sprays.

Because the eradicant action of most fungicides is limited to a few hours or days after infection, fungicides must be applied soon after conditions for infection are satisfied. If a protectant fungicide is not applied before or within 9 hours after the beginning of a rainfall, an eradicant fungicide must be used.

Bacterial Diseases

Fire blight, caused by the bacterium *Erwinia amylovora*, is the major disease problem faced by pear growers. Blight is also a problem on susceptible apple varieties. The disease causes an annual loss of blossoms and fruit, but its most serious effect is reduced future production because of the destruction of branches and scaffold limbs.

Infected blossoms become water soaked and dark green as the bacteria invade the succulent tissues. Within a few days, the entire fruiting spur may be invaded. Infected tissues wilt and turn dark brown to black on pears and brown to dark brown on apples. The disease usually moves into the leaves through the petiole, resulting in discoloration of the midvein first, followed shortly by a darkening of the lateral veins and surrounding tissue. Infected terminals wilt from the top and often develop a crook or bend at the growing point. The disease sometimes progresses into the shoot from its base, blighting the lower tissues and girdling the parts above. Infected leaves and fruit often persist into winter as a reminder of the previous summer's activity.

Following infection, fire blight can move long distances within the living tissue and kill an entire tree in one season. Bark of invaded branches and scaffold limbs is darker than normal. When the outer bark is peeled away, the inner tissues are water soaked with reddish streaks when first invaded; later the tissues are brown. When development slows, the margins become sunken and sometimes cracked, forming a canker. The presence of reddening helps to distinguish fire blight cankers from low temperature damage to bark.

Under certain conditions, apple and pear fruit develop a brown to black decay from blight. The rotted areas remain firm but the fruit eventually shrivels into mummies and remains on the tree.

During wet, humid weather, blighted tissues often ooze a milky, sticky liquid containing the bacteria. These droplets are produced in areas where the bacteria are multiplying. The ooze turns brown upon exposure to air. Appearance of ooze on the surface of diseased blossoms, terminals, fruit or wood is the most obvious characteristic of blight.

Bacteria overwinter at the margins of cankers on branches. Survival is most likely in cankers with indefinite margins located on large branches. The proportion of these "holdover cankers" is highest following mild winters. Ooze containing the bacteria begins to appear on the surface of the cankers when the trees are in the prebloom stage. Bacteria must move from overwintering cankers to exposed flowers before primary infection can occur. Splashing rain, flies and other insects that visit both the bacterial ooze and the blossoms move the bacteria.

Only a small portion of the blossoms are infected in this manner, particularly if overwintering cankers are eliminated before growth begins. Eventually, however, a honeybee visits a diseased blossom and picks up pollen or nectar contaminated with bacteria. Once this occurs, spread can be rapid and infection severe. Splashing rain also spreads secondary infections.

Climatic conditions are important in determining the amount of spread and severity of blossom blight. Temperatures between 65°F and 86°F favor infection. At the optimum temperature of 76°F blossoms begin to show blight in four to five days. At lower temperatures, symptom development takes much longer.

Although bacteria invade the flower primarily through natural openings, wounds are important in the infection of terminal shoots, leaves and fruit. Water sprouts and shoots may be inoculated directly by piercing insects, primarily aphids and leafhoppers, or indirectly through the feeding wounds left by these pests. Wounds from hailstones are invaded frequently by blight bacteria, leading to severe disease outbreaks. Any fresh wound can serve as an infection point, but wounds become less susceptible with age. Under prolonged periods of wetness and high humidity, infection of leaves, shoots and fruit through natural openings may occur.

Fire blight can be controlled only by strict adherence to a full-scale program that includes sanitation measures, antibiotic sprays, balanced fertilization, and good insect control. All cankers and infected shoots should be pruned during the dormant period. Avoid excessive nitrogen fertilization because it causes an abundance of succulent terminal growth that is more susceptible to infection. Bearing apple trees should not produce more than 12 inches of terminal growth per year, pears, about 8 inches. Following a season in which fire blight was a problem, apply a recommended chemical at silver tip. Apply a bactericide on a protective schedule beginning no later than the pink stage and continuing through the petal fall or first cover period at regular intervals of 5 to 7 days. Finally, maintain close spray intervals for aphids and leafhoppers during the early cover sprays to reduce the incidence of shoot blight.

Viral Diseases

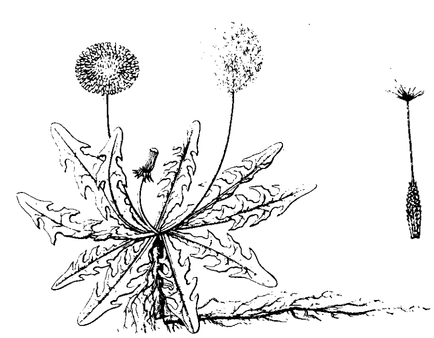
Stem pitting is a destructive virus disease that kills peach, nectarine, plum and cherry trees in Maryland orchards. The aboveground symptoms include: stunted terminal growth, chlorotic (yellowing) leaves that may droop, early defoliation and premature fruit ripening. Because these symptoms generally resemble those caused by other soil-borne pathogens and because infected trees are weakened and predisposed to winter injury, stem pitting can be identified only by examining the trunk in the region of the graft union. Here, the trunk is enlarged, the bark is 2 to 4 times thicker than normal and is punky and yellow to yellow-orange in color. Elongated pits are evident in the wood of either the rootstock, the scion variety or both.

The virus is introduced most often through infected nursery stock. Thereafter, it is spread by dagger nematodes and in the seeds of certain broadleaf weeds such as dandelions. The emphasis of any control program for stem pitting is on preventing introduction of the virus and by adopting cultural practices that limit its spread. Only certified, virus-free planting stock should be purchased. On replant trees, the soil should be fumigated with a broad spectrum fumigant before planting. A cover crop of Kentucky 31 tall fescue is recommended because it withstands the travel of orchard equipment well and because it tends to exclude many broadleaf weeds. Vegetation within the dripline of the trees should be treated with a herbicide. Treatment of sodded row middles with one of several herbicide formulations also may be required to exclude broadleaf weeds. Where nematode assays (check with your county Extension agent) show that populations of dagger nematodes are building, treatment of the area within the dripline with a postplant nematicide is recommended highly.

Weeds in Fruit Crops

Weeds reduce crop yields by competing for water, nutrients and light. Some weeds release toxins (naturally occurring toxic chemicals) that inhibit crop growth, and others may harbor insects, diseases or nematodes that attack crops.

