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ABSTRACT

This manual is intended to assist pesticide applicators prepare for certification under the Michigan Pesticide Control Act of 1976. The primary focus of this publication is on fruit pest control. Sections included are: (1) Causes of fruit diseases; (2) Fruit fungicides and bactericides; (3) Insect and mite pests; (4) Insecticides and miticides; (5) Principles of insecticide/miticide usage; (6) Weed pests of fruit crops; (7) Fruit herbicides; and (8) Principles of herbicide usage. A list of self-help questions and instructions for completing the questions are presented at the end of each section. (HM)

Fruit pest Control

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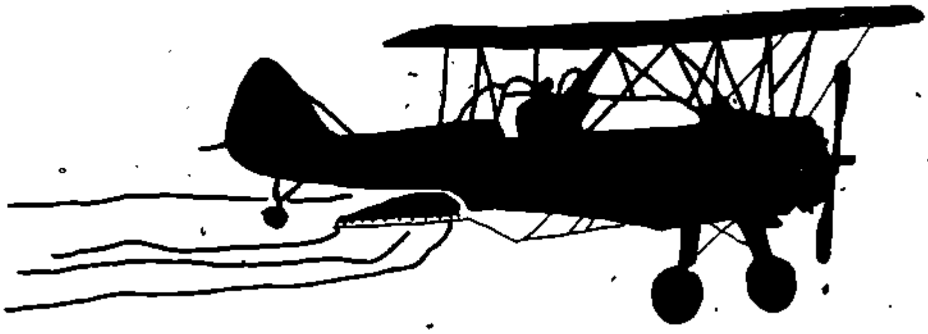
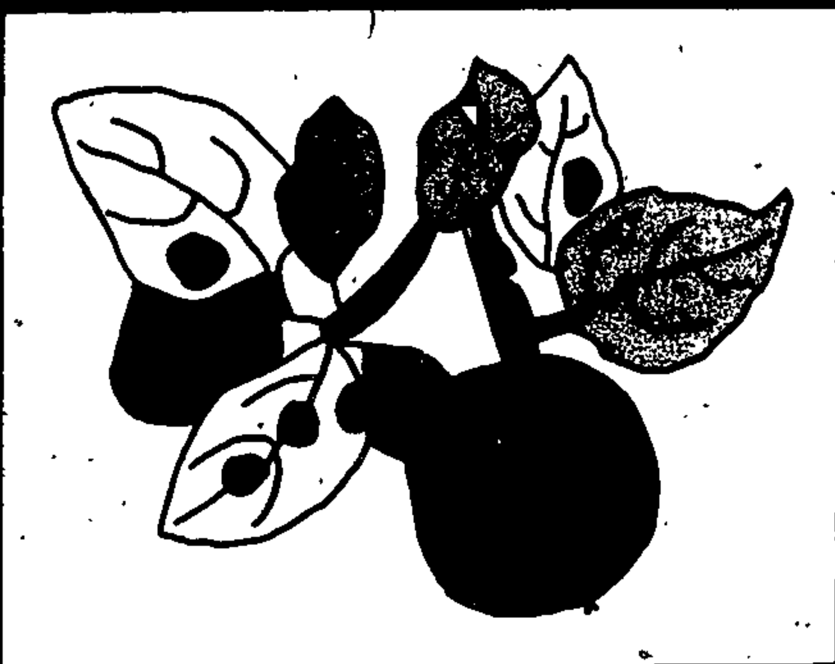
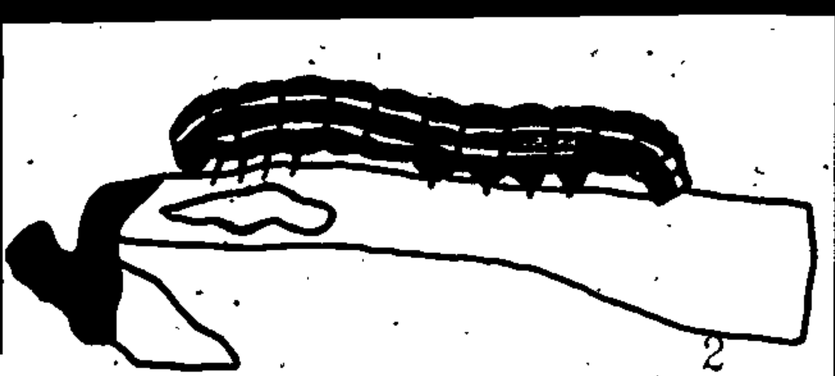


SAFE, EFFECTIVE USE OF PESTICIDES
A MANUAL FOR COMMERCIAL APPLICATORS





PREFACE

This manual is intended to assist pesticide applicators prepare for certification under the Michigan Pesticide Control Act of 1976. The manual was prepared by Drs. J. Brunner, A. L. Jones, and A. R. Putnam of Michigan State University.

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

Some suggestions on studying the manual are:

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

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

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INTRODUCTION

Michigan is the leading deciduous fruit producing state east of the Rocky Mountains. Its volume of production and diversity of crops ranks it among the top five states in ten important fruits: apples, peaches, pears, tart cherries, sweet cherries, plums, grapes, blueberries, strawberries, ~~and~~ raspberries.

The annual production of these crops during recent years has returned more than $75 million to producers. This does not include the value added through storing, processing, packaging, and distribution. Approximately two-thirds of Michigan's fruit tonnage is processed.

Control of diseases, weeds, insects, and mites represents a major cost item in the growing of each of these crops. For several of these crops, pest control is the number one expense. Moreover, spray materials—largely fungicides, herbicides, insecticides, and miticides—account for over one-half of the total spray costs.

<u>Pest management</u>: The term "pest management" has become a familiar one to fruit producers in recent years. Because of its popularity the term has been overused and in some cases misused. Pest management has been equated on the one hand as a move to completely eliminate pesticides from agriculture and on the other as merely a shift to a more judicious use of the pesticides already employed in agriculture. Both of these views of pest management are wrong and misleading. Pest management is not merely a new technique of pest control but represents a new philosophy of crop protection stressing the utilization of a multiplicity of control or regulatory strategies in a manner predicated by a thorough understanding of agricultural ecology. <u>Don't</u> equate biological or integrated control with pest management, for while these tactics have been successfully employed in some programs they are only a small part of the overall pest management philosophy.

Following the discovery of organic pesticides in the late 1940's, pest control "philosophy" was one of pest eradication from agricultural crops. Goals of agriculturalists were to maximize yields and it was felt the best manner to accomplish this was to eliminate competition. The occurrence of pest organisms was automatically associated with potential damage and thus a loss in yield. Pesticides (insecticides, fungicides, rodenticides, and herbicides) were liberally employed to eliminate pests. The initial high degree of effectiveness and low cost of pesticides discouraged attempts to set values on the economics of pest control or investigate the effects of these practices on nontarget organisms both within and outside agricultural areas.

The panacea associated with pesticides and their use in agriculture was soon shattered by the appearance of problems very few had foreseen. Insect resistance was one of the first signals that pesticides were not the final answer to crop protection as they were once thought. Insect resistance is discussed in another section but basically involves the inability of an insecticide to control an insect it once easily controlled. The appearance of secondary pests (organisms not previously considered of importance) has been associated with the liberal and unscientific use of pesticides. These organisms were previously kept at low levels either by natural enemies or because of competition with other organisms. Pesticides killed off natural enemies or the competing organisms allowing the previously innocuous organism to multiply and reach levels where it was considered a new pest. The detrimental effects of pesticides on the environment outside of agriculture have in recent years been demonstrated and numerous governmental regulations and bans have resulted. All of these factors plus the increased cost of fuel and pesticides have stimulated interests in new approaches to crop protection.

Pest management is the crop protection philosophy which has emerged from a search for alternative approaches to the exclusive use of pesticides. The goal of pest management is to employ a multiplicity of control and regulatory strategies based on a thorough understanding of agricultural ecology, and aimed at maintaining pests at acceptable levels. There are a number of differences between pest management and previous crop protection philosophies.

1. Pest management stresses ecological understanding, or an understanding of the organisms within a cropping system and their interrelationships. This outlook has necessitated a truly interdisciplinary approach to problems in agriculture. By eventually understanding the relationships between organisms and the factors which influence their abundance many scientists feel that most pests can be managed.

2. Living with acceptable levels of pests in agricultural crops is an important premise of pest management. Recent studies have shown that pest organisms present at low levels inflict such a low degree of damage that it is not economically feasible to apply controls. Thus, agricultural producers are beginning to accept the idea that pests should be tolerated up to a level where their abundance begins to threaten the loss of a crop in excess of the cost required to control it.

3. The use of natural control agents (pathogens, predators or parasites) to regulate pest populations at low levels has been successfully employed in a number of pest management programs. An example in Michigan is the successful encouragement of predator mites by the proper choice of pesticides which in many cases result in total biological control of phytophagous mites. As more is learned about natural control agents and how to best take advantage of their presence, similar types of programs will appear.

4. Pest management programs stress monitoring of agricultural crops to detect the presence and seasonal activity of pest organisms. Numerous sensitive monitoring techniques have been developed in the past few years which permit extensive surveillance of pests with a minimum of effort.

Pest management today is in its infancy. Many so called pilot pest management programs have been considered tremendous successes because they have led to the reduction of pest control costs by reducing pesticide usage. Most of the saved pesticide usage, however, were sprays that had previously been applied that were in reality unnecessary. The future successes in pest management will come from a better understanding of pest organisms, their relationship to crop damage and factors and techniques which influence their activity and abundance. These successes will take longer to achieve than those presently attributed to pest management, but will be as or more substantial in terms of economic and resource savings in agriculture.

Tree Growth Stages and Timing of Control Measures

Historically, the timing of chemical treatments for the control of plant diseases and insect and mite pests has been based on the stage of blossom bud development in the spring. Although bud development stages are used less today than in previous years for timing of pesticidal spray treatments, growth stages are still commonly referred to by fruit growers and various industry personnel in their day-to-day dealings with fruit crops. Thus, a knowledge of the key bud stages for the various fruit crops is useful to those who serve the fruit industry in an advisory capacity or as suppliers of pesticides, fertilizers, etc.

The following listing of the various growth stages in fruit trees was taken from New York's Food and Life Science Bulletin No. 58 by P. J. Chapman and Gertrude A. Catlin. This is an excellent reference publication and may be ordered from the Mailing Room, New York State Agricultural Experiment Station, Geneva, N. Y. 14456. The cost per copy is one dollar. Each growth stage is illustrated in the bulletin in color.

Apple growth stages: (1) dormant, (2) silver tip, (3) green tip, (4) half-inch green, (5) tight cluster, (6) pink, (7) bloom, (8) petal fall, and (9) fruit set.

Pear growth stages: (1) dormant, (2) swollen bud, (3) bud burst, (4) green cluster, (5) white bud, (6) bloom, (7) petal fall, and (8) fruit set.

Tart and sweet cherries growth stages: (1) dormant, (2) swollen bud, (3) bud burst, (4) white bud, (5) bloom, (6) petal fall, and (7) fruit set.

Peach growth stages: (1) dormant, (2) swollen bud, (3) half-inch green, (4) pin bud, (5) bloom, (6) petal fall, and (7) fruit set.

Plum and prune growth stages: (1) dormant, (2) swollen bud, (3) bud burst, (4) green cluster, (5) white bud, (6) bloom, (7) petal fall, and (8) fruit set.

Definition of Key Growth Stage Names

The following definitions apply to the thirteen different growth stage names.

Dormant: Fruit buds relatively inactive. This is the overwintering stage (applies to all fruits).

Silver tip: Applies only to apple. Fruit bud scales separated at tip, showing light gray tissue.

Swollen bud: Equivalent to silver tip stage in apple. Fruit buds swollen, scales separated to expose areas of lighter colored tissue. Applies to all fruits except apple.

Green tip: Applies only to apple. Fruit buds broken at tip, showing about 1/16 inch (1-2 mm) green.

Bud burst: Equivalent to green tip stage in apple. Fruit buds broken at tip, showing tips of blossom buds. Applies to pear, sweet and tart cherry, plum, and prune.

Half-inch green: Applies only to apple and peach. In apple, when about 1/2 inch (1 cm) of leaf tissue is projecting from the fruit buds. In peach, when the leaf bud occurring between a pair of fruit buds has produced about 1/2 inch (1 cm) of new growth.

Tight cluster: Applies only to apple. Blossom buds mostly exposed, tightly grouped, stems short.

Pink: Applies only to apple and peach. For apple, all blossom buds in cluster pink, stems fully extended. For peach, when the blossom shows a pink tip.

White bud: Applies to pear, sweet and tart cherry, plum, and prune. Blossom buds white, separated in the cluster and stems lengthened.

Bloom: Blossom buds open (applies to all fruits).

Petal fall: After about 75 percent of the petals have fallen (applies to all fruits).

Fruit set: A stage ranging from about four (cherry) to ten (peach) days after bloom when the blossoms that have or have not set fruit, initially, are clearly evident (applies to all fruits).

SELF-HELP QUESTIONS

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

1. How can secondary pests become a problem through liberal and unscientific use of pesticides?

2. List four important premises of pest management philosophy.

3. What is the definition of the growth stage called "petal fall"?

CAUSES OF FRUIT DISEASES

Tree fruit diseases are caused by organisms which live and feed on various plant parts. Most tree fruit diseases are caused by fungi, bacteria, mycoplasma, viruses, or nematodes. The fungal, bacterial, and nematode diseases are controlled primarily by pesticides while the mycoplasma and virus diseases are generally controlled by cultural methods.

DISEASE CYCLES

Each orchard disease has a developmental pattern or cycle it passes through during the year. Control chemicals and methods are generally effective only at certain times or stages in the disease cycle. If the disease pathogen is not in a susceptible stage of development when control is attempted, results will be disappointing. Improper timing of sprays is a common reason for control failures.

Disease developmental patterns or cycles are of two kinds: primary and secondary. Primary cycles are those first initiated by the pathogen after a period of seasonal inactivity. In Michigan, primary cycles usually begin after the winter rest or dormant period. Secondary cycles are those initiated by inoculum for the primary cycle, or other secondary cycles. Thus, the primary cycle usually occurs in spring or early summer while the secondary cycle occurs throughout the summer.