Perennial Weeds



Dandelion is a perennial herb with a thick taproot often several feet deep, with many branched crowns and a milky juice. It reproduces by seeds and by new shoots from the root crowns. Stems are very short and wholly underground. The leaves are in a rosette at the ground surface and have toothed edges. Lower leaves are sometimes a foot long. Flower heads are numerous and button shaped, about ½ of an inch in diameter. Dandelions bloom in early spring, coinciding with apple bloom. Honeybees are attracted to dandelion bloom; thus, fewer bees are available to work the apple bloom. Otherwise, dandelion is of no particular concern in orchards.

Mowing will destroy many of the blossoms; cultivation is not practical. Herbicides can be used in early spring just ahead of blossom time; however, fall spraying is more practical, because dandelions become active when cooler temperatures prevail.

Horsenettle (sand briar), reproduces by seeds and by underground roots. The stem is simple or branched, 1 to 4 feet tall. Leaves are alternate, 3 to 5 inches long, and about half as wide. The leaf margin is divided into lobes with coarsely toothed rough, yellow prickles on petioles, midribs and veins. Flowers are white or bluish, five-lobed, about an inch across. Berries are yellow, ⅜ to ⅝ of an inch in diameter, and borne in clusters.

Roots may be up to 5 feet in depth. New growth emerges in late spring, after usual herbicides have been applied. Horsenettle tends to become vigorous and more abundant when competition from grasses is eliminated or reduced.

Cultivation or application of approved chemicals provides control. Quick regrowth will occur from contact herbicides, although the top growth is fairly easy to kill.

Poison ivy is a woody shrub or vine, reproducing by seeds and by creeping rootstocks from the basal stem nodes. Stems are erect and shrubby or vines climbing high into trees. Leaves consist of three large shiny leaflets each 2 to 4 inches long, pointed at tip. Leaf edges are smooth, or irregularly toothed. Berries are small, white, round and hard. All parts of the plant contain a poisonous material that may cause blistering of the skin.

Leaves drop in late fall and new ones begin to grow about the time of apple bloom. This weed grows vigorously under shade of trees, and if not controlled will produce a thick ground cover up to 2 feet high. Plants next to the trunk of

a tree will climb far up into the tree, endangering fruit pickers.

Destroy new plants by cultivation or by approved chemicals. In heavy infestations, regrowth usually will occur. Prevent the plant from climbing trees if possible; when this happens, pull the climbing portion from trunks. Remember to wear gloves.

Vertebrate Pests of Fruit Crops

Meadow Mice

Meadow mice live and forage on the orchard floor. They damage trees by feeding on the bark near the soil line, partially or completely girdling the trunks. Their feeding usually is more severe during the late fall and winter under snow cover when other food sources are more difficult to locate.

Problems with meadow mice can be reduced by keeping the ground under the trees free of vegetation (including watersprouts) and, on young trees, by using wire tree guards. A close, fall mowing of the orchard cover also discourages meadow mouse populations by reducing nesting sites and by exposing them to natural predators. Unless large accumulations of mowed grass are removed, however, the success of this fall mowing is reduced.

Where foraging trails clearly are apparent in the sod cover, place bait stations (boards, shingles, cut tires or commercially available bait boxes placed on the ground) in the orchard at least a month before baiting with rodenticide-treated cracked grain. The stations protect the bait from excessive weathering and are attractive to mice as protection. An alternative approach is to apply bait as a broadcast treatment. Broadcasting is more effective when done in November during periods of warm, sunny weather. Rainfall quickly destroys the effectiveness of broadcast baits. Depending on the degree of infestation, you may need to repeat bait treatments one or more times during the winter.

Pine Mice

Pine mice live in underground burrows and damage trees throughout the year by feeding on small roots and on the bark of large roots. Well-established, pine mouse colonies develop extensive tunnel systems that may involve one or more trees in localized areas. Within these pockets of infestation, numerous holes opening into the tunnel system usually are evident.

Broadcast treatments of rodenticides for meadow mice are not effective against pine mice. Instead, additional openings into the tunnel system should be made with a trowel or pipe. Rodenticide-treated grain or bait packs should be placed in all openings. The use of bait stations generally is very effective for pine mice.

CHAPTER 4

TOBACCO

If you are a commercial applicator, you should study this section if you wish to become certified in Category 1, Agricultural Pest Control. If you are a private applicator, you should study this section if you wish to become certified in the Tobacco specialty.

Insect and Mite Pests of Tobacco

Plant-damaging insects have mouthparts adapted to chew plant tissue or to suck plant juices. As pests, they may be categorized according to the specific type of damage they cause. Examples follow, along with discussions of life history and control. For more specific information on chemical control, refer to the appropriate University of Maryland Fact Sheet.

Chewing Insects

hornworm

Tobacco hornworms are very large, green caterpillars with diagonal lines on their sides and a prominent spine or "horn" on their rear ends. Larvae may be 4 inches long when fully grown. The hornworms feed on foliage, consuming large chunks. Adults are large, swift-flying moths known as sphinx moths.

Tobacco hornworms overwinter as large pupae in the soil. In the spring the moths emerge and lay large spherical eggs on the leaves. There are two prominent broods per year; one in June and July and another in August and September.

An insecticide should be applied to control hornworms when small caterpillars average five or more per 50 plants. Small hornworms are the most susceptible stage. For recommended insecticides, see Fact Sheet 123.

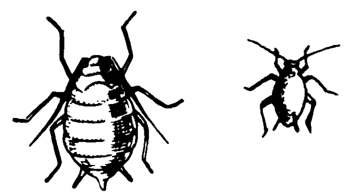
Tobacco budworms are pale green, hairy caterpillars, about 1½ inches long when full grown. They injure the buds or growing tips of plants. Adults are moths with green forewings.

Budworms overwinter as pupae in the soil. Moths emerge and lay eggs on the undersides of leaves. There are two or more generations per year, but budworms are generally most serious on early planted tobacco.

An insecticide spray is recommended when small caterpillars average five or more per 50 plants. Direct spray into terminal buds, preferably in the morning. Two or more applications at 7-day intervals may be necessary if populations are heavy.

Sucking Insects

Aphids



Green peach aphids are tiny, green, soft-bodied sucking insects that often cluster on leaves and stems. Some may have wings. All forms suck plant sap from leaves and stems causing withering and stunting. Aphids also produce a sweet, sticky substance called "honeydew". Heavily infested leaves cure improperly. These aphids overwinter as females on weeds near beds and fields. In the spring, females give birth to live young and population buildup results on favored hosts including tobacco in beds. Winged aphids are produced in early summer, and these forms move to field tobacco. Aphids continue to build up on tobacco during the summer.

Keep beds free of weeds. Do not plant crucifers such as cabbage and kale in or near beds. Use a systemic insecticide as a preventive treatment or treat with an aphicide if aphid colonies become conspicuous on plants in beds. See Agronomy Fact Sheet 10 for more information.

Tobacco Diseases

Several tobacco diseases are discussed below to illustrate types of diseases and methods of control. More specific information is available from the Maryland Cooperative Extension Service.