During the time a pathogen is active and causing disease, it passes through three distinct stages, namely the inoculation stage, the incubation stage, and the infection stage. The length of each stage varies with the pathogen, the environment, and the susceptibility of the plant. These stages occur during both the primary and secondary cycle.

Inoculation Stage

Inoculation consists of the transfer of the inoculum from the source of the inoculum to the infection court. The inoculation stage ends when the inoculum is deposited in the infection court. Sources of inoculum include such things as cankers, diseased fruit, or dead leaves that harbor the pathogen. An infection court is that part of the tree where the inoculum of the pathogen can establish itself. Examples of infection courts are wounds, leaf or fruit surfaces, stoma or air pores in leaves, and blossom nectaries. The inoculum is usually carried to the infection court by wind, rain, insects, and man.

Incubation Stage

Incubation is the period of time from when the inoculum is deposited on the susceptible tissue or infection court to when the pathogen is established in the host plant. This is an important step because it is during this period when the pathogen must establish itself to the point that it can survive and develop, even during periods of unfavorable weather. Pathogens may penetrate the host cells directly or may penetrate through natural openings or wounded tissues.

Infection Stage

The infection stage is the period from when the pathogen is sufficiently established in the host that it can survive and the stage extends through the development of the lesion. During the early stages of this process there is usually no visible external evidence of infection. The time between when the host begins responding to the pathogen to when the lesion first appears is commonly called the latent period of infection. The infection stage continues until a lesion is no longer visible.

Examples of Fruit Disease Cycles

Over 30 diseases occur periodically as a problem on tree fruits in Michigan. It is not possible to describe the life history of each of these diseases in this manual. However, a few examples are provided to stress the relationships between the life history and the use of control procedures. For information on diseases not described here the following bulletins may be consulted: "Diseases of Tree Fruits in Michigan," Michigan Extension Bulletin E-714 or "Diseases of Tree Fruits," North Central Regional Bulletin Publication No. 45.

APPLE SCAB

Scab is caused by the fungus *Venturia inaequalis*. It occurs in most areas of the world where apples are grown. It is less severe in semiarid regions than in cool, humid areas with frequent rainfall. The climate in the Midwest is extremely favorable for scab. Fortunately, successful control procedures have been developed and losses from scab can be prevented.

Symptoms

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 are often distorted. Severe infection can also dwarf leaves and cause defoliation. Trees severely defoliated two or three years in a row are weakened and susceptible to low temperature damage.

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

Fruit infections resemble leaf infection 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 often develop around the blossom end of the fruit early in storage. These lesions are usually small, varying in size from specks to spots one-fourth inch in diameter, and are known as pinpoint scab.

Disease Cycle

Primary cycle: The fungus overwinters in leaves on the orchard floor. In late fall and early spring, microscopic, black pimplelike structures, called perithecia, are produced in these dead leaves. Within each perithecium are asci, each with eight ascospores. The ascospores produce the first or primary infections to 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-seated 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 the mid.60s. 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 forcibly ejected into the air. 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 two hours. Maturation and discharge of ascospores usually lasts five to nine weeks.

Germination begins as soon as a spore lands on new, green leaves or fruit, providing 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, and determine the length of time it takes for infection to occur. For example, at an average temperature of 58°F, primary infection will occur 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 fungicide sprays are needed.

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 cycle: Secondary infections are initiated by conidia produced in primary lesions. Since conidia may develop as soon as seven to nine 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 apical portions 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 by wind. Conidia germinate and infection occurs under about the same conditions as for ascospores.

Secondary infection to fruit can occur in the fall but 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.

FIRE BLIGHT OF PEAR AND APPLE

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 due to destruction of branches and scaffold limbs.

Symptoms

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 pear, brown to dark brown on apple. 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 tip and often develop a crook or bend at the growing point. At first, the tissues are water-soaked and dark green, later turn brown to black. 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, 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 down, 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 persists on the tree.

During wet, humid weather, blighted tissues often extrude a milky, sticky liquid or ooze containing the bacteria. These droplets are produced in areas where the bacteria are actively 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.

Disease Cycle

Bacteria overwinter at the margins of cankers on branches. Survival is most likely to occur 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 of development. Bacteria must move from overwintering cankers to exposed flowers before primary infection can occur. This is accomplished through the action of splashing rain and by flies and other insects which visit both the bacterial ooze and the blossoms.

Only a small portion of the blossoms are infected in this manner, particularly if care has been taken to eliminate overwintering cankers 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. Secondary infections also occur from splashing rain.

Climatic conditions are important in determining 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 frequently invaded 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.

BROWN ROT OF STONE FRUITS

Brown rot is a destructive fungus disease of apricot, peach, nectarine, plum, and cherry throughout the Midwest. The disease reduces yields in the orchard by infecting blossoms, twigs, and fruits. After harvest, fruit decay poses a constant threat. In seasons with climatic conditions favorable for infection, entire crops may be lost, almost overnight.

There are two brown rots of stone fruit crops. American brown rot is caused by the fungus *Monilinia fructicola* and occurs throughout the Midwest. European brown rot, caused by *M. laxa*, occurs primarily on tart cherry in Michigan and Wisconsin. The European fungus is generally a blossom and spur blighter, not a fruit rotter.

Symptoms

Brown rot attacks blossoms, spurs, shoots, and fruit. Symptoms may develop on a few or all of these plant parts during the growing season. Infected blossoms wilt, turn brown, and persist into summer. The fungus of American brown rot may progress downward from the blossom into the flower cluster base and into the spur, particularly on apricot, peach, and nectarines; infrequently on sour cherry. European brown rot infection commonly blights fruit spurs on sour cherry.

When the fungus moves into the woody tissue, down the spur of blighted twigs to the branch below, small cankers are formed. As they expand, cankers may girdle the branch or twig and cause the terminal growth to wither and die. Gummosis may accompany the blighting of spurs and formation of cankers. Succulent shoots are sometimes blighted by direct infection near their tip.

Fruit decay is worst on mature fruit although immature fruit may develop the disease under certain conditions. At first, a small, circular, light brown spot develops on the surface of the fruit. The disease expands rapidly under favorable conditions, destroying the entire fruit in a few hours. Rotted fruit may fall to the ground or persist as mummies on the tree.

Under wet, humid conditions, ash-gray tufts of fungus growth develop over the surface of the lesions. These structures, called sporadochia, produce conidia or spores important in spread of the disease. Appearance of the fungus on a lesion is the most obvious characteristic of brown rot.

Disease Cycle

Brown rot fungi overwinter in mummies on the tree or ground and in twig cankers. While fruit buds are opening, small, cupshaped mushrooms called apothecia arise from mummies on the ground. Formation of the apothecial stage is most important for American brown rot. The sexual stage of the European form is rare. Moisture is required for apothecial development. Development is also favored by temperatures of 63°F to 68°F.

Spores containing asci, each with eight ascospores, are produced within the apothecia. Upon wetting, the ascospores are forcibly ejected into the air and carried by wind to the blossoms where they infect. Apothecia disintegrate by early summer and do not contribute directly to infection at harvest.

Infection may also arise from conidia produced on the surface of mummies and cankers in the tree. Spores are carried by wind or splashing rain to susceptible tissues. Relative humidity of 85 percent or higher is necessary for conidial production.

In summer, brown rot activity is reduced but activity increases as the fruit start to mature. Infected blossoms and green fruit are the main source of conidia for infecting fruit at harvest. Infection may occur directly through the cuticle or through natural openings in the fruit. Wounded fruit are infected much more readily than unwounded fruit. Since rotting and spore production can occur in a few days, the disease is able to build up rapidly, even from low levels.

Environment plays an important role in development of the disease. Warm, wet, humid weather is particularly favorable for brown rot. The hours of wetting necessary for blossom infection decrease from 18 hours at 50°F to 5 hours at 77°F. Infection rate decreases above 80°F and below 55°F, but may continue at temperatures as low as 40°F. Mature fruit decays in 36 to 48 hours under optimum decay conditions.

FRUIT FUNGICIDES AND BACTERICIDES

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

INORGANIC FUNGICIDES

Copper Compounds

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

Bordeaux mixture is sometimes used for the control of fire blight on apples and pears, for peach leaf curl on peaches, and for brown rot blossom blight on sweet cherries. In a 2-6-100 Bordeaux, for example, the first figure of the formula is copper sulfate in pounds, the second figure is spray lime in pounds, and the third figure is water in gallons. Homemade Bordeaux is superior to prepared dry mixes.

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

The "fixed" or "insoluble" copper compounds are sometimes used in place of Bordeaux mixture for disease control. There are several fixed copper products available, containing either basic copper sulfate, basic copper chlorides, copper oxides, or various other formulations. At one time they were used extensively for the control of cherry leaf spot but today their use on fruit crops is limited.

Sulfur Compounds

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

Lime-sulfur is used on apples primarily as an eradicant in the silver tip to prepink period of bud development for the control of scab. It is available as a liquid or in dry form. The liquid is the common formulation. Lime-sulfur is also used to some extent as a dormant spray on peach for peach leaf curl, on prune and plum for black knot, and as a bloom spray on each of these crops for brown rot blossom blight. Although the use of lime-sulfur was once quite prevalent, it has generally been replaced by less phytotoxic or milder fungicides.

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

Sulfur is effective against powdery mildew and is used in combination with scab fungicides for the control of the disease on mildew susceptible apple varieties. When sulfur is used, superior oil should not be used with or near the sulfur applications because the combination is phytotoxic.

Sulfur is used on all stone fruits, except apricots, to control brown rot. It is especially important in the bloom and early cover sprays on peaches to control not only brown rot, but also peach scab and powdery mildew.

Mercury Compounds

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

ORGANIC FUNGICIDES

Benzene Compounds

There are several fungicides in this chemical class but most of them are relatively specific in the diseases they control or in how they may be used. Dinocap is specific for powdery mildew and is sold under the trade name of Karathane or Mildex. Dichloran or Botran prevents decay of fruit crops caused by *Rhizopus*, a common bread mold. It is used as a spray or as a postharvest treatment on certain fruits. Daconil or Bravo is a relatively new compound for use on vegetables, but registration for use on cherries has been requested. It differs from the other benzene compounds in being effective against a spectrum of foliage and fruit pathogens.

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

Botran (2, 6-dichloro-4-nitroaniline) is a 75 percent yellow, wettable powder for use in spraying in the postharvest dips of stone fruits. It has brown rot control activity and is particularly specific in its control of rhizopus rot on fruit. On peaches it is used as a spray to prevent brown rot infection and in a dip treatment for the fruit. It is not cleared at this time for the dip treatment of other stone fruits, but can be sprayed on sweet cherry fruit while sorting. For application to peaches in postharvest sprays it is usually mixed with captan in a half-and-half mixture to minimize visible residue.

Benzimidazole Compounds

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

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

Benomyl (methyl-1-(butylcarbamoyl)-2-benzimidazole carbamate) is used for the control of scab on apples, and powdery mildew, sooty blotch, flyspeck, and postharvest fruit rots caused by Botrytis (gray mold), Penicillium (blue mold of soft rot), and Gloesporium (bull's-eye rot) on apples and pears. It is formulated as a 50 percent wettable powder under the trade name Benlate. On apples, it is often combined with a nonphytotoxic superior type oil of 60 to 70 sec. vicosity.

On stone fruits, it is used on peaches, nectarines, apricots, cherries, prunes, and plums for the control of brown rot, powdery mildew, peach scab, and cherry leaf spot. It is not effective for control of peach leaf curl. Benomyl is particularly effective for the control of brown rot. Sprays may be started at early bloom and continued as necessary through harvest. Benomyl may also be used as a postharvest dip or spray. It will not control fruit rots caused by *Rhizopus sp. or Alternaria sp.*

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

Thiabendazole, 2-(4-thiazolyl) benzimidazole, is used for control of storage rots of apples and pears. Thiabendazole is active against Penicillium and Botrytis (blue mold and gray mold) but will not control rots caused by *Alternaria and Rhizopus*. Dip, drench, or spray the harvested fruit with a suspension of the fungicide. Thiabendazole is compatible with DPA, but not Stop-Scald.

Carbamates

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

The carbamate fungicides are all derivatives of dithiocarbamic acid, an organic acid used in vulcanizing rubber. They are classified into three groups.

1. The thiuram disulfides. These are sold under many trade names such as Thiram, Arasan, Tersan, Thylate, and are known by the common name of thiram. On fruit crops they are used primarily for the control of the apple rust disease complex.

   Thiram, tetramethylthiuram disulfide, is sold under the trade names of Thylate and Thiram. Thiram can be used for combined control of scab and apple rusts on varieties subject to fruit russet by ferbam.

2. Ferbam, ferric dimethyl dithiocarbamate, is formulated as a 76 percent wettable powder. It is used as a protectant from control of apple scab,

pear scab, cedar-apple rust, peach leaf curl, and brown rot. It is used in combination with wettable sulfur on plums, prunes, and sweet cherries for control of leaf spot. Ferbam can also be used as a lead arsenate safener where lime cannot be used for this purpose. In some cases, yellow apple varieties have produced inferior finish when this material is used.

3) The ethylene bisdithiocarbamates. Nabam, zineb, and maneb are important members of this class. Maneb and certain related compounds are used extensively for the control of several diseases on fruit crops. Like the dithiocarbamates, each of these chemicals contains a metal such as sodium, zinc, iron, or manganese.

Maneb, manganese ethylene bidithiocarbamates, causes injury on apple trees. Therefore, in all formulations recommended for use on apples, zinc is added to the maneb to prevent injury.

Zinc-maneb (Manzate D. or Dithane M-22 Special) is an 80 percent dry, wettable formulation of maneb containing zinc as a safener. This formulation is used for control of apple scab and cedar apple rust.

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

These products are used for apple scab and rust control from green tip through primary scab season. They have excellent sticking properties.

These products are compatible with most pesticides and can be used in combinations similar to ferbam. They are compatible with oil. They cannot be depended upon as a corrective for lead arsenical injury.

Polyram is sold as an 80 percent wettable powder and is a mixture of 5.2 parts by weight (83.9 percent) of ammoniates of (ethylenebis (dithiocarbamato)) zinc with 1 part by weight (16.1 percent) of ethylenebis (dithiocarbamic acid), biolecular and trimolecular cylic anhydrozulfides, and disulfides. It is used in a protective schedule against apple scab and apple rust diseases and is used against fly speck and sooty blotch of apple. Polyram has good retention and redistribution properties. It is a mild eradicant, approximately equivalent to captan.