Bacterial Diseases

Wildfire of tobacco causes damage in both seedbed and field. In tobacco beds, wildfire produces circular, light green leaf spots surrounded by a yellow ring or halo. Older spots have a small, brown dead spot at the center. In the field, large, irregular dead patches develop on the leaves, which may eventually drop. Occasionally spots may form on stems, petioles, flowers and seed capsules.

During the winter the wildfire bacterium remains dormant in soil, in cured tobacco leaves, on seeds, and in many other crops and weeds. These bacteria are spread by wind, rain and contaminated plants or tools that come in contact with healthy tobacco plants. The disease also is transmitted by some insects including aphids, flea beetles and whiteflies. For infection to occur, high humidity or dew on the plants is required.

Use resistant varieties of tobacco. Sterilize the seedbed if wildfire was a problem in the area during the preceding year, and plant only disease-free seed. Do not transplant infected plants into the field. Control of the potential insect vectors may also be helpful in controlling wildfire. Rapidly growing plants are more susceptible to this disease; therefore, avoid overfertilization.

Viral Diseases

Tobacco mosaic virus is a major disease problem on tobacco grown in Maryland. While this disease almost never kills plants, it can damage leaves, flowers and fruit. Irregular areas of mottled light and dark green develop on the leaves. Early infections cause stunting of the plants. Both quantity and quality of the crop will be affected.

This virus overwinters in infected leaves and stalks in the soil, on seeds, on contaminated seedbed cloth, and in cigarettes, snuff and other tobacco products. It can be spread by contact with these items, especially if the plant has been wounded.

Resistant varieties are available and should be planted. Sanitation is extremely important in the control of this disease. To avoid infecting healthy plants, do not handle tobacco in barns or other sources before transplanting. Discourage chewing and smoking tobacco while handling tobacco plants. Wash your hands in soapy water before planting. Skim milk deters the virus; it may be sprayed on tobacco beds 24 hours before planting, and used as a hand dip during planting.

Nematode Diseases

Root-knot nematode can be a serious problem in tobacco. Small knots develop on the roots of infested plants. The roots may also become distorted. Infested plants tend to be stunted and wilt rapidly in the sun. Soil-applied nematicides may be used to control root-knot nematodes.

Weeds in Tobacco

Weeds reduce 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 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 a year in advance.

Usually, effective weed control requires a combination of management techniques. You may need to use a combination of different herbicides or alternative methods. 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, eradicate it immediately. Wherever possible, prevent weeds from producing seed. One plant can produce thousands of seeds, and these seeds will live in the soil for many years.

Perennials

Horsenettle has deep creeping rootstocks. Leaves are alternate and have wavy edges with spines on midribs and veins. Stems are single or branched, 1 to 2 feet tall, also with spines. Flowers are white or mixed bluish, five-lobed and borne in clusters. Berries are yellow skinned, juicy and contain many seeds. Berries are round until near maturity and then become wrinkled. Seeds are yellow, round and flattened.

Young plants develop to produce underground rootstock and new plants. In late summer, plants bloom to form new berries. This weed is readily found in fields, gardens and waste areas.

Cultivate and hand hoe horsenettles. Do not apply herbicides.

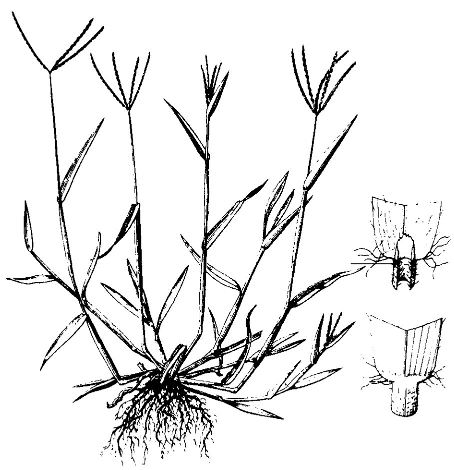
Summer Annuals

Redroot pigweed grows erect to 6 feet tall. It has dull-green leaves with long petioles. Stems are rough and freely branched with roots appearing reddish. Leaves are dull-green with long petioles. Flowers are green, small in dense clusters in upper leaf axils and at the top end of the stem. Each flower is surrounded by three spiny bracts. Seeds are small, shiny, black and lens-shaped. Seeds germinate mainly from late spring to early summer, producing flowers in late summer to early fall. Each plant produces numerous seeds.

Cultivate, hand hoe or pull, or apply herbicides to control this weed. For specific recommendations, see Agronomy Mimeo No. 102.

Crabgrass is a very common annual weed. It has smooth stems with small, individual flowers in rows on one side of the flattened stalk. Seeds are long, oval, finely granular and light yellow. Two common species are large crabgrass and small crabgrass. Large crabgrass leaves are somewhat hairy.

Seeds germinate in the spring to early summer. Flowering occurs in midsummer as the plant matures; rooting can occur at the nodes of prostrate stems. It spreads rapidly and frequently and is found readily in gardens, fields, lawns and waste areas. Crabgrass grows well under dry, hot conditions and will germinate throughout the summer if moisture is available. Good first cultivation and hand hoeing are important for control in tobacco. For recommended herbicides, see Agronomy Mimeo No. 102.



Sprayer Calibration

Proper calibration of application equipment is essential for safe, effective use of pesticides. Tobacco growers may use small sprayers, which have not been included in the application equipment section of this manual. Therefore, suggested methods of calibration are outlined.

Single Nozzle Hand Sprayers

1. Mark off an area 10 feet by 10 feet.
2. Fill the sprayer with water to a known mark, and spray the area.
3. Refill the sprayer, measuring the amount of water required to fill to the original mark.
4. Determine the rate of spray delivery per acre from the following chart:

Nozzle discharge per 100 sq. ft.	=	amount of spray delivered per acre
½ pint	=	27 gal
1 pint	=	55 gal
1½ pints	=	82 gal
1 quart	=	110 gal

Knapsack Sprayers

1. Lay out an area 16½ feet by 16½ feet.
2. Using water, determine the time in seconds to spray this area at your normal pace.
3. Catch the spray from the nozzle or nozzles used for the period determined in step 2.
4. Calculate the rate per acre as the number of pints caught × 20 = gallons per acre.

Pints of spray	Rate in gal/A
¼	5.0
⅜	7.4
½	10.0
⅝	12.5
¾	15.0
1	20.0

CHAPTER 5

VEGETABLES

If you are a commercial applicator, you should study this section if you wish to become certified in Category 1, Agricultural Pest Control. If you are a private applicator, you should study this section if you wish to become certified in the Vegetable Crops specialty.

Insect Pests of Vegetables

Insects can be separated into two groups depending on their mouthparts. The type of mouthparts determines the type of damage caused by a given insect. Representative insects and control strategies follow. For more specific recommendations, see Extension Bulletin 236.