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

Dikar is a coordinated product of zinc ion and manganese ethylene bisdithiocarbamate, dinitro (1-methyl hepthl) phenylcrotonate and certain other dinitro phenols and derivatives. These are the active ingredients of Dithane M-45 and Karathane. Dikar has provided combined control of powdery mildew and apple scab on mildew susceptible varieties when used routinely. For best mildew control, the addition of a spread-sticker is suggested.

European red mite suppression has been obtained when applied on a seasonal schedule and where superior oil was used before bloom. Dikar is incompatible with oil. Good fruit finish has been obtained with Dikar except workers in states other than Michigan have reported moderate fruit russet on McIntosh and Cortland where used at high spray concentrations.

Zineb (zinc ethylene bisdithiocarbamate) is sold as a 75 percent active wettable powder. It is used mainly for control of black knot of plums and prunes. Where sooty blotch and fly speck are a problem on apples, zineb plus captan, are used starting at third cover and repeated every 10 to 14 days until 30 days before harvest.

Guanidine Compounds

The main fungicide in this class is dodine. It is used for the control of foliage diseases of apples, cherries and strawberries.

Dodine (n-dodeclyguanidine acetate) is an excellent fungicide for apple scab and cherry leaf spot control. It is sold under the trade name Cyprex and is formulated as a 65 percent wettable powder. Dust formulations are also available. Dodine is primarily used as a protectant against apple scab, but also has eradicant properties.

Dodine is particularly effective in reducing secondary spread of scab where it has been applied at regular intervals. It will reduce the production of spores in established lesions and also reduce spore germination.

Dodine is commonly used with oil, but a physical incompatibility may occur when a hard water source is used. Furthermore, lime should not be used with dodine since it reduces its effectiveness.

Dodine will control cherry leaf spot on tart cherries. It is also used on sweet cherries where brown rot is not a problem.

Trichloromethylmercapto Compounds

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

Captan (n-trichloromethylthio-4-cyclohexene-1, 2-dicarboximide) is used for control of apple scab, brown rot, and cherry leaf spot. It is also fairly effective against several minor diseases including: black rot, Botrytis blossom-end rot, Brooks fruit rot, bitter rot, sooty blotch, and flyspeck. It will not control apple rust, powdery mildew or fire blight. It is usually marketed as a wettable powder formulation. Several dust formulations and an 80 percent wettable powder formulation are available and should be used at equivalent rates.

Though primarily a protectant fungicide, captan will eradicate scab if used within 18 hours after the beginning of an infection period at average temperatures about 50°F. It should be applied at relatively short intervals during critical scab periods, when growth is rapid, or when rains are frequent.

Captan is associated with good finish on russet-susceptible apple varieties — like Golden Delicious. On Red Delicious, it has caused a leaf spotting when used at full strength early in the season, especially when used in combination with sulfur. On other varieties, it may be combined with sulfur or with dinocap for powdery mildew control. It is incompatible with oil and should not be used in combination with oil or near oil applications.

On stone fruit crops, captan is used for early season control of brown rot on apricots and for combined control of brown rot and cherry leaf spot on sweet cherries starting at petal fall. It also is used on prunes, plums and peaches for the control of brown rot.

Difolatan (cis-N-(1, 1, 2, 2-tetrachloroethyl)thio)-4-cychlohexene-1, 2-dicarboximide) is used on machine-harvested tart cherries to control cherry leaf spot. It is formulated as an emulsifiable solution contining 4 pounds of Difolatan per gallon. On apples, Difolatan is used as a single application at green tips for apple scab.

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

Quinones

Several quinones have been tested as fungicides but only one, dichlone, has been developed for use commercially on fruit crops. Dichlone is used as a foliar and fruit protectant on fruit and certain other crops.

Dichlone (2, 3-dichloro-1, 4-naphthoquinone) is sold as a 50 percent active wettable powder under the trade name Phygon. It is used for the control of apple scab where it is generally combined with a protectant fungicide. It is used only from bud-break through the first-cover period of apples. On stem fruits, it is used mainly for the control of brown rot blossom blight on peaches, plums, prunes, tart cherries and sweet cherries. For this purpose, it is applied during the bloom period.

Antibiotics

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

Streptomycin, an antibiotic produced by a soil microorganism, is used for the control of bacterial diseases. It is used against fire blight on apples and pears. It is very effective against the blossom blight phase of this disease if sprays are well timed and thorough.

Postbloom sprays of streptomycin are approved on pears up to 30 days before harvest, on apples up to 50 days before harvest.

Tetracycline antibiotics, similar to those used in veterinary medicine, are active against several bacterial plant pathogens. Since their spectrum of activity resembles that of streptomycin, the tetracyclines have not gained wide usage. Today, there is renewed interest in the tetracyclines because of their activity against mycoplasma (the cause of aster yellows). X-disease of peach and cherry are related "yellow" diseases.

Cycloheximide is an antibiotic active against fungi. It has been used on tree fruit for the control of cherry leaf spot, and powdery mildews. Although it was used extensively at one time, it has generally been replaced by synthetic organic fungicides.

FUNGICIDES, THE DISEASE CYCLE, AND CONTROL

Much goes into the planning of an economical and effective spray program. A successful disease control schedule must be based on knowledge of: (1) the life history of the important diseases likely to be encountered; (2) the characteristics of the various fungicides and bactericides available, and their proper use; and (3) susceptibility of the different kinds and varieties of fruit to disease and spray injury.

The following information relates the control of apple scab to the characteristics of the various fungicides. It is an example of how to put together a control program and a similar approach should be used with other diseases. Five general approaches are described here.

Protectant Spray Programs

Protectant sprays are applied before infection occurs. They set up a chemical barrier between the susceptible plant tissue and the germinating spore.

The scab fungicides listed in the following sections may be used as protectants, although some act in other ways as well.

During primary infection, protectants are usually applied on a five to seven day schedule. The frequency of application depends on the ability of the compounds to resist the weathering action of rainfall and the rate of new growth during this time. Generally, compounds such as ferbam, glyodin, and sulfur, which only protect, are applied more frequently than compounds that can act in other ways as well.

Eradicant Spray Programs

Eradicant sprays "burn out" the fungus within certain periods of time after infection begins. Eradicants should be used at their full recommended rate, because at lower rates, their ability to eradicate is reduced or lost. The number of hours a compound remains effective after the beginning of an infection period is as follows:

Fungicide	Rate/100 gal. dilute	Eradication from beginning of infection period*
benomyl 50% WP	-	curative#
captan 50% WP	2 lb.	18 to 24 hr.
dichlone 50% WP	½ lb.	36 to 48 hr.
dichlone 50% WP	¼ lb.	30 to 36 hr.
dodine 65%	½ lb.	30 to 36 hr.
lime sulfur	2 gal.	60 to 72 hr.
Polygram 80% WP	2 lb.	18 to 24 hr.
ferbam 76% WP	2 lb.	none
glyodin 30% sol	2 pt.	none
sulfur 95% WP	5 lb.	none

* Growers should use beginning of rain as the start of infection. Based on average temperature of 50°F to 60°F. At average temperatures lower than 50°F, use higher eradicative time figures.

\# Benomyl at 4 to 6 oz/100 gal or at 2 to 3 oz with superior oil will inhibit development of sensitive scab strains up to about 4 days after the beginning of the infection period. To maintain inhibition of lesions, continue benomyl applications for a few applications or alternate with dodine at ½ lb/100 gal.

Timing of eradicant schedules for primary apple scab is based on wetting and prevailing air temperatures (see Table 1). Eradicants are applied after the length of wetting is sufficient for infection to occur. For example, at an average temperature of 58°F, primary infection will occur 10 hours after the start of the rain. After 22 hours of wetting, the degree of infection will be

Table 1. Approximate number of hours of wetting required for primary apple scab infection at different air temperatures.*

AVERAGE TEMPERATURES	DEGREE OF INFECTION		
	Light	Moderate	Heavy
oF	hrs.[a]	hrs.	hrs.
78	13	17	26
77	11	14	21
76	9½	12	19
63 to 75	9	12	18
62	9	12	19
61	9	13	20
60	9½	13	20
59	10	13	21
58	10	14	21
57	10	14	22
56	11	15	22
55	11	16	24
54	11½	16	24
53	12	17	25
52	12	18	26
51	13	18	27
50	14	19	29
49	14½	20	30
48	15	20	30
47	17	23	35
46	19	25	38
45	20	27	41
44	22	30	45
43	25	34	51
42	30	40	60
33 to 41[b]	-	-	-

* From W. D. Mills, Cornell University.

[a] The infection period is considered to start at the beginning of the rain.

[b] Data incomplete at these temperatures.

will be severe. Because the eradicant action for most fungicides is limited to a few hours or days after infection, they 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 the rain, chemicals with eradicative properties must be used.

Protectant-Eradicatn Schedules

Today, most fungicides used for apple scab control are active as protectants and as eradicants. When applied at the eradicant rate, they control infections that may have occurred a few hours or days previous and also protect exposed tissues for several days after the time of application. These compounds are usually applied on a 5- to 10-day interval, depending on the weather and tree growth.

Single Application Technique

A single spray is applied at the green tip stage of bud development and through retention and redistribution protects new growth for several weeks. The only fungicide registered for use in this manner is Difolatan. It is used on apples as a single spray applied at the green tip stage of bud development. In this program, start using other suitable fungicides in a regular program at pink or at early petal fall, depending on the rate of fungicide applied at green tip.

Tank Mixture Programs

Applying two or more fungicides simultaneously in the same spray has been practiced for several years to achieve increased protection or eradicant action against apple scab or to increase the range of diseases that are controlled. Occasionally, manufacturers will sell fungicides in mixed form, thereby relieving the grower of the job of mixing compounds on his own.

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

TOLERANCE TO FRUIT FUNGICIDES

Fungi have rarely developed tolerance to the fungicides used to control them under field conditions. However, recent experience with some of the new organic fungicides with selective action on fungi indicates fungicide tolerance can be a problem.

Tolerance problems on fruit in Michigan include benomyl-tolerant apple scab, dodine-tolerant apple scab, benomyl-tolerant brown rot, and benomyl-tolerant cherry leaf spot. Tolerance problems with apple scab appear to be widely distributed while tolerance in brown rot and leaf spot currently appear to be restricted in distribution. Also, benomyl-tolerant apple scab is much more tolerant to benomyl than dodine-tolerant scab is to dodine.

Although it is seldom possible to determine the source of tolerant fungal strains, the pattern of fungicide application has a marked effect on where tolerance problems will occur. High and continuous selection pressure, such as from using one or closely related fungicides repeatedly year after year, tends to enhance the tolerance population. Thus, detectable populations of benomyl-tolerant fungi have been found primarily where benomyl was used regularly for about 3 years and dodine-tolerant apple scab has been found where dodine was used for about 10 years.

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

SELF-HELP QUESTIONS

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

1. Are control methods and chemicals usually effective during all stages in a disease cycle?

2. What is a primary disease cycle?

3. List at least three sources of inoculum.

4. What is the incubation period?

5. Is there usually visible external evidence of infection during the early stages of the infection process?

6. On what parts of the apple tree are symptoms of apple scab most apparent?

7. What type of weather favors perithecial development of the apple scab causal organism?

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

9. Where do the bacteria that cause fire blight overwinter?

10. Is brown rot of stone fruits caused by a virus, a fungus, or bacteria?

11. Is brown rot fruit decay worse on mature or immature fruit?

12. What type of weather is favorable for brown rot?

13. Under what conditions can Bordeaux mix be phytotoxic to fruit and foliage?

14. Why is lime-sulfur not used as extensively as it once was?

15. Can superior oil be safely used with or near sulfur applications?

16. Why have mercury compounds been suspended for use as fungicides?

17. Are most benzene compounds relatively specific in the diseases they control or in how they may be used?

18. Are the benzimidazoles systemic or contact fungicides?

19. What is the primary use of the thiuram disulfides on fruit crops?

20. Do the dithiocarbamates and the ethylene bisdithiocarbamates all contain metals such as zinc, sodium, iron, and manganese?