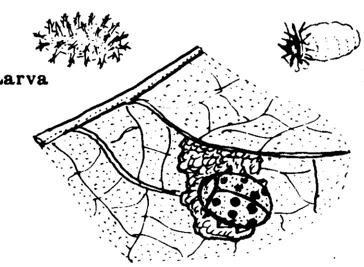
Chewing Insects

Examples of insects with chewing mouthparts are Colorado potato beetles, cabbage loopers, cutworms, cucumber beetles and bean beetles. The damage consists of holes in the leaves and/or consumption of whole leaves, roots and stems. Insects with chewing mouthparts generally do not transmit plant diseases, with the exception of the cucumber beetles that transmit bacterial wilt of cucumbers.

Colorado potato beetle. Adults are bulky, yellow beetles with black stripes and are ⅜ of an inch long. Larvae are brick red and humpbacked, up to ⅜ of an inch long. Both adults and larvae chew foliage.

The Colorado potato beetle overwinters as an adult several inches beneath the soil surface. Orange-yellow, cigar-shaped eggs are deposited in groups of 10 to 30 on the undersides of leaves. The larvae feed for 2 to 3 weeks before entering the soil to pupate. There are two generations a year. They will feed on tomatoes, potatoes and eggplant.

Thresholds for determining when to use insecticides have been developed. Procedures are detailed in Extension Bulletin 236.



Adult and damage

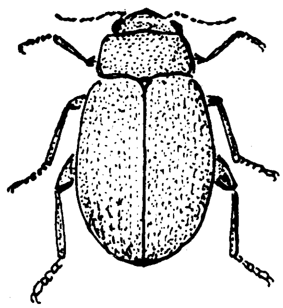
Mexican bean beetle. Adults are ¼ of an inch long, oval, copper colored beetles with eight small, black spots on each wing cover. Larvae are orange to yellow, fuzzy or spiny. Adults and larvae skeletonize foliage and pods.

Adults overwinter on the ground among leaves and rubbish. Hedgerows and woodland areas are favored overwintering sites. Orange-yellow, cigar-shaped eggs are deposited on the undersides of the leaves in groups of 40 to 50. Normally, there are two generations a year.

Treat with a recommended insecticide if defoliation exceeds 20 percent during prebloom or 10 percent during podding and there is a population potential for further defoliation. These levels of defoliation may result in earlier maturity of the crop. Wait until hatch or adult emergence when eggs and pupae are present.

Larvae appearing in late summer may be parasitized by a small wasp, which is currently being released by the Maryland Department of Agriculture. During the growing season, weekly information on the Mexican bean beetle is available through the Maryland Cooperative Extension Service Pest Management Program.

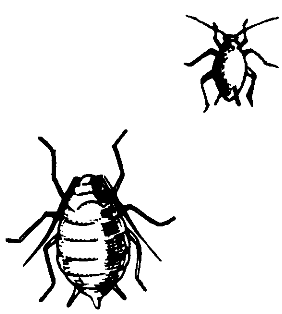
Flea beetles are small, black, jumping beetles that attack young sweet corn plants. These beetles transmit a bacterial wilt disease. Flea beetles overwinter as adults in hedgerows, along roadsides or along the edges of woodlands. Eggs are laid on the leaves or in the soil around the roots. Most of the damage on corn is caused by the overwintering adults. There are one or two generations a year. Beetles are numerous after mild winters.



Plant bacterial wilt-resistant varieties of sweet corn. Treat susceptible varieties with a recommended insecticide at spike stage when 6 or more beetles per 100 plants can be found.

Sucking Insects

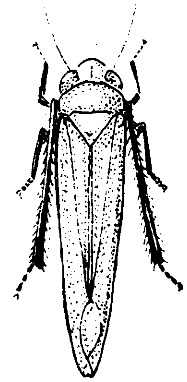
Examples of insects with sucking mouthparts include aphids, leafhoppers and tarnished plant bugs. These insects pierce the leaf surface and suck out the plant juices. This results in the stunting of the plants and/or curling and wilting of the leaves. Also, in some cases there is plant reaction to the insect's saliva. An example of this type of plant reaction is leafhopper "burn" in snap potatoes. There is a yellow to yellowish-brown spot wherever the insects pierce the leaves.



Aphids that infest cucumbers, melons, squash and pumpkins are small, soft-bodied, greenish insects, usually found on undersides of leaves. They suck plant juices causing leaves to curl and lose color. In addition to the damage caused by their feeding, aphids may transmit a mosaic virus disease.

All stages may occur annually and many may occur in a year. Aphids are unusual in that the female may produce young without mating. Also, they can produce young that are already hatched from the egg. During adverse weather conditions winged aphids may be produced. At certain times male and female aphids are produced, and these may mate and produce young. Aphids overwinter in the egg stage.

Insecticide application is advised at the time aphids appear in clusters on leaves. Repeated treatment may be necessary. Thorough spray coverage of the undersides of leaves is important.



Potato leafhopper. Adults are green, wedge-shaped insects, up to ⅛ of an inch long. Nymphs resemble adults but are smaller. Both nymphs and adults cause leaves to curl or roll downward. Most leafhoppers migrate north from southern climates. Heaviest populations occur in late June to the end of September. There are several generations a year.

Treat only if the number of adults plus nymphs exceeds 100 per 20 sweeps during prebloom, 250 per 20 sweeps during bloom, or 500 per 20 sweeps during pod development.

Harlequin bug. Adults and young are brilliant red or yellow. They are shield-shaped and up to ⅜ of an inch long. Their feeding causes leaves to turn brown and plants to wilt. Adults overwinter in the field or in rubbish. Eggs are laid in groups of 10 to 15 and are found on the undersides of leaves. Individual eggs resemble kegs. The nymphs resemble the adults. There may be several overlapping generations a year. Treat with a recommended insecticide when bugs are first seen and repeat only if necessary.

Diseases of Vegetables

Representative diseases and strategies for control follow. For specific control recommendations, refer to Extension Bulletin 236.

Leaf Spots

The leaf spot diseases are recognized by the marks or blotches produced on plant foliage or stems. Each disease produces characteristic spots with a typical size and shape.

The spots may be pinpoint spots in the dead tissue, or each spot may be surrounded by a yellow ring. A spot may be composed of concentric rings (target spot) or the dead tissue may fall out leaving a hole (shot hole). Feeding by insects and mites may also cause spotting and holes in leaves.

Anthracnose diseases are caused by several fungi that overwinter in old, diseased refuse in the soil as well as on and in the seed. Spots on foliage begin as small yellowish or water-soaked areas that enlarge rapidly and turn brown in most cucurbits but black in watermelon. Elongated lesions, similar to those on the leaves, are present on the stems. On the pods of beans or the fruit of peppers, tomatoes and cucurbits, circular, black, sunken areas are formed.

To control Anthracnose, use disease-free seed and practice crop rotation. Resistant varieties of cucurbits are available. Plow under diseased crop refuse. Protectant fungicide sprays may be necessary on some crops.

Wilt Diseases

Wilt conditions can be caused by a variety of agents. Wilting may result from drought or because pathogens such as nematodes, bacteria or fungi have infected roots and stems. In most cases, there has been a blockage of the water conducting systems of the plant because of disease or mechanical injury.

Bacterial wilt is caused by bacteria that overwinter in flea beetles in corn, and in striped and 12-spotted cucumber beetles in cucurbits. The disease is transmitted to the vegetables by the feeding of these insects. On corn, pale green to yellow streaks appear on leaves and later turn brown. Early infected plants may die; late-infected plants may be stunted or may merely have streaked leaves. On cucurbits, the bacterium causes wilting and subsequent death of the plant. Early control of the insect vector is essential. Also, resistant varieties of sweet corn are available.

Several fungi also cause wilt disease in vegetables. Fusarium wilts attack cucurbits, tomatoes, peppers and others. Most fungal wilts are soil-borne. Crop rotation and use of resistant cultivars are the best controls for fungal wilts.

Damping-Off

Any of several fungi can cause this rotting of seedlings and cuttings. Seedlings may be attacked after germination but before they break through the soil. Postemergence attack can also occur, resulting in the killing of roots and stems at the soil surface. As cells are destroyed the plant weakens and falls over.

Rots

Any large-scale decay of living plant material by an organism may cause rot. The name "rot" is used to describe many conditions that are caused by bacterial or fungal infestations.

Damping-off and seed rot of beans can be caused by numerous soil fungi that are common in many soils and are active during cool, wet periods. Seeds are more susceptible to infection and decay under conditions that inhibit rapid germination and growth. Infection results in poor germination, seed decay, rotting of stem at soil surface, death of growing seedlings, and severe reduction in stand of plants.

Therefore, plant seed under conditions favorable for germination and rapid growth, if possible. A fungicide seed treatment is helpful, too.

Smuts

These diseases are called smuts because of the sooty-black masses of spores that they produce. The heads of corn and other cereal crops usually are the target of the infections. The cause of the diseases are the true smuts fungi in the order Ustilaginales. The powdery masses break into dust-like powder when disturbed and the spores are then dispersed by the wind. Many of the fungi enter the host plant at an early stage of the plant's development and grow with it until the plant reaches maturity. The fungus overwinters in the soil. Large, fleshy, irregular galls may be formed on leaves, stems, ears and tassels. The immature galls are white and spongy, and the mature galls turn brown and contain powdery, black spores of the fungus. If practical, remove small galls as they form. Use a long rotation. If possible, reduce insect injury. Use available resistant varieties.

Rusts

Although this name is applied commonly to many ailments that result in reddish-brown spotting or color change in plants, it is used most accurately to describe infections caused by fungi in the family Uredinales. They must live on and grow inside living plants. The rust fungus penetrates cells and then removes the cell's nourishment. On asparagus, the fungus overwinters in the black spore stage on old stems in the soil. Rust appears as orange pustules on stems and foliage. These pustules turn black in late summer.

Use resistant varieties. Clean up and destroy all unused beds as well as volunteer or wild asparagus plants. Apply postharvest protective fungicidal sprays.

Blights

This is a commonly used term for a disease that causes rapid death of leaves, stems and flowers. Undesirable climatic conditions also are a contributing factor. The target area is usually the young growth of a plant.

Late blight. The fungus that causes late blight of white potato overwinters in infected tubers. Blight symptoms can appear on the tops of the plants at any time if weather is wet and cool. On leaflets, look for brownish to purplish-black spots that enlarge rapidly. Potato tubers may be infected while in the hill, at harvest and sometimes in storage. The first sign of disease on a tuber is a brown discoloration of the skin followed by brownish dry rot that extends ½ of an inch below the surface. Use resistant varieties and a protective fungicidal spray.

Mildew Diseases

Plant pathogens of this type produce fungal growths that form on the surface areas of a plant, such as the leaves and stems. They may appear white, gray, downy or powdery, giving rise to such names as "downy mildew" or "powdery mildew". The severity of infection depends on the specific fungus.

Powdery mildew of cucurbits may overwinter on perennial weed plants. The fungus also overwinters in the far South and is blown northward in the spring. It appears as a talcum-like growth on the plant surfaces, especially on the upper side of the leaves. Infected leaves turn brown and die. Use resistant varieties and protective fungicidal sprays.

Mosaic diseases

Many virus diseases are given this name because of the mosaic-like appearance of diseased leaves of the host plant. The leaves are mottled with light and dark areas and may show wilting and curling.

Tobacco mosaic virus can infect tomatoes. It may overwinter in perennial weeds and may be carried in the seed. Insect transmission may be a factor in the spread of this virus. Light and dark green mottling with curling and malformation of leaflets appears. Fruit may be mottled and malformed. Plants may be stunted or dwarfed. Use disease-free seed to produce healthy transplants. Remove perennial weeds adjacent to tomato fields, which can serve as hosts for this disease. Control insects, especially aphids, as soon as possible. Do not handle tobacco products when handling tomato transplants.

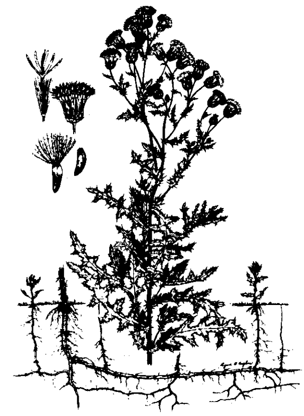
Weeds in Vegetable Crops

Weeds reduce 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.

Usually, effective weed control requires a combination of management techniques. You may need to use a combination of different herbicides or alternative methods. 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, eradicate it 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.

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

Perennials



Canada thistle is a perennial weed that causes serious problems throughout the northern half of the United States and Canada. This weed reproduces either by seed or by its extensive horizontal and vertical root system. Single plants may spread from 10 to 15 feet through the soil by root growth in one season and may reach a depth of 6 to 10 feet. In the spring new shoots emerge from the root system. These new shoots become fully developed plants, with flowers, in 7 to 8 weeks. When the underground roots are cut or broken into pieces through plowing, discing, or cultivating, each root piece is capable of developing a new plant.

The flowers of Canada thistle can produce nearly 50 viable seeds per head. Most plants bear purple to rose colored flowers although white flowered plants are found occasionally. The flower heads are ¾ of an inch or less in diameter. They form in clusters at the end of branches that arise from the leaf axils (the joining of the leaf and stem). Thus, a single plant may produce thousands of seeds. When the seeds are mature they are brownish in color and each seed is attached to a small tuft of hairs or plume, which allows it to be carried long distances by the wind. The seeds mature quickly after the flowers open and are capable of germinating in 8 to 10 days.