21. In what class of fungicides is dodine?

22. Does Captan control apple rust, powdery mildew, and fire blight?

23. At what growth stage or stages is dichlone used?

24. What are antibiotics?

25. List three factors to consider in planning a successful disease control schedule.

26. When are protectant sprays applied?

27. Why must eradicant sprays be used at the full recommended rate?

28. How often are protectant-eradicant compounds usually applied?

29. At what growth stage should a single application of difolatan be applied?

30. Will the use of closely related fungicides repeatedly year after year reduce the tolerance population?

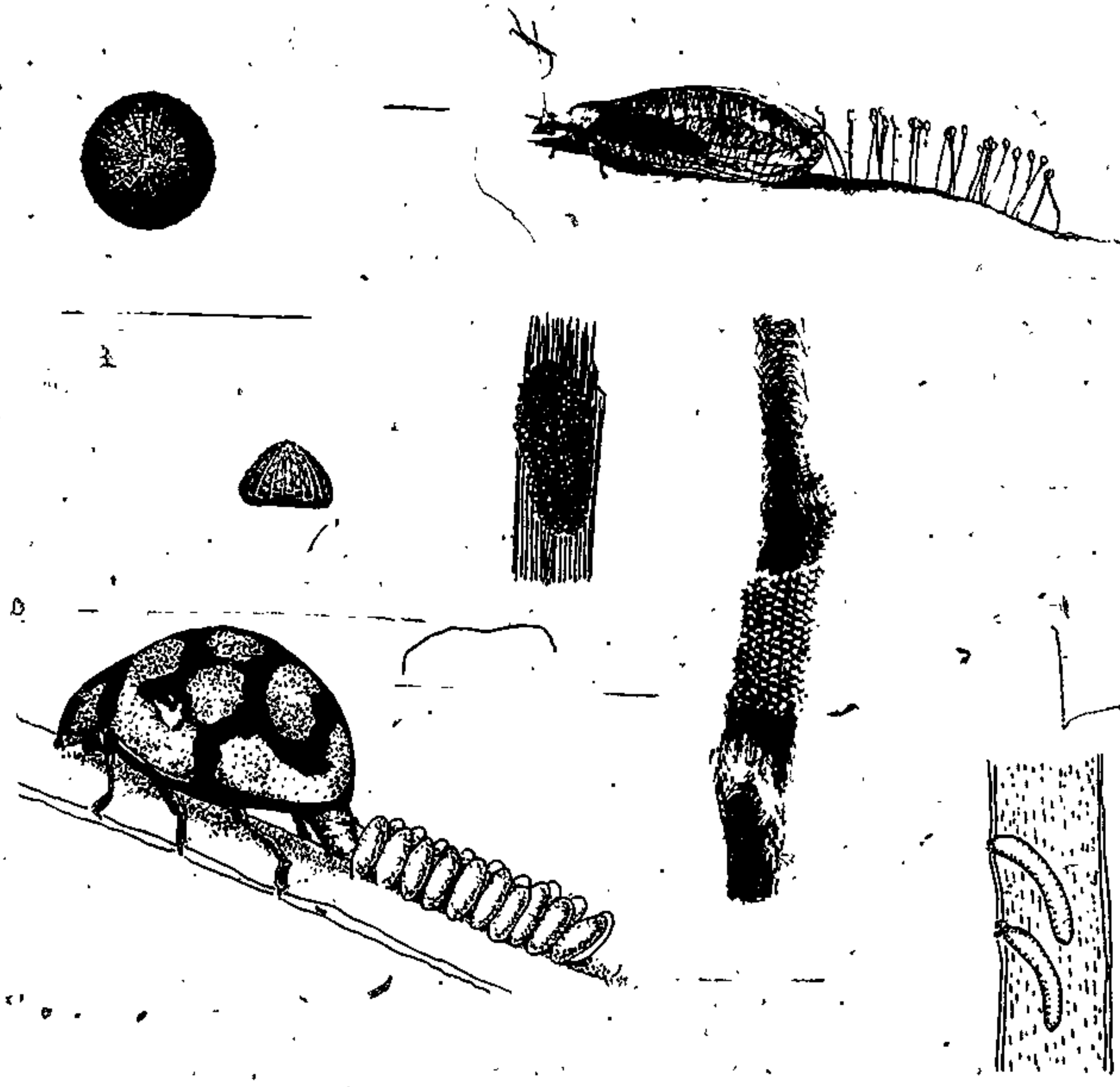
INSECT AND MITE PESTS

Basic Facts of Insect and Mite Development

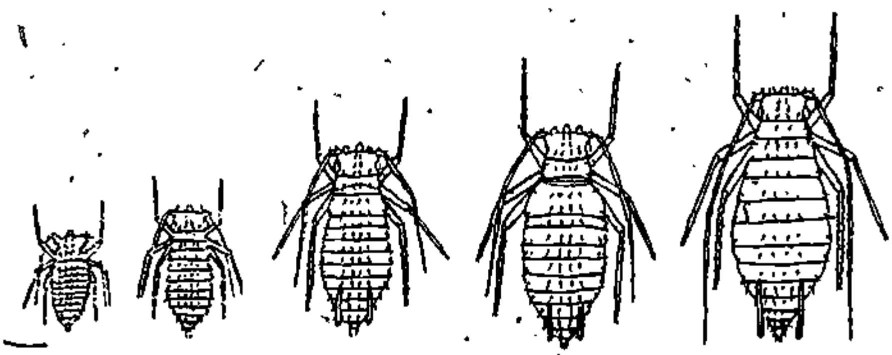
This section is initiated with a discussion of insect and mite development. The discussion is intended to lead the reader through the basics of insect and mite development. Concepts presented may at first be judged unnecessary to an understanding of how and when to control insect and mite pests of fruit crops but they are building blocks of knowledge that must be grasped if more complex and critical concepts are to be mastered.

Insects and mites belong to a phylum of organisms referred to as arthropods. Examples of common arthropods other than insects and mites are crabs, spiders, ticks, scorpions, and harvestmen (daddy long-legs). All arthropods grow and reproduce in a similar manner. In the following discussion of insect and mite development, primarily insects will be used as examples and mite development may be considered similar unless otherwise indicated.

The life of an insect can be divided into three stages; the egg stage, a series of immature stages, and a sexually mature or adult stage. All insects begin as eggs. The egg stage varies tremendously in color, size, shape, and placement on or in the host plant. For example, the eggs of the codling moth are very small, flat, and laid singly on leaves or apples; eggs of the red-banded leaf roller are also small and flat but are laid in clusters of from to to 70 eggs on the trunk and scaffold limbs (first generation) or on the foliage (second generation); and eggs of the white apple leafhopper are long, slender and laid singly beneath the bark of one to five year-old wood (overwintering eggs) or in the tissue of leaves (summer generation). With the exception of mites, few chemical control measures are directed against the egg stage.

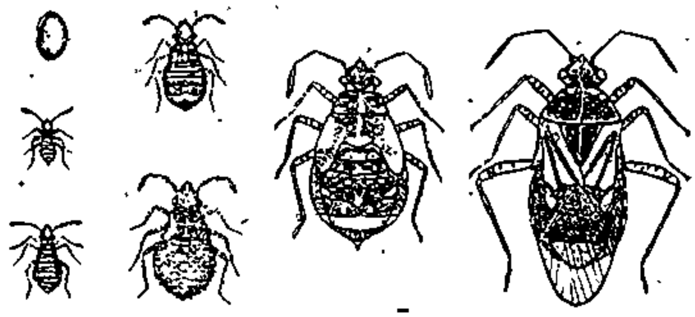


Development following the egg stage is a period of growth characterized by progression through a series of distinct stages. The skin of insects does not stretch and to accommodate an increase in size, the insect must periodically shed the old, small skin and replace it with a new larger one. The process of shedding the old skin and replacing it with a new one to allow continued growth is referred to as molting. Most insects molt between three and six times while progressing from the egg to the adult stage. With very few exceptions, the molts for a particular species follow a set sequence as to number, increase in size and duration between each molt. The insect between successive molts is referred to as an instar. Instars are numbered sequentially from egg hatch to the adult stage. For example, the first stage following egg hatch of the strawberry aphid is the first instar, following the first molt, it is the second instar, following the next molt, it is the third instar, etc., until the adult stage is reached.

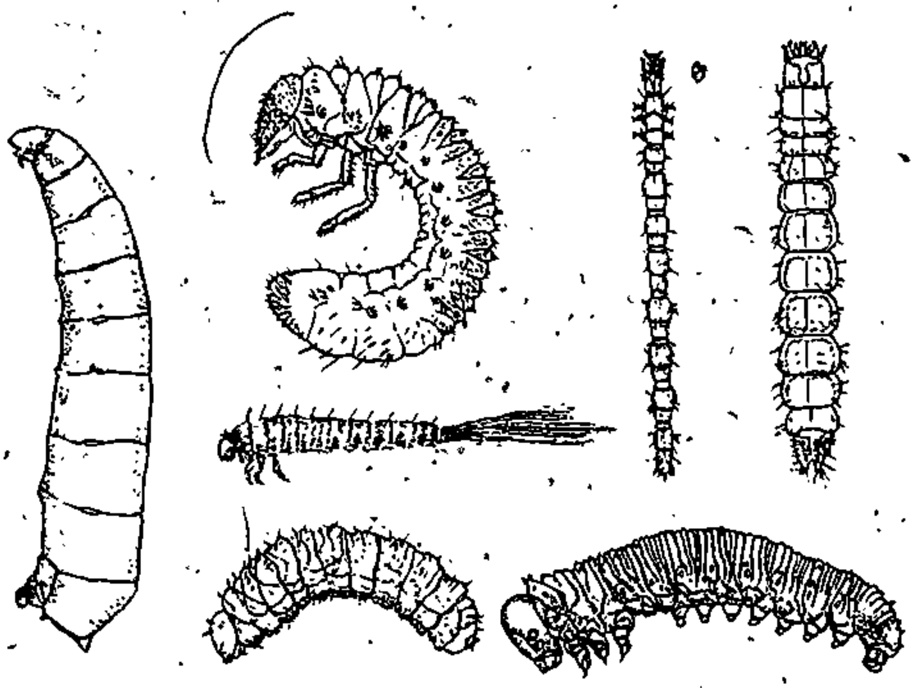


The progression of insects from one instar to another is accompanied by anatomical and physiological changes. Most obvious are changes in size and form associated with the different instars. The change which occurs during the development of insects is termed metamorphosis. Insect development can be classified as either gradual or complete metamorphosis.

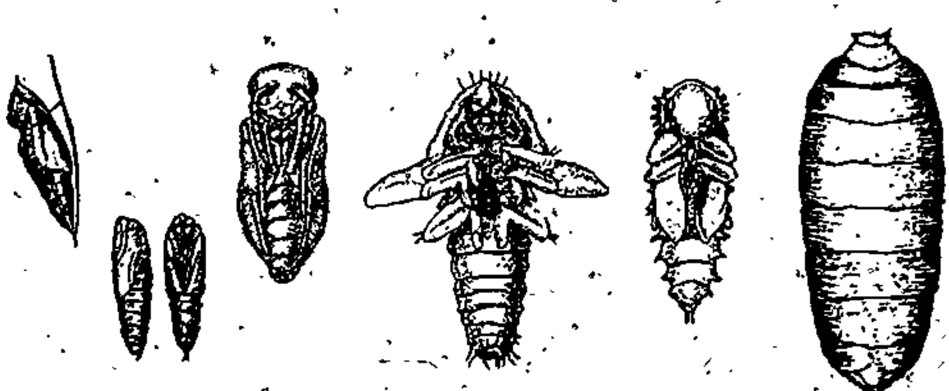
Gradual metamorphosis is characterized by a series of immature stages referred to collectively as nymphs. Successive nymphal instars appear similar in body form exhibiting primarily an increase in size from one instar to the next. With the exception of a smaller size, lack of wings and reproductive organs, the nymphs closely resemble the adult stage. Characteristically, nymphs are found near and feeding on the same host plant as the adult.



Complete metamorphosis is characterized by two immature forms (the larva and pupa) which appear as different from one another as they do from the adult stage. The larval stage (commonly referred to as worms, maggots, caterpillars or grubs) is represented by a series of instars that, like nymphs, are similar in appearance and primarily increasing in size while progressing from one instar to the next. The number of larval instars is constant for a species. The larvae are usually found feeding on a different host, or at least a different part of the same host, than the adult. For example, the codling moth larvae feed internally in the apple while the adult may take nectar or water from a wide variety of sources. Figure 4 depicts some examples of common types of insect larvae



The pupa is the final immature stage before the adult and is the resting or inactive stage in which the changes take place transforming a wormlike caterpillar into a moth. The pupa may be found in the same habitat as the larva (e.g., red-banded leaf roller) or it may be in an entirely different habitat (e.g., plum curculio). In general, the pupa is resistant to harsh environmental conditions and many insects spend the winter in this stage. Many of the most serious fruit pests exhibit complete metamorphosis; examples are given in the section on identification.



Temperature and Insect and Mite Development

The growth and development of insects and mites, like all cold-blood organisms, are regulated by factors of their physical environment. While environmental parameters as rain, humidity, photoperiod, wind, etc., effect growth and development, temperature seems to be the most important. In general, the higher the temperature, the more rapid the growth rate of the insect.

Provided an adequate nutritional source (food) is available, the rate of insect growth will be regulated by temperature. Each stage of an insect requires so many heat units (referred to as degree days) to reach maturity and change (molt) into the next stage. Research has shown that there are temperatures below which insect development ceases or procedes at a very slow rate.

In general, as temperatures rise above the lower developmental threshold, insect growth resumes and the higher the temperature, the more rapidly growth proceeds. Of course, there are upper temperature limits which actually inhabit growth but these are not usually of critical importance. Thus, an insect views a day where the average temperature is 45°F much differently from one where the average is 75°F. An insect with a lower developmental threshold of 50°F would not grow any in a five day period where average daily temperatures were 45°F, while it would grow considerably and may even change to another stage in a five day period where temperatures averaged 75°F. This point is being emphasized to stress the importance of the effects of temperature on insects and its relationship to chemical control applications. For years, fruit growers have essentially followed a set schedule of spraying following petal fall. The interval between sprays usually being determined by the effective residual life of the material used. While this strategy is safe, it is wasteful, expensive and unnecessary. By knowing how temperature affects key pests, the first occurrence and duration of a critical stage against which controls are aimed can be adequately predicted.

Lower developmental thresholds have been determined for many insects and though they differ from insect to insect and even between stages of the same insect, they usually fall between 40°F and 50°F. Upper developmental thresholds (the temperature above which the growth rate begins to decrease) have been determined for some insects but are not usually as critical as lower thresholds. Entomologists, utilizing their knowledge of the relationship between insect growth and temperature, have devised systems to predict insect development in the field and assist in monitoring insect activity and timing the application of chemical control programs. By accumulating heat units, referred to as degree-days, above the lower developmental threshold, critical events in the life cycle of an insect can be predicted with a high degree of accuracy. A degree-day is defined as a day in which the average daily temperature is one degree above the lower developmental threshold. There are a number of methods for determining degree-days, but among the easiest is the averaging of daily high and low temperatures using a standard high-low thermometer. For example, if the daily high was 80°F and the low was 40°F, the average daily temperatures would be $\frac{80+40}{2} = 60$. For an insect with a lower developmental threshold of 50°F, there would be an accumulation of 10 degree-days, determined simply be subtracting the lower developmental threshold from the average daily temperature.

Studying insect populations in the field, entomologists have been able to determine the number of accumulated degree-days required for the development of various stages in the life cycles of certain insects. For example, the codling moth adult emerges from overwintering sites after an approximate accumulation of 250 ± 20 degree-days after January 1. Following emergence (determined by pheromone trap catches), it requires an accumulation of 243 ± 21 degree-days for first egg hatch and 458 ± 16 degree-days for 50 percent egg hatch of first generation. Other events in the life cycle of the codling moth are shown in Table 2.