Once it is established, Canada thistle is very difficult to control and eradicate. The best control program depends on the size, age and location of the patch as well as the crops grown and available labor. Choose the control measures that interfere least with your normal crop production, but give the greatest economic return. The program you choose may have to be implemented for at least 2 to 3 successive years. Plan your eradication program and adhere to it until control is complete.

Yellow nutsedge, or nutgrass. This perennial weed forms rhizomes and nutlets in August. It may be a pest in cucurbits, beans, sweet corn and tomatoes. Leaves have a triangular shape in cross-section. Nutlets are formed at the ends of

rhizomes. A dense, branched (2 inches in length) seed head is formed on a stalk. Nutsedge usually is controlled in vegetable crops with herbicides. For a high level of infestation, the nutsedge population should be reduced by growing corn in crop rotation since corn herbicides are available for effective control. In the spring, disc nutsedge-infested areas frequently to prevent the development of large plants because nutsedge plants over 5 inches tall are difficult to kill by tillage, and herbicides also are less effective.

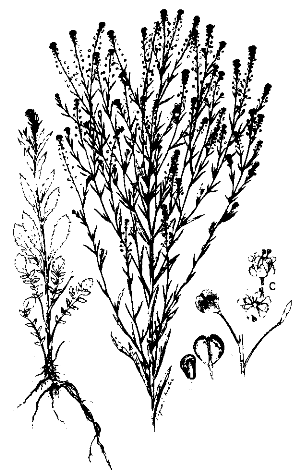
Smooth pigweed. Leaves are more narrow and tapered than redroot pigweed with fewer hairs on the leaves. The leaf edges are not wavy like redroot. The terminal spike is longer than redroot pigweed. Smooth pigweed is the most common type of triazine-resistant pigweed. If triazine resistance occurs, it is extremely important to prevent seed formation. Higher herbicide rates are advised to prevent weed escapes that would produce resistant-type seed. These weeds also may have increased tolerance to the asymmetrical triazines.

Summer Annuals

Tall morningglory and ivy leaf morningglory can become pests in beans, cucurbits, sweet corn and tomatoes. They are viny weeds with 2- to 3-inch long, heart-shaped leaves (tall morningglory) or three large lobes (ivy leaf morningglory). Flowers are large, 2 inches in diameter, and range in color from white to blue. The stem is hairy, with alternate leaves. Seeds are poisonous. This weed grows very slowly in late-planted vegetables, but seeds are produced before frost. Most vegetable herbicides do not control morningglory with the exception of sweet corn. Timely cultivation when the morningglory has just emerged is required.

Jimsonweed is a poisonous weed that germinates deep in the soil and makes control difficult. It has large, purplish, and trumpet-shaped flowers with strong scented leaves. It has large, 6-inch long leaves and spiny seed pods. Preemergence herbicide control is weak. Cultivate and hand hoe as necessary. Postemergence herbicides are most effective.

Galinsoga, or ***quickweeds***, germinates throughout the summer and early fall. It grows very fast, and produces seed abundantly. This weed is shaped like a bush up to 3 feet tall, and the first flowers usually occur when the plant is only 4 inches tall. Galinsoga has 1- to 3-inch long, oval-shaped leaves and is covered with small (½ of an inch in diameter) yellow flowers. This weed is tolerant to many vegetable herbicides, and therefore, herbicides that selectively control galinsoga should be used. Check tomato transplants for this weed before planting.



Winter Annuals

Pepperweed initially forms a rosette of deeply notched, lobed leaves up to 4 inches long. Leaves are alternate and stems may grow to a 3-foot height. Seeds are round and flat and formed on a stalk-like cluster at the ends of the stems and branches. Frequent cultivation and postemergence herbicides are best for control.

APPENDIX

Restricted Use Pesticides

The pesticides listed below are among those classified for restricted use. The materials are listed by their common names with some familiar brand names in parentheses. Materials that have no common name established are listed by the most familiar brand name. These pesticides can be bought and used only by, or under the direct supervision of, a certified pesticide applicator.

Understanding why these pesticides were classified for restricted use will help you to avoid endangering yourself, others or the environment. In this context, the word "domestic" means in and around the home. For definitions of unfamiliar terms, refer to the Toxicology chapter of your *Pesticide Applicator Training Core Manual*. In order to allow restricted use materials to remain on the market, the Environmental Protection Agency (EPA) requires different use patterns, protective clothing, or other changes that render them safe. These changes have been incorporated into the pesticide label.

Alachlor (Lasso). All formulations are restricted for all uses due to oncogenicity. Alachlor also has the potential to contaminate groundwater.

Aldicarb (Temik). As sole active ingredient, aldicarb is restricted for all ornamental uses; all granular formulations are restricted for all ornamental and agricultural uses. Accident history is the reason for restriction. This material also has the potential to contaminate groundwater.

Amitraz (Baam). All formulations for use on pears (the only registered use) were originally restricted due to concerns about oncogenicity. After further review, EPA has determined that amitraz does not pose a threat of oncogenicity through this application; therefore, amitraz is now reclassified as a general use pesticide. However, it is possible that applicators might encounter some of the originally packaged products labeled for restricted use; applicators must comply with the restricted labeling on these older products.

Amitrole (Amitrol, Amizine). All formulations are restricted for all uses *except* homeowner uses, because of oncogenicity.

Atrazine (Aatrex). All formulations *except* lawn care products containing less than 2 percent atrazine are restricted for all uses due to groundwater contamination potential.

Avitrol. All formulations are restricted for all uses because of the hazard to fish and nontarget birds.

Azinphos-methyl (Guthion). All liquids with a concentration greater than 13.5 percent are restricted for all uses due to the human inhalation hazard. All dusts and WP's are restricted for all uses because of the history of misuses and accidents. All liquids with a concentration of 13.5 percent or less are restricted for the following uses: all domestic uses; all uses on orchards, citrus, nut crops and ornamentals; and all aerial applications. The reasons are acute oral and dermal toxicity, residue effects on mammalian species, and effects on aquatic organisms from drift.

Captafol (Difolatan). All formulations are restricted for all uses because of the risk of exposure for farm workers. This material causes skin irritation in many people.

Carbofuran (Furadan). All concentrate suspensions and WP's 40 percent or more are restricted for all uses because of acute inhalation toxicity. All granular formulations are restricted for all uses because of the potential effects on wildlife.

Carbophenothion (Trithion). All formulations are restricted for all uses because of the potential effects on aquatic species, birds and other wildlife.

Chlorfenvinphos (Apachlor, Birlane, Supona). All concentrate solutions or EC's 21 percent or greater are restricted for all uses because of acute dermal toxicity.

Chlorpyrifos (Dursban, Lorsban). All formulations are restricted for all uses because of acute toxicity.