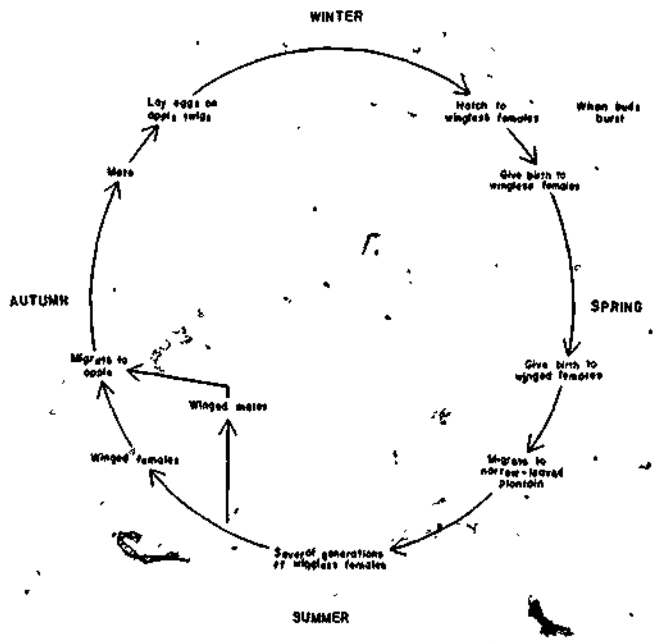
Table 2. Relationship between accumulated degree-days and critical events within the life history of the codling moth.

Critical Event	Accumulated D°* since January 1	Accumulated D° after first adult emergence
First adult emergence	248	0
First egg hatch	491	243
Peak adult emergence	500	252
50% egg hatch (1st generation)	710	458
50% egg hatch (2nd generation)	1550	1302
Peak adult emergence (2nd generation	1577	1329

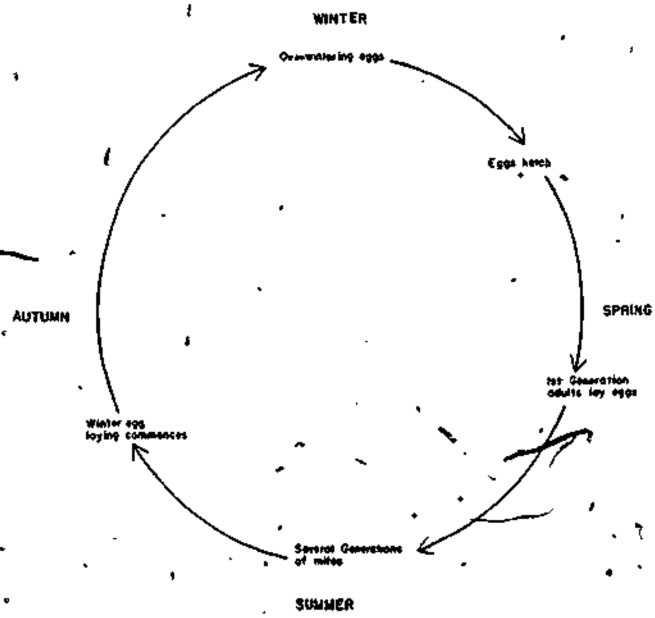
* D° = degree-days

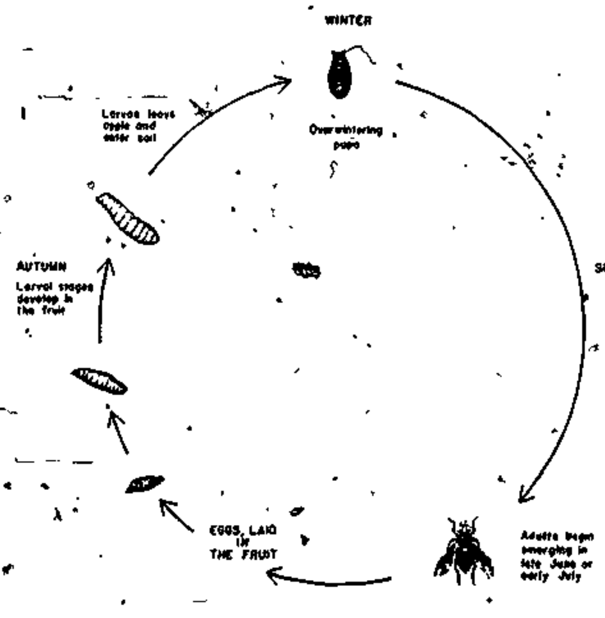
Life Histories

As discussed above, insects progress through a definite succession of developmental stages from the egg to adult. One complete cycle from egg to egg is referred to as a generation. The number of generations per year of fruit insect pests varies from 1 (plum curculio) to as many as 10 to 12 (European red mite). Generally, there are a consistent number of generations within a year; however, the number may vary considerably from year to year for insects and mites with short generation cycles, depending upon the relative coolness or warmness of the growing season.



The life history of an insect can be defined as the sequence of stages through which it progresses during a growing season taking into account host plant shifts or migrations. Insects pass the winter in one particular stage specially adapted to withstand harsh environmental conditions. The overwintering stage varies and, depending on the insect, may be either the egg (e.g., fruit tree leaf roller or European red mite), larva (e.g., codling moth), pupa (e.g., apple maggot) or adult (e.g., plum curculio). When temperatures warm in the spring, the insects resume development and progress sequentially through their life stages. Life histories of insects are commonly represented as diagrams.


WINTER
Overwintering eggs
Eggs hatch
SPRING
1st Generation adults lay eggs
Several Generations of mites
SUMMER
Winter egg laying commences
AUTUMN


WINTER
Overwintering pupa
SPRING
Adults begin emerging in late June or early July
SUMMER
EGGS LAID IN THE FRUIT
AUTUMN
Larval stages develop in the fruit
Larvae leave apple and enter soil

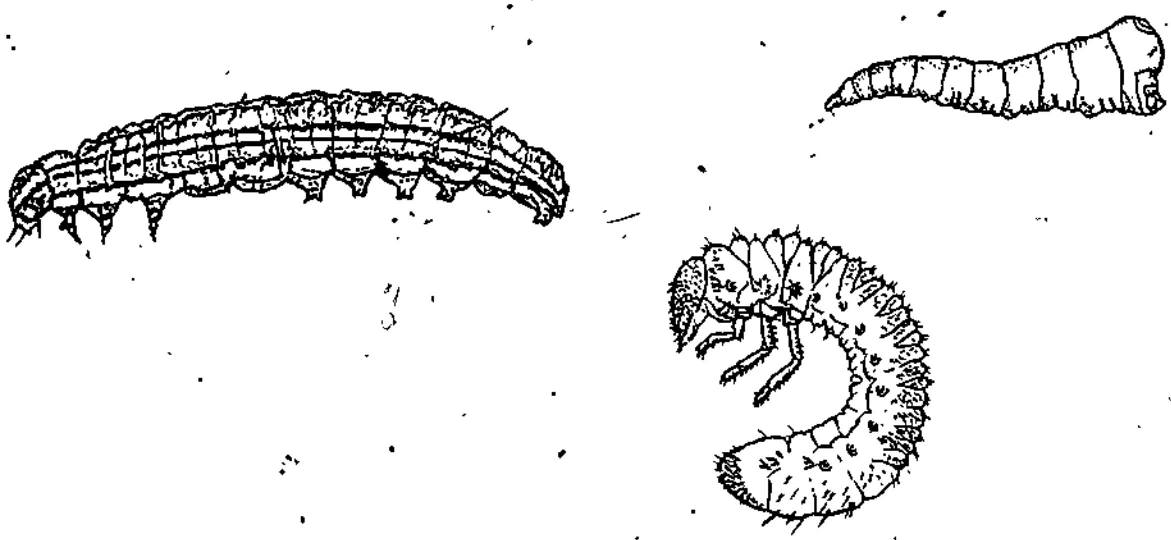
A knowledge of and the ability to identify the stages in the life history of pest insects—beginning with the overwintering stage and progressing throughout the growing season—is of key importance to optimum insect control. The primary technique used currently to maintain insect pests at noneconomic levels is chemical control (the use of insecticides or miticides). If chemicals are to have their greatest effect, they must be applied and present throughout the duration of a susceptible stage of the pest. A knowledge of the life history of key fruit insect pests (knowing what stages are present and when) is thus of prime importance to the proper timing of chemical controls. All the life histories of fruit insect and mite pests cannot and should not be discussed here. Brief discussions of tree fruit insect life histories are available in the Fruit Pesticide Handbook (Bulletin E-154).

Insect and Mite Identification

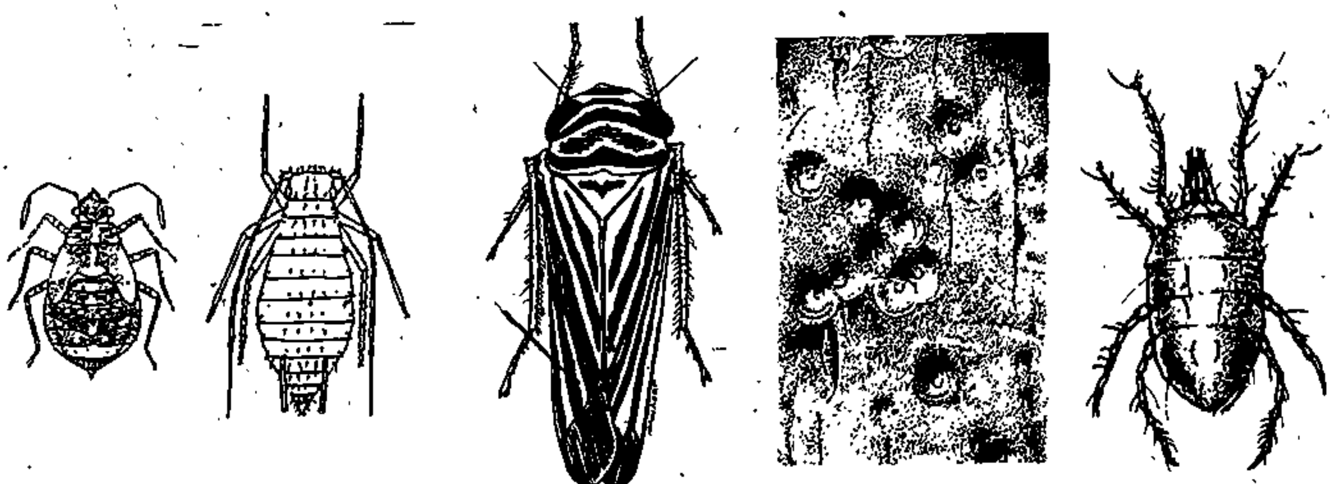
Many decisions concerning insect control are made in the field following the detection of an infestation. Contingent on making the correct choice of available control measures is the correct identification of the insect causing the problem. It is necessary that there be some procedure for the field identification (or at least reduction in the number of possibilities) of insects found in fruit crops. The following discussion is not intended as a short course in taxonomy, but only as a guide to familiarize you with some basic principles which can assist in the field identification of insects. There are three classes of information that may be considered about any insect in an attempt at making an identification: morphological, ecological and temporal.

Morphology refers to the form or shape, color, size, etc., of an insect. The first step in determining the identification of an insect is whether it exhibits gradual or complete metamorphosis. This criterion quickly divides the pests occurring on a crop into two camps and eliminates many possibilities. Next, take note of the general body form. Once the insect is placed in one of these groupings, the possible choices can be further narrowed by taking note of specific color, color patterns, size, other morphological characters specific to certain pests or by referring to one of the other classes of information.

General characteristics of the body forms of some common fruit insects exhibiting gradual metamorphosis



General characteristics of the body forms of some common fruit insects exhibiting gradual complete metamorphosis



Consideration of the ecology of insects will be restricted to a discussion of the crops on which a particular insect may be found, where on the crop it occurs (foliage, fruit, scaffold limbs), and what type of feeding or other injury is produced. The simple consideration of the crop and a knowledge of pests likely to be found there eliminates many possibilities immediately. Insects and mites most likely to be found attacking various fruit crops are indicated in the Fruit Pesticide Handbook (Extension Bulletin E-154).

The location on the crop where an insect is most likely found can provide a valuable clue to its identity. Associating specific habitat preferences of key life stages of an insect is of great importance. Such knowledge is also helpful when monitoring the presence of insects by concentrating searching activities in those specific locations.

To illustrate this point, let us take the apple crop and discuss the range of pests which might be found attacking the fruit and how the manner in which these attacks differ assist in making decisions as to which pest is involved. The first decision would be to simply determine if the insect is feeding internally or externally. If feeding is internal, the pests would probably be either the codling moth, lesser apple worm, or apple maggot. The codling moth characteristically feeds in the apple core where the seeds, its favorite food, are found. It usually enters the apple from the calyx end. The lesser apple worm also feeds internally. It seldom enters the core area where seeds are developing but restricts its feeding to the flesh around the core. The apple maggot does not enter the core but tunnels around quite profusely in the flesh of the apple.

Most of the insects directly attacking the apple externally are leaf rollers, that is, they characteristically fold leaves or attach leaves together or to the fruit with silken webbing. All leaf rollers (red-banded leaf roller, oblique-banded leaf roller, tufted apple bud moth, and variegated leaf roller) often attach a leaf to the side of the apple and feed beneath it. Though the leaf rollers seem to exploit the same habitat and their behavior appears similar, they can be differentiated by the manner in which they feed on the apple. For example, the feeding of the red-banded leaf roller is usually deeper than the oblique-banded or fruit tree leaf rollers but usually does not appear to be as extensive as these two. The feeding of the tarnished plant bug does not generally show up until some time after it has occurred. The plant bug sucks juices from the apple and in so doing, kills some cells. As the apple grows, a depression is left in an area where the feeding was done.

A discussion of where and how each insect or mite pest feeds upon a particular crop cannot be conducted here. The important concept to grasp is that by knowing where a particular pest is most likely to occur is a great aid in the field identification of insects and an invaluable assist in developing monitoring programs as well.

Temporal considerations refer to the association of particular stages in the growth and development of an insect or mite with certain periods of the growing season. A knowledge of an insect's life history and some experience in associating different growth stages with specific times during the growing season will assist in the elimination of possibilities when an insect is detected. For example, if a very small caterpillar larva was found in an apple orchard about petal fall, one could quickly eliminate as possibilities the oblique-banded leaf roller or fruit tree leaf roller since they would be nearly full grown by that time. The codling moth could also be eliminated since egg hatch had not as yet occurred. Thus, the remaining choices would be a few leaf roller species (probably red-banded) or the green fruitworm which could be separated using other criteria.

None of the three categories discussed above is intended to stand alone in making field identifications of insects (mites). However, taken together, they provide a way to organize one's thinking and assist in eliminating many possibilities after an insect is detected; thus providing a logically arrived at answer in most situations.