Cyanazine (Bladex). All formulations are restricted for all uses because of the potential for contamination of groundwater, and possible teratogenic and fetotoxic effects.

Cycloheximide (Acti-Dione). All formulations greater than 0.027 percent are restricted for all uses. Formulations of 0.027 percent or less are restricted for domestic uses. The reason for all restrictions is acute dermal toxicity.

Cyfluthrin (Baythroid). All formulations are restricted for all uses. Both indoor and outdoor applications are restricted on the basis of acute toxicity. Outdoor applications are restricted also on the basis of toxicity to fish and aquatic organisms.

Cypermethrin (Ammo, Barricade, Cymbush). EC's of 30 percent are restricted for agricultural uses because the manufacturer requested this classification.

Demeton (Systox). The 1 percent fertilizer formulation and all granular formulations, all EC's, and all concentrated solutions are restricted for all uses. Reasons are acute oral and dermal toxicity, and residue effects on mammals and birds.

Diallate (Avadex). All formulations are restricted for all uses because of potential oncogenic and mutagenic effects.

1,3-Dichloropropene (Telone). All formulations are restricted for all uses on the basis of acute toxicity by ingestion and inhalation, and oncogenicity.

Diclofop methyl (Hoelon). All formulations are restricted for all uses because of potential oncogenicity.

Dicrotophos (Bidrin). All liquid formulations 8 percent and greater are restricted for all uses because of acute dermal toxicity and residue effects on birds.

Diflubenzuron (Dimilin). WP's are restricted for all uses until further data on environmental hazards are submitted to the EPA.

Dioxathion (Delnav, Deltic). All concentrate solutions or EC's greater than 30 percent are restricted for all uses. Solutions 3 percent and greater are restricted for domestic uses. Acute dermal toxicity is the reason.

Disulfoton (Di-Syston). Nonaqueous solutions 95 percent and greater are restricted for commercial seed treatment uses because of acute dermal toxicity. All EC's 65 percent and greater, all EC's and concentrate solutions 21 percent and greater that are formulated with fensulfothion 43 percent and greater, all EC's 32 percent and greater in combination with 3 percent fensulfothion and greater have been restricted for all uses since 1979 because of acute dermal and inhalation toxicity. All end-use formulations greater than 2 percent have been restricted for all uses since September 1, 1986.

Dodemorph acetate (Milban). All formulations of Milban are restricted for all uses because the material is corrosive to the eyes.

Endrin. All emulsions, dusts, WP's, pastes, granulars and concentrates are restricted for all uses because of acute dermal and inhalation toxicity and hazards to nontarget organisms.

EPN. All liquid and dry formulations greater than 4 percent are restricted for all uses. Of concern are acute dermal and inhalation toxicity, residue effects on birds, and effects on aquatic organisms.

Ethion. Niagara Aqua Ethion 8 and Niagara Ethion 8EC are restricted for all uses because of acute toxicity.

Ethoprop (Mocap). EC's 40 percent and greater and all granular formulations are restricted for all uses because of acute dermal toxicity.

Fenamiphos (Nemacur). EC's 35 percent and greater are restricted for all uses because of acute dermal toxicity.

Fensulfothion (Dasanit). Concentrate solutions 63 percent and greater, all EC's and concentrate solutions 43 percent and greater in combination with disulfoton 21 percent and greater, all EC's 32 percent and greater in combination with disulfoton 32 percent and greater, and all granulars are restricted for all uses because of acute inhalation and dermal toxicity.

Fenvalerate (Pydrin, Sumicidin). EC's (30 percent) are restricted for outdoor uses because of possible adverse effects on aquatic species.

Flucythrinate (Pay-Off). EC's (30 percent) are restricted for outdoor uses due to possible adverse effects on aquatic species.

Fonofos (Dyfonate). EC's 44 percent and greater and granulars 20 percent and greater are restricted for all uses because of acute dermal toxicity.

Methamidophos (Monitor). Liquid formulations 40 percent and greater and dust formulations 2.5 percent and greater are restricted for all uses. Reasons are acute dermal toxicity and residue effects on birds.

Methidathion (Supracide). All formulations are restricted for all uses *except* nursery stock, safflower and sunflower because of residue effects on birds.

Methiocarb (Mesurol). Dusts (50 percent) are restricted for control of blackbirds in newly planted corn because of potential hazard to nontarget organisms.

Methomyl (Lannate, Nudrin). All concentrate solutions, all formulations as sole active ingredient in 1 percent to 2.5 percent baits *except* 1 percent fly bait, and 90 percent WP's not in water-soluble bags are restricted for all uses because of residue effects on mammals and history of accidents.

Methyl parathion (Penncap-M). All dust and granular formulations less than 5 percent are restricted for all uses because of their history of accidents; all foliar applications are restricted based on residue effects on birds and mammals. All dust and granular formulations 5 percent and greater, and all WP's and liquids are restricted for all uses due to residue effects on mammals and birds. The microencapsulated formulation is restricted for all uses because of the hazard to bees and residue effects on birds.

Metribuzin (Lexone, Sencor). All formulations are restricted for all uses until further data on chronic toxicity, teratogenicity, mutagenicity and reproductive effects are submitted.

Mevinphos (Phosdrin). All EC's and liquid concentrates are restricted for all uses because of acute dermal toxicity. Psycodid filter fly liquid formulations are restricted because of acute dermal toxicity. The 2 percent dust is restricted for all uses because of residue effects on mammals and birds.

Monocrotophos (Azodrin). Liquid formulations 19 percent and greater are restricted for all uses because of residue effects on mammals and birds. Liquid formulations 55 percent and greater pose the additional hazard of acute dermal toxicity.

Oxamyl (Vydate). Soluble concentrates and granulars are restricted for all uses due to acute oral and inhalation toxicity to humans and acute oral toxicity to birds.

Oxydemeton-methyl (Metasystox-R). All formulations are restricted for all uses due to adverse reproductive effects.

Paraquat dichloride and ***paraquat bis (methyl sulfate).*** All formulations *except* those listed below are restricted for all uses on the basis of human toxicological data and history of misuse and accidents. The following formulations and uses are *not* restricted: pressurized spray formulations containing 0.44 percent paraquat bis (methyl sulfate) and 15 percent petroleum distillates for spot weed and grass control; and liquid fertilizers containing concentrations of 0.025 percent paraquat dichloride and 0.03 percent atrazine, 0.03 percent paraquat dichloride and 0.37 percent atrazine, or 0.04 percent paraquat dichloride and 0.49 percent atrazine.

Parathion. All granular and dust formulations greater than 2 percent, fertilizer formulations, WP's, EC's, concentrate suspensions, and concentrate solutions are restricted for all uses based on acute inhalation and dermal toxicity and residue effects on mammals, birds and aquatic organisms. Smoke fumigants are restricted for all uses due to inhalation hazard. Dust and granular formulations 2 percent and less are restricted for all uses because of accident history.