Agro-ecosystems are by their very nature much less diverse than natural occurring ecosystems and the apple orchard or strawberry field is no exception. Chemicals used on tree and small fruit crops are used to maximize production and in doing so, they eliminate many species that would occur on the crop in nature. This in itself makes the identification of insect and mite pests of fruit crops easier by simply eliminating many of the possibilities. On occasion, however, insects other than those commonly considered pests are found making field identification difficult, if not impossible. Before immediately applying or recommending an insecticide, determine the amount of damage being causes and then if the situation permits, contact a specialist for assistance. The needless application of expensive insecticides to control an innocuous insect is a tremendous waste of resources and in fact, is technically illegal. Pesticides can legally be applied only to control those pests listed on the label—another reason to have a good grasp of the principles of insect field identification.

Monitoring Insect Activity

Monitoring insect activity simply refers to the process of determining what insects are present in the orchard and following their development by regular inspections. Why monitor insect pests? With increased costs of insecticides, miticides, labor and fuel, insect control is one aspect of a grower's production program which can be altered to maximize profits. By establishing monitoring programs, pests present are identified and control programs designed specifically for them. Following the development of a pest through the season permits the most vulnerable stage to be attacked very precisely. Biological monitoring of insects doesn't always mean reduced control costs, but this is certainly one of its goals. As many or more sprays may be needed as in the past but they are only applied if the pest is present in numbers considered to be a threat to the crop.

As discussed earlier, all insects are cold-blooded organisms and their seasonal development is tied primarily to the fluctuations of temperature. Likewise, temperature patterns vary from year to year, making it impossible to associate the presence of a pest with a particular date or even a stage in the development of the fruit tree. By following the development of a pest through the season, the vulnerable stage may be precisely determined and appropriate controls applied. This requires extra effort on the part of the grower, scout, or professional fieldman. The following are some techniques and tools used for biological monitoring of fruit insect pests.

Regular inspections: Inspection of overwintering sites or sites where a pest is likely to be found during the growing season is perhaps an underrated monitoring method. This may require more effort and may not be as specialized or sensitive as other monitoring techniques, but it is especially useful in detecting the presence of small, relatively immobile pests, such as aphids, scales, mites, or pear psylla nymphs. Regular inspections are the only practical means of detecting the presence of some pests, such as climbing cutworms, before they cause damage. By simply marking sites where pests are located and returning at regular intervals, stage changes can be observed to aid in the timing of control applications.

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Leaf sampling and brushing: Another monitoring technique used specifically to detect the presence and relative numbers of mite pests is leaf sampling and brushing. A sample of leaves, usually 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.

Bait-lure trap: There are currently two trapping techniques used to monitor the presence and seasonal activity of fruit insect pests. Bait-lure traps are designed to monitor fruit flies whereas pheromone traps are designed to attract moth species which attack fruit. The bait-lure attracts adult fruit flies (cherry fruit flies, apple maggot, or blueberry maggot) through a combination of their attractive color and the odor given off by the bait (usually a mixture of protein hydrolasate and ammonium acetate). The flies are trapped in a sticky substance coating the trap. By inspecting them at regular intervals, their presence and relative activity, or abundance, can be judged. The attractive powers of these traps are not known, and if fly populations are low (as in most commercial orchards) the ability of the trap to attract, and therefore detect, individuals is questionable. However, traps placed in abandoned orchards, or commercial orchards with annual problems are useful for this purpose.

Pheromone traps: The other type of monitoring trap is the pheromone trap (sex-lure). Pheromones are synthetic chemical substances, which imitate the natural hormones for sex attraction in the female of an insect species. Plastic wicks or capsules with minute quantities of these attractants lure the males of the insect involved. The interior of these specially designed traps is precoated with adhesive. Since each insect species generally has its own sex hormone, only a pure culture of the specific insect monitored is collected. This feature makes insect detection and identification easier.

Pheromone traps offer new dimensions in near perfect orchard detection, emergence timing and monitoring of red-banded leaf roller, codling moth, fruit tree leaf roller, tufted apple bud moth, oriental fruit moth and others. These traps might be used for no other purpose than to determine insect presence or absence in an orchard. They may lead to an eventual systems approach to asses insect populations, emergence trends, and economic damage thresholds. They eliminate much of the previous guesswork in spray timing for many of the more troublesome fruit insects.

These traps are supplemental reinforcements and not replacements for other commonly used insect monitoring procedures. They can help you better know your insects: which ones are present, and when to or not to fight them.

INSECTICIDES AND MITICIDES

The following discussion centers around general characteristics and properties of insectides and miticides commonly used in Michigan's fruit growing industry. An awareness of the class of chemicals to which a product belongs, formulations available, residual activity, and the spectrum of pests controlled or maybe more important, the spectrum of pests not controlled) is necessary if proper and optimum use of the chemical tools is to be achieved. The list of chemicals discussed is not intended to include all products available for use on fruit crops since this list is expected to change with time. What is important is the type of information presented and as new products make their way into chemical control programs of the future, similar types of information should be mastered for these compounds.

Carzol is a carbamate miticide/insecticide registered for use on apples and pears. It can provide residual mite control of up to 30 days from single applications. Although most effective for controlling immature and adult forms of European red and two-spotted mites, it does prevent the hatching of mite eggs present at time of spraying. It is especially efficient against organophosphate-resistant mites and also controls those resistant to other types of pesticides. Carzol effectively controls the white apple leafhopper if applied when young nymphs are present.

Formulated as a completely water-soluble powder, containing 92 percent formetanate hydrochloride, it dissolves rapidly in water to leave an invisible-crop residue. Correct dosage rates and thorough tree coverage are important, since Carzol primarily kills the active stages of mites. Repeat applications should be made as needed or whenever mite infestations appear.

The product is not stable in alkaline water. Its spray mixture must be freshly prepared just before application. It is compatible with many orchard spray materials, moderately toxic to honeybees and comparatively nontoxio to fish, birds, man and animals.

Chloropropylate, trade-named Accaralate, is a chlorinated miticide for control of European red and two-spotted mite on apples and pears. Formulated as an emulsifiable concentrate, it kills only the active stages of these mites. It is useful in prebloom preventive sprays or whenever mite infestations first appear. Prebloom applications are made as close to egg hatch as possible for best results.

Postbloom spraying must be done as often as necessary to keep mite populations at a minimum. Two applications spaced 7 to 10 days apart are required for maximum performance. It is essential that correct dosage is used and thorough coverage of trees obtained. Dilute or concentrate spray must reach all parts of the tree, especially the underside of leaves. Do not mix Acaralate with spray oils due to possible plant injury. Virtually nontoxic to warm-blooded animals, it is also safe to bees and other beneficial insects.

Demeton is better known as Systox. It is formulated as a 6 lb/gal EC and a 2 lb/gal EC. The Systox 6 EC mixes with Cyprex. Systox 2 EC does not mix with Cyprex. It is a contact and systemic phosphate formulated as an emulsion concentrate. It is generally recognized for systemic control of sucking insects such as aphids, leafhoppers and mites, used no more than three times in a growing season. Its major use in Michigan has been on apples and pears, either prebloom or early postbloom, for clean-up of aphids, although Systox does have label clearance on apricots, peaches, plums, prunes, grapes, and strawberries for similar purposes. As a systemic, it quickly penetrates plant tissues and is then translocated throughout the plant. This distinctive feature makes it harmless to beneficial insects. ~~This chemical is highly toxic~~ to man and safety precautions must be given due attention.

Diazinon is a moderately toxic organophosphate to humans. It is active against a variety of fruit pests, offers residual activity of 11 to 14 days and has clearance for use on apples, pears, cherries, peaches, plums, ~~prunes~~, strawberries, grapes, and brambles. The principal uses of diazinon in Michigan involve a 50 percent wettable powder formulation for control of cherry fruit fly on sweet and tart cherries, summer insect complex on apples after first cover and insects troublesome to strawberries in midseason. Drenching crown treatments of emulsifiable concentrate will kill the overwintering stage of raspberry root borers when they are a problem. Diazinon is proving to be a selectively useful insecticide in integrated control programs, since it is relatively nontoxic to

Dimethoate is marketed as Cygon and De-Fend for a wide range of insects on bearing apples and pears. Formulated as a 2.65 lb/gal emulsion concentrate and 25 percent wettable powder, its systemic properties have specific value in aphid control, either prebloom or early postbloom. It is likewise quite effective for white apple leafhopper at twice the rate of application required for aphids. Compared to many insecticides, it is practically without compatibility problems. While toxic to bees, the product is one of the least poisonous of the organic phosphates to humans and wildlife.

Ethion has use on apples, in combination with oils, for preventive European red mite, aphid, and scale control. Application of oil and Ethion is made between green tip and the prepink period of apple bud development. Under Michigan conditions, oil plus Ethion has given better control of San Jose scale than oil alone. However, the addition of a phosphate insecticide does not improve the miticidal effectiveness of oil. Ethion should not be sprayed after bloom on apple varieties maturity before McIntosh, since severe leaf injury and subsequent fruit drop are likely to occur.

Galecron and Fundal are identical twins in active ingredient and are non-phosphate miticide/insecticide materials. Registration approves their application prebloom and postbloom on apple and pear trees. Both compounds are formulated as completely water-soluble powders (forming no visible crop residues) and 4 lb/gal emulsion concentrates.

As members of an entirely new and different class of acaracides—the formamidines—Galecron and Fundal give effective control of nonresistant and resistant mite strains. Both will destroy European red and two-spotted mites in all stages—eggs, nymphs and adults. They can be used to control eggs and nymphs any time up to bloom and postbloom whenever mites appear, with repeat applications as necessary. Summer cover sprays for mites on apples and pears will combat codling moth as well. Before and after-bloom spraying of pears can help manage pear psylla nymphs.

Unlike most present day miticides, Galecron and Fundal are relatively slow-killing chemicals. Periods of 48 to 96 hours or more are frequently required for effect, but there is compensation in long-term residual activity. In addition to compatibility with the majority of orchard spray products, Galecron and Fundal are practically harmless to man, animals, plants, bees and other useful insects.

Toxicity to birds, fish and wildlife in general is likewise favorably low.

Guthion effectively controls most insects that commonly infest both tree and small fruits. It has probably been the first line of defense in Michigan orchards since DDT and related chlorinated hydrocarbons began phasing out. Among the phosphates, it has proven itself as a broad-spectrum insecticide in every sense of the word. Available as a 50 percent wettable powder or 2lb/gal spray concentrate for dilution at equivalent rates, Guthion is registered for appl[illegible] on all major and most minor fruit crops with a residual action of 10 [illegible]. The spray concentrate is <u>not</u> cleared for apples and pears. There [illegible] phytotoxicity or residue problems when the compound is used properly and [illegible]rdance with label directions.

While Guthion is similar to parathion in toxicity to humans, it is not greatly injurious to natural parasites and predators of fruit pests. Make use of the safety measures reserved for many organophosphate insecticides.

Imidan is a phosphate chemical with a low toxicity to mammals comparable to Sevin. It is formulated as a 50 percent wettable powder for prebloom and postbloom application on apples, pears, peaches, cherries, plums, prunes, grapes, and apricots. It has given broad-spectrum control of many key fruit pests in Michigan.

Imidan has been outstanding in performance on the apple maggot. The material can be a boom in attacking maggot outbreaks close to harvest. It also suppresses European red mite and two-spotted mite when used in a seasonal program, without significant interference to species of predatory mites important to integrated pest control. Imidan represents a biodegradable pesticide which in a short time interval dissipates into nontoxic residues harmless to man, wildlife and other living forms.

Kelthane has been used as a specific miticide in Michigan against the active stages of red mite, two-spotted mite and rust mites during the past. Kelthane is formulated as a wettable powder or emulsifiable concentrate. For best results, apply Kelthane when the average temperature is predicted to be above 70°F for 5 to 7 days. Repeat applications 7 to 10 days apart are often necessary and advisable. It is relatively nontoxic to man and wildlife.

Malathion as a mild phosphate controls an unusual variety of fruit insects and is especially useful against several species of aphids. However, its residual effectiveness seldom exceeds 2 to 3 days. It can often be employed to best advantage in late season sprays. Its use is particularly indicated where a high degree of safety to man and animals is desirable. Obtainable as emulsifiable concentrate, wettable powder or dust, malathion is presently used in Michigan for certain insect pests attaching brambles, currants and blueberries. Unlike many chemicals, it is generally compatible with every insecticide in common usage.

Methoxychlor has long residual activity and, although a close relative to DDT, exhibits very low toxicity to humans and other warm-blooded animals. It will restrain such major fruit invaders as plum curculio, codling moth, apple maggot and cherry fruit fly, but is generally inferior to alternative chemicals for these purposes. Also sold under the trade name Marlate, its only suggested use is in dust form as an optional material on blueberry insects.

Omite is closely related to Aramite in chemical structure and gives good control of mites. It is effective against the mite strains resistant to phosphate and chlorinated hydrocarbon miticides, and is cleared for use on apples, peaches, pears, plums, and prunes. Complete coverage of upper and lower leaf surfaces and fruit is important for maximum results. It is not a prebloom miticide, since performance is best when temperatures are 70°F or higher. Mites hit by the spray stop feeding within 48 to 72 hours. Initial kill is slow, often 3 to 5 days, but is compensated for by long residual action. This material is not an ovicide, and is mainly effective against young and adult mite stages. It doesn't affect beneficial insects, is reportedly less harmful to predator mites and data indicate it to be relatively nontoxic to man and animals. For best performance in cleaning up summer mite populations, make two applications 7 to 10 days apart.

Parathion is an extremely toxic organophosphate to man and animals. Along with a complete understanding of the label, adequate safety precautions include rubber gloves, suitable protective clothing and an approved face mask. It has been widely used since 1949 for control of a wide variety of fruit pests. Some effectiveness from the 15 percent wettable powder and its liquid equivalent is apparent against mites and red-banded leaf roller. No injury from this material has been observed on peaches, plums, and cherries. Apples, and occasionally pears, have been injured when parathion was used in excess of suggested dosages. Parathion can often be used to good advantage in combination with other insecticides.