Permethrin (Ambush, Ectiban, Pounce). EC's and ready-to-use formulations 0.05 percent to 38.4 percent are restricted for all uses because of potential effects on aquatic organisms.

Phorate (Agrimet, Geomet, Granutox, Thimet). Liquid formulations 65 percent and greater and all granular formulations are restricted for all uses because of acute dermal toxicity. Residue effects on birds and mammals from foliar applications are another reason.

Phosphamidon (Dimecron). Liquid formulations 75 percent and greater, and dusts 1.5 percent and greater are restricted for all uses because of acute dermal toxicity and residue effects on mammals and birds.

Pronamide (Kerb). All formulations *except* those in water-soluble packets are restricted for all uses because of potential oncogenicity.

Simazine (Aquazine, Princep). All formulations for use on land were originally restricted due to potential for contamination of groundwater. EPA has since changed its position and reclassified simazine products as general use pesticides. However, it is possible that applicators might encounter some of the originally packaged products labeled for restricted use; applicators must comply with the restricted labeling on these older products.

Sulprofos (Bolstar). All formulations are restricted for all uses because of the hazard to wildlife.

Terbufos (Counter). Granular formulations 15 percent and greater are restricted for all uses because of acute oral and dermal toxicity.

Terbutryn (Igran). All formulations had been classified restricted for all uses due to oncogenic risk to applicators and dermal exposure risk. However, EPA has reclassified terbutryn products for general use following submission of new data.

Triphenyltin hydroxide (Du-ter). All formulations are restricted for all uses because of possible mutagenic effects.

Study Questions

Chapter 1

1. How do insects and mites differ?

2. How does gradual metamorphosis differ from complete metamorphosis?

3. How do stomach poisons and contact poisons kill?

4. Are systemic insecticides usually more effective against small sucking insects or large chewing insects?

5. Are broad spectrum insecticides generally safe for beneficial insects? Why or why not?

6. List five factors important in determining whether an insecticide will be effective against a particular pest.

7. How do fungi reproduce?

8. How are plant bacteria spread?

9. How can insect and weed control reduce the severity of virus diseases on plants?

10. What is a nematode?

11. List five disease symptoms and give a brief description of each.

12. How do protectant and eradicant fungicides work?

13. How can development of tolerance to fungicides be avoided?

14. How can nematicides be brought into contact with nematodes?

15. What are the differences in life cycles of annuals, biennials, and perennials?

16. Are contact herbicides more effective against annuals or perennials?

17. Explain the differences in time of application of preplant, preemergence and postemergence herbicides.

18. List 15 factors important in determining herbicide effectiveness.

19. Is cholinesterase testing appropriate for applicators who use herbicides only? Why or why not?

20. What four variables can be adjusted to change the amount of spray delivered by boom sprayers?

21. How can nozzle dribble be eliminated?

22. Why are herbicides best applied with a fan or flat pattern nozzle?

23. Are broadcast nozzles a good choice for spraying when there is a breeze? Why or why not?

24. If you find that your granular applicator is delivering 15 percent less than the recommended rate, should you change the settings and recalibrate the applicator? Why or why not?

25. What are the two methods of metering out liquid fumigants?

26. How can nozzles be unplugged safely?

27. Are airblast sprayers designed to apply insecticides, herbicides and fungicides?

28. How often should sprayers be cleaned?

Chapter 2

1. If an insecticide treatment for European corn borer is necessary, what is usually the best time of year to treat? Explain.

2. What is the adult form of the black cutworm?

3. Describe the damage caused to corn by corn rootworm adults and by corn rootworm larvae.

4. How many generations of armyworm occur each year in Maryland, and which is the most damaging?

5. Where are the eggs of the stalk borer laid?

6. List four natural enemies of aphids.

7. Which stage in the life cycle of the Mexican bean beetle usually causes the most damage to soybeans?

8. What weather conditions encourage spider mite injury and outbreaks?

9. Which is the most damaging stage of the alfalfa weevil? Explain.

10. Does the potato leafhopper live in Maryland year-round? Explain.

11. Is loose smut caused by a bacteria or a fungus?

12. How can you be sure of producing blight-free beans?

13. How does the presence of johnsongrass contribute to maize dwarf mosaic virus problems?

14. How does Canada thistle reproduce?

15. List four ways to prevent the spread of triazine-resistant weeds.

Chapter 3

1. Describe feeding and oviposition injury caused by the plum curculio.

2. If an insecticide is necessary to control grape berry moths, when should it be applied?

3. List three natural enemies of aphids.

4. How can the presence of both pest mites and predator mites be monitored?

5. Under what weather conditions should you use eradicant sprays for primary apple scab infection? Explain.

6. What is the most obvious characteristic of fire blight?

7. How is the stem pitting virus usually introduced into orchards?

8. Why are fall sprays more practical than early spring sprays to control dandelion?

9. How does horsenettle reproduce?

10. How does poison ivy reproduce?

11. Are broadcast treatments of rodenticides appropriate for control of meadow mice and pine mice? Explain.

Chapter 4

1. How do tobacco hornworms overwinter?

2. What is the adult form of the tobacco budworm?

3. Are systemic insecticides appropriate for controlling aphids in tobacco?

4. How is wildfire of tobacco spread?

5. List three methods of preventing and controlling tobacco mosaic virus.

6. What are the symptoms of root-knot nematode on tobacco?

7. What are the best control strategies for horsenettle?

8. When does redroot pigweed produce seeds?

9. What weather conditions encourage the growth of crabgrass?

Chapter 5

1. On which crops do Colorado potato beetles feed?

2. Where does the Mexican bean beetle overwinter?

3. What winter weather conditions favor flea beetle populations?

4. What are the symptoms of aphid infestations?

5. When do the heaviest populations of potato leafhopper occur?

6. If an insecticide treatment is necessary to control harlequin bugs, when should the treatment be made?

7. List five strategies for controlling *Anthracnose.*

8. Where does the organism that causes bacterial wilt of corn and cucurbits overwinter?

9. What type of organism (fungus, bacterium, virus, or nematode) causes damping-off and seed rot of beans?

10. Where does the smut fungus overwinter?

11. List three control strategies for rust diseases.

12. What weather conditions favor the late blight fungus?

13. Where does the fungus that causes powdery mildew of cucurbits overwinter?

14. Can insects transmit tobacco mosaic virus?

15. How does Canada thistle reproduce?

16. Why is it important to prevent the development of large nutsedge plants?

17. When is the best time to cultivate for control of morningglory?

18. Are preemergence or postemergence herbicides more effective in controlling jimsonweed?

19. When does galinsoga germinate?

20. Is pepperweed an annual, a biennial or a perennial?

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