Perthane exhibits the lowest human toxicity of any presently available chlorinated hydrocarbon. It is unstable and without a reputation for persistence. Formulated as a 4 lb/gal emulsifiable concentrate, it appears in the pear spraying schedule specifically for early spring and summer control of pear psylla where Guthion, Sevin, Imidan and Parathion are no longer effective. Being nonactive on eggs and nymphs of psylla, it is most important that Perthane applications be so timed as to kill adults before they have opportunity for egg laying.

Phosalone, sold as Zolone, is a nonsystemic phosphate insecticide/miticide that acts as a contact and stomach poison. Presently registered for use on apples, pears, grapes, and the stone fruits, it controls aphids, codling moth, apple maggot, leaf rollers, plum curculio, pear psylla, leafhoppers, oriental fruit moth, and phosphate-susceptible European red and two-spotted mites. Marketed as an emulsifiable concentrate containing 3 lb of active ingredient per gallon, and a 25 percent wettable powder, it can be applied to within 14 days of harvest on the crops indicated.

Phosalone is compatible with most fruit fungicides and some insecticides, and offers residual properties averaging 7 to 14 days. While somewhat hazardous to fish, Phosalone is only moderately toxic to honeybees, comparable with diazinon in having an average mammalian toxicity and being much less harmful than DDT to wildlife. It does not persist and accumulate, but rapidly metabolizes to noncontaminants in soils.

Phosphamidon offers limited usefulness in the battle between man and insects for fruit crops. Its chief asset lies in its ability to control aphids and mites as both a contact and systemic poison. Therefore, as an 8 lb/gal emulsifiable concentrate it favorably joins Systox and Dimethoate as an optional choice on apples prebloom and early postbloom for disposal of aphid populations. Phosphamidon warrants the same precautions granted any cholinesterase-inhibiting chemical.

Plictran is formulated as a 50 percent wettable powder. It is a non-phosphate miticide with outstanding activity on destructive plant-feeding mites—both those susceptible and resistant to other miticides. It is registered for postbloom use on apples and pears to control the motile forms of European red, two-spotted and rust mites. First application is recommended as soon as mites are active, usually at or shortly after petal fall, with repeat treatments as needed or whenever mite infestations appear. Since Plictran kills the active stages of mites, coverage of foliage must be thorough and complete to include uniform wetting of upper and lower leaf surfaces. The product mixes readily in water to form a suspension that can be applied with any conventional spray equipment. It is usable alone or compatible in tank-mix combinations with those insecticides and fungicides generally employed in orchard spray schedule. No phytotoxicity or adverse effects on fruit finish have been reported. Plictran is a preferred miticide for integrated-control programs since it is not harmful to beneficial insects or predatory mites. Used as recommended, it presents no unusual health, contamination or environmental problems. It is nontoxic to honey bees, only somewhat hazardous to birds and fish, moderately toxic to animals and of low toxicity to man.

Sevin is formulated as a 50 WP and 80 S. It controls a wide range of insects. Carbaryl by common name, it finds its place somewhere in the spray program for every fruit crop grown in Michigan. Its residual effectiveness varies from 10 to 14 days, depending on the insects to be controlled. In most cases, it can be applied within a day or closer to harvest without fear of excessive residues. Sevin is not a miticide, may encourage aphid buildups and is inclined to be seriously toxic to bees. It is compatible with most pesticides and gives good control of certain pests resistant to other frequently used insecticides. Sevin offers a high degree of safety to animals and plants. There is the added advantage of its low toxicity to man and fish. Inasmuch as Sevin is a recognized fruit thinning agent, its use should be avoided until at least 30 days after full bloom on McIntosh, Jonathan, Northern Spy and Delicious apples varieties.

Thiodan, a distant relative to most conventional chlorinated hydrocarbons, has been the single effective insecticide available for peach tree borers. Thiodan is suggested for growers who have severe borer problems on peaches, plums, and cherries. It has further use on pears, in a comparable manner to Perthane, for control of pear psylla and especially where they are tolerant to other chemicals. Summer applications should be made 7 days apart and when the nymphs are still small for best results. Its excellent insecticidal effectiveness against aphids, white apple leafhopper, tarnished plant bug and rust mites is of additional benefit. Plant bug control for peaches and strawberries would be difficult, if not impossible, with Thiodan. A 50 percent wettable powder and 2 lb/gal emulsifiable concentrate are available for any of the described uses. Of moderate toxicity, Thiodan requires the same caution granted any chlorinated product similar to it.

Vendex is formulated as a 50 percent wettable powder, nonphosphate miticide with very good activity against a wide range of plant-feeding mites. It is registered for use on apples and pears to control European red, two-spotted and rust mites. Do not apply within 14 days of harvest. This product mixes readily with water to form a suspension that can be applied with any conventional spray equipment. It is usable alone or in tank-mix combinations with those insecticides and fungicides generally employed in orchard sprays. No phytotoxicity or adverse effects on fruit finish have been reported. Apply when mites appear. Vendex is a preferred miticide for integrated mite control and has the same good attributes as Plictran. It is of low toxicity to predaceous mites and can be utilized to adjust predator-prey ratios. Used as recommended it presents no unusual health, contamination or environmental problems. It is toxic to fish and should be kept out of ponds and streams. It is nontoxic to honey bees and of low toxicity to humans.

"Superior oil" has been recommended for several years as one of the preventive European red mite control programs. Currently only the 70-sec. viscosity superior oil is recommended for use in Michigan. Based on research information from Michigan it is felt the 70-sec. oil gives better European red mite control than some of the lighter viscosity oils recommended in the past.

The 70-sec. viscosity oil is not a dormant-type oil. It is lighter and more volatile than the original superior soil which was used as a dormant spray. The ~~principal~~ advantage of the lighter 70-sec. oil is the reduced possibility of plant injury. It is safer because it is more volatile, resulting in less persistence on the tree. It remains on the tree long enough to kill the mites but not so long as to interfere with vital plant processes or oil-incompatible pesticides which may be applied later.

Because of this safety factor, the 70-sec. oil can be applied between green-tip and prepink stages of tree development. European red mite eggs are most susceptible to control by oil when they are about to hatch. Under Michigan conditions, the period of egg hatch starts about the time the trees are in the prepink to pink stage. The closer the application is to prepink, the greater the kill of mite eggs. Oil applied earlier than green-tip is not as effective as later applications. The addition of a phosphate insecticide does not increase the miticidal value of oil.

Recent research indicates that spraying all four sides of the tree with the oil mixture provides better control of red mites than spraying only two sides. Two oil sprays, the first applied during green-tip to prepink stage, have given better red mite control than a single prebloom spray.

Because of the danger of phytotoxicity from using oils not meeting certain specifications, it is important to always check to determine if "superior" type spray oils meet the guidelines outlined in Michigan Fruit Pesticide Handbook (Extension Bulletin 154).

PRINCIPLES OF INSECTICIDE/MITICIDE USAGE

Pesticide Timing

The efficacy of an insecticide application depends to a great extent on proper timing. Generally, chemical controls are aimed at only one stage in the life history of an insect. This stage is either the most susceptible one or the one that the poses the greatest threat to the crop. A generalization holding for many fruit insects is as the immature stages become older and larger, they become more difficult to kill. The egg and pupal stages are usually more resistant to chemicals than the immature stages and susceptibility of the adult seems to vary between insects.

Traditional spraying schedules have been established for many of the most important tree fruit pests that coincide with developmental stages of the tree. These schedules have been established through the years by consistent association of the critical or susceptible stage of a pest with a particular growth stage of the tree. For example, red-banded leaf roller egg hatch occurs at or, very close to petal fall of apples. Sprays are timed at petal fall to attack the young larvae before they roll leaves and increase in size, making them tougher to kill. The Introduction to this manual illustrates and discusses the key developmental stages of various fruit tree crops. Anyone involved in the application of pesticides to these crops should know the different stages and be able to associate them with the presence of critical stages of insect and mite pests. Petal fall or shuck split are the final growth stages of a tree easily identified and for which timing of control sprays are recommended. Following these three growth stages, sprays have traditionally been applied on a 10 to 14 day schedule. This is probably the poorest means of timing insecticide or miticide controls for fruit pests. The best method is to establish a monitoring program designed to detect the presence and follow the development of pests so that control sprays may be precisely timed. Schedules that associate the development of a crop with common insect and mite pests are outlined in the Fruit Pesticide Handbook (Extension Bulletin 154).

Pesticide Selectivity

Proper timing of chemical controls is only a portion of the information required to meet with success. Proper selection of the chemical(s) is just as important.

Fifteen, even ten years ago, fruit growers were blessed with a wide variety of chemicals from which they could choose to control pests attacking their crops. Initially, many of these chemicals were broad spectrum and had long residual activity so that only one or two chemicals were needed to control insect pests. Gradually, the great efficacy of many of these chemicals was lost due to insecticide resistance and new chemicals or chemical combinations became necessary. With the advent of the EPA and new regulations and restrictions on the use of some chemicals, the possible choices provided the fruit grower of today are much more limited. Today, and even more so in the future, the chemicals fruit growers have to work with are more selective, generally more toxic to humans, and have shorter residual activity than chemicals used in the past. For these reasons, it is important that pesticide applicators become familiar with the capabilities of the insecticides and miticides available and design control programs to specifically attack the spectrum of pests which may be present at any point in time.

Sprayer Calibration

As important to the effective control of insect or mite pests as proper timing and the correct selection of chemicals is spray calibration. Improper calibration can result in inadequate control because too little material was applied or lead to a waste of chemical and a potential for excessive crop residue levels if too much material is applied. Because so many different types of sprayers are used on fruit crops, no standard method of calibration can be outlined here. Extension materials are available on methods of calibrating different sprayers and these should be referred to for further information. Spray recommendations are based on the amount of pesticide required to accomplish an indicated task per unit area. Regardless of the dilution of the chemical, the proper amount must be applied per unit area (usually acre) to achieve adequate control.

Sprayer calibration should be checked before each usage, especially if different chemicals are employed. Factors which effect the amount of spray applied are changes in the chemical used, variation in rate of travel, pressure changes, and worn or different nozzles.

Many tree fruit growers are now using concentrate sprayers. That is, spraying less water per acre than the standard or normal dilute recommendation. This technique permits increasing the acreage covered by a tank of spray, thus reducing the time and costs of spraying. Commonly growers concentrate sprays by 3 to 10 times which makes it practical for one person to treat between 40 and 175 acres. Insecticide and miticide rates per unit area have been cut successfully by growers when concentrate spraying. This is possible because the spray is not applied to the point of runoff, thus, even by cutting rate 10 or 15 percent, the same amount of chemical is deposited on the tree as with dilute sprays.

Low volume or ultra volume sprayers are currently becoming popular in Michigan. These sprayers are designed to apply between ½ and 10 gallons of spray material per acre. The principle behind these sprayers is to apply very uniform small spray droplets randomly throughout the tree. Rates of insecticides and miticides have been cut using these sprayers with great success. Calibration for these sprayers is easy but extremely critical.

There are four inseparable acts which must be performed correctly if a successful chemical control program is to be achieved: (1) identification of the pest(s), (2) proper timing of the chemical application, (3) selection of effective chemical(s), and (4) proper calibration of delivery equipment. Failure to properly carry out any one of these four tasks could lead to either inadequate control, or a waste of resources (time and money) and a potential residue problem on the crop.

Pesticide Compatibility

Frequently, it is desirable to combine chemicals designed for different purposes and apply them as a single spray application. Multiple combinations of fungicide, plus various combinations of fungicides, insecticides, miticides, growth regulators, liquid nutrients, etc., are often used to save time and labor. This shortcut may be profitable or disastrous, depending on the compatibility of the materials mixed.

When pesticides are used in combination without impairing the efficiency of the component chemicals or resulting in injury to the plants to which they are applied, the combination is "compatible." If the combination results in reduced efficiency, causes plant damage, or has undesirable physical properties, the mixture is "incompatible."

Incompatibility may be due to the alteration of either the chemical or the physical properties of one or more products in the spray mixture. Alteration is frequently the cause of poor performance of multiple pesticide combinations.

Chemical incompatibility is the breakdown or loss in effectiveness of one or all of the components. The mixture, therefore, may not be as effective in controlling unwanted pests or may cause injury to the plant (phytotoxicity). For example, many organic pesticides break down when used with alkaline materials (lime, lime-sulfur, and bordeaux mixture).

Physical incompatibility occurs when the mixture becomes unstable and results in the formation of a heavy precipitate or buttery mass, excess foaming, or poor distribution of the chemical. Often, this type of incompatibility causes settling-out of the chemicals in the spray tank and leads to clogging of sprayer nozzles and screens. Solubilization of captan and oil or sulfur and oil are examples of physical incompatibility.

Preharvest Intervals

Pesticide labels show the legal interval in days between the last spray and harvest. These intervals are established from residue studies required before a compound can be registered on a crop and are designed to prevent residues from exceeding the allowable limit at harvest. This interval should be kept in mind before recommending any material just prior to harvest.

Re-Entry Intervals

A general re-entry statement has been adopted primarily for cholinesterase-inhibiting pesticides by the EPA. The guidelines are: (1) "Do not treat areas where unprotected humans or domestic animals are present"; or (2) either, (a) "Do not allow entry into treated areas until sprays have dried or dusts have settled, unless full protective clothing is worn," or (b) "Do not allow entry into treated fields within 48 hours of treatment, unless full protective clothing is worn." There may be more restrictive wordage than this with some products.

Keep these in mind when recommending pesticides.

Insect Resistance

This topic is discussed here in an attempt to familiarize you with the problem and possible ways to avoid or, at best, delay it. Insects and mites are remarkably adaptable creatures and their ability to deal with all sorts of adverse conditions is evidenced by their long history on earth. Insect resistance to insecticides refers to the inability of once effective insecticides to control a pest. The general pattern of insect resistance can be outlined as follows:

1. The insect pest is easily controlled by low to moderate rates of the insecticide applied at infrequent intervals.
2. Intervals of application are increased as the insect seems to rebound rapidly from treatments.
3. Dosage levels are raised (sometimes two or three times) to acquire the same degree of control previously experienced.
4. The insect is not controlled at acceptable levels even by higher rates and increasing the number of applications.
5. A switch is made to a new class of insecticides which provides satisfactory control.

This sequence of events can occur within one year for insects or mites with many generations per year or may take several growing seasons.

Researchers have established that certain members of a pest insect population are tolerant of a given class of insecticides. These individuals can in some way detoxify or avoid contact with toxic doses of the pesticide. Generally, the percentage of these individuals making up the total population is quite low, less than one percent. When intense selective pressure is placed on the pest population by the application of insecticides, only a few individuals survive. There is an advantage to those individuals which can tolerate the insecticide and as pressure is maintained on the population, these individuals become more and more prevalent. As the tolerant strain of the pest population becomes the predominant component, the pest is increasingly difficult to control. A shift to another insecticide may result in adequate control if it belongs to another class. Generally, when an insect is resistant to one insecticide in a class, it will be resistant, in varying degrees, to other insecticides within the same class. For example, an insect resistant to one organophosphate insecticide will be resistant to another organophosphate as well. Some insects have even exhibited cross-resistance. This means that the mechanism conferring resistance to one class of insecticides also provides protection against another class. Thus, by creating a pest population resistant to one insecticide, we may lose the benefits of other pesticides in that class and possibly in others as well. Those involved in agriculture can ill-afford to pursue practices which encourage the loss of chemicals through the development of resistance.

How then to avoid the problem of insect and mite resistance? There are few, if any, insects which do not have the potential of developing resistance to insecticides. If this statement is indeed true, and it seems to be, then what we must strive for is a plan of attack on our pest complexes which prevents or at least delays resistance from developing. Following a few simple guidelines will help avoid the severe selection pressure on populations which promotes resistance.

1. Reduce populations below economically important levels but don't attempt to completely eliminate all individuals. This can be accomplished by alternate row, boarder spraying techniques or by reducing dosage rates.

2. Do not spray or remove all wild food sources of the pest. Leave the residual wild type susceptible strain to freely breed with the resistant types.

3. Avoid using one material over long periods of time. Switch from chemicals in different classes at frequent intervals to avoid selecting resistant strains of one chemical class.

4. Take advantage of natural enemies as much as possible. Natural enemies don't differentiate between susceptible and resistant strains.

By following these suggestions, resistance to insecticides and miticides can be at least delayed giving research much needed time to develop new classes of chemical control or perfect other regulatory mechanisms.

SELF-HELP QUESTIONS

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

1. What are the three basic stages of an insect's life?

2. What is the name for the immature stage of an insect that undergoes gradual metamorphosis?

3. Do the young of insects that undergo complete metamorphosis usually feed on the same part of the same host as the adult?

4. What factor of the physical environment seems to have the greatest effect on insect development?

5. What is the definition of the upper developmental threshold?

6. List all the stages that can act as the overwintering stage of an insect.

7. What is the first step in the identification of an insect?

8. Can knowing where a particular pest is most likely to occur aid in the field identification of an insect?

9. What are temporal considerations?

10. Why should pest populations be monitored?

11. How is the leaf sampling and brushing monitoring technique used?

12. Which insects is the bait-lure trap designed to monitor?

13. What are pheromones?

14. List three miticides that kill mites in the egg stage.

15. List seven insecticides or miticides with a relatively low toxicity to humans.

16. List six miticides that are relatively harmless to beneficial insects and predatory mites.

17. What is the best method for timing insecticide or miticide applications for fruit pests?

18. Are the present chemicals that fruit growers have to work with generally more selective than those used in the past?

19. Why can insecticide and miticide rates per unit area be cut when concentrate spraying?

20. Explain the difference between chemical and physical incompatibility.

21. Why must there be a certain interval between application of a pesticide and harvest?

22. For what class of pesticides was the re-entry statement primarily adopted?

23. What is cross-resistance?

WEED PESTS OF FRUIT CROPS

Why Control Weeds?

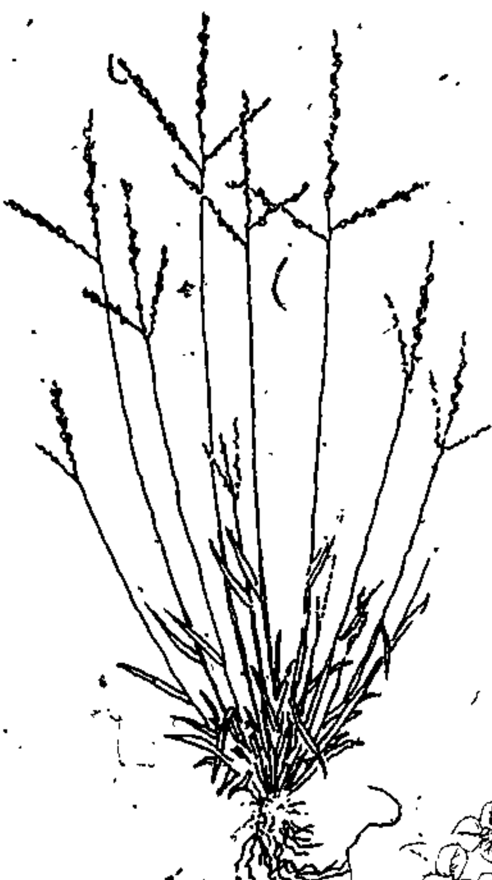
Professional horticulturists have long recognized the need for controlling weeds in their orchards and vineyards. Weeds compete directly with tree or bush fruits for soil moisture and nutrients and often serve as hosts for insects, nematodes, and diseases. Some weeds release toxic chemicals that reduce tree growth. Weeds may also provide cover for rodents which attack tree trunks during the winter months. Certain noxious weeds, such as poison ivy or Canada thistle, may pose a health hazard for orchard workers.

To produce a healthy tree with a strong trunk and scaffold branches, it is necessary to provide optimum growing conditions the first few seasons. Perennial weeds, such as quackgrass, nutsedge, or Canada thistle, can seriously reduce the growth of newly planted trees and should be controlled with repeated tillage or herbicides prior to planting a new orchard. Annual weeds may also inhibit the growth of young trees, particularly stone fruit trees, and should be controlled during times of the year that the trees are actively growing. Control of weeds in an area 2 to 3 feet from the trunk is adequate in the first two years. As the tree becomes bigger and the roots spread over larger areas, weeds should be controlled on an area about equal to the drip-line of trees. One should be satisfied to control 90 to 95 percent of the vegetation under trees. The extra chemical and effort required to get every last weed is not justified. In fact, there are indications that a few weeds left under apple trees can help make predator mites more effective in biological control of the European red mite.

Types of Weed Pests in Fruit Crops

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

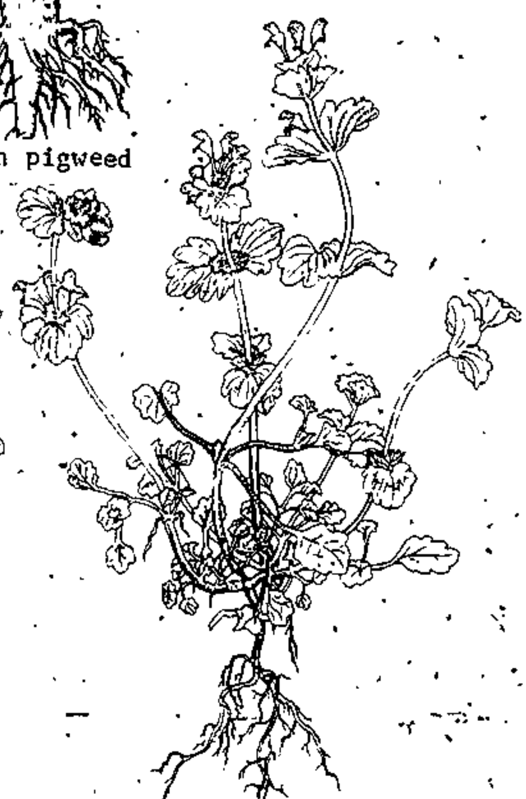
Annual weeds are plants which complete their life cycle from seed to seed in one year. If they germinate in the spring, grow, mature, and produce seed that summer they are called summer annuals. Examples are large crabgrass and redroot pigweed. Plants that germinate in late summer, overwinter, and produce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



Crabgrass

Rough pigweed

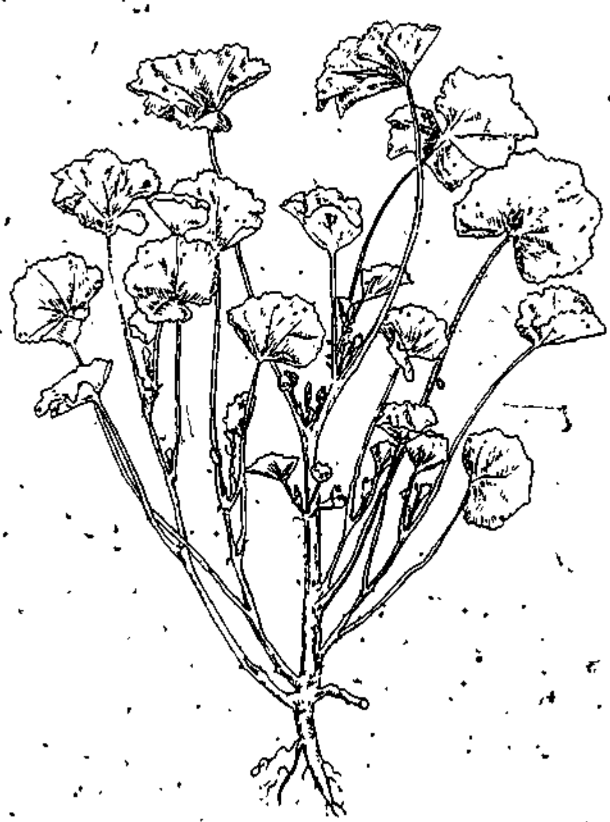
Common chickweed



Henbit

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

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



Roundleaved mallow

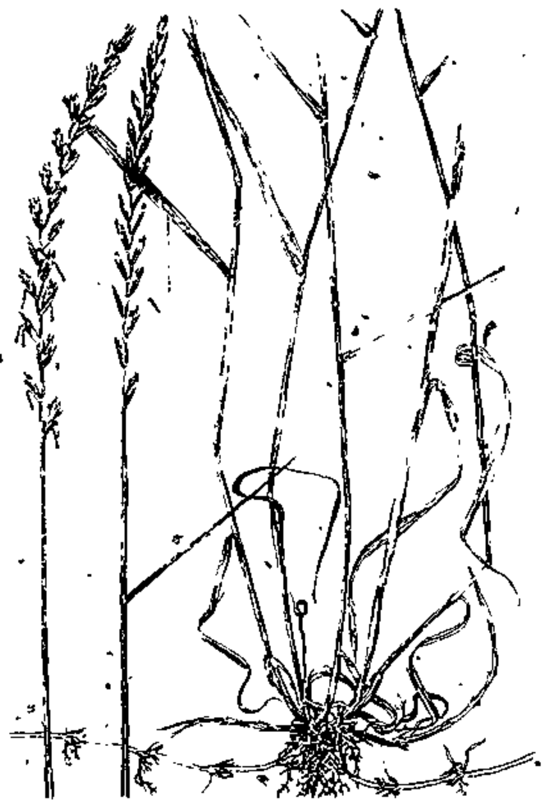
White cockle

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

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

Plantain

Dandelion



Quackgrass

Hedge bindweed

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

Poison ivy

FRUIT HERBICIDES

Herbicides for Tree and Bush Fruits

Several herbicides are utilized effectively by commercial fruit growers and they provide economic advantages over other cultural weed control methods. Fruit trees are not completely immune to herbicide injury, but will often tolerate dosages much higher than those required to kill weeds. Generally, trees gain herbicide tolerance with age. Newly planted trees may be susceptible to herbicide injury, gain some tolerance when 2 or 3 years old, and become very tolerant when older. Trees growing on sandy soils which are low in organic matter are more susceptible to soil-applied herbicides than trees growing on heavier, loam soils. Because a margin of tolerance is involved, herbicides must be applied as accurately as possible.

AMS (Ammate-X): Ammate is an herbicide which is effective on woody perennials such as poison ivy. It kills both on contact and translocation. It may be utilized safely in apple and pear orchards if care is taken not to allow the chemical to contact the foliage or newly formed bark. Ammate is extremely poisonous, may be corrosive to sprayers and should be handled carefully. It is usually used as a spot spray with a small hand sprayer.

2, 4-D (Weedone 638, Dacamine 4D): These nonvolatile forms of 2, 4-D may be utilized safely on the orchard floor if care is taken to avoid drift onto the foliage of trees. The primary use is to control perennial broad-leaved weeds such as dandelions and field bindweed. 2, 4-D is absorbed through the foliage of these weeds and translocated to the root system. The chemical should be applied at low pressure using 1 pound of active chemical per acre on perennials which are growing actively. At this rate of application, the chemical disappears from the soil in two to three weeks. Several spot applications are often needed to completely eradicate these deep-rooted perennials. 2, 4-D is only registered for use under apple and pear trees. Never use in sprayers that will later be used for foliar applications on fruit and vegetable crops.

Dalapon (Dowpon): Dalapon is utilized primarily for quackgrass control under apple and pear trees which are well established. Dalapon is absorbed both by the foliage and root system. It is usually combined with simazine (Princep) or diuron (Karmex) to obtain season-long control of the entire weed spectrum. Dalapon should not be used under stone fruits or grapes in Michigan because of toxicity that has occurred, particularly on sandy soils.

Dichlobenil (Casoron): This chemical is effective for controlling quackgrass in established tree fruits and bush fruits. It has broad clearance on all tree fruit, brambles, grapes, and blueberries. Research has shown the granular formulationis superior to the wettable powder for controlling quackgrass. Proper timing of application is critical for obtaining optimum results. The most consistent results have been obtained by applying the chemical in November prior to snowfall. Six pounds of chemical (150 lb. of 4 percent granules) per acre will normally provide good control of quackgrass and annual weeds until late summer of the following year. Some other perennial weeds such as field bindweed and Canada thistle are also suppressed by this chemical. Casoron has been the most effective chemical that is currently registed for quackgrass control in blueberries and brambles. It has also been used effectively on established nursery trees but may cause injury on extremely sandy soils low in organic matter.

The application of herbicide granules may be a new approach for most fruit growers. There are tractor mounted granular spreaders available which will apply Casoron accurately in bands along the rows. Application with hand spreaders has been less satisfactory. Granules should not be applied when it is windy.

Diuron (Karmex): Diuron is particularly effective on annual grasses and broad-leaved weeds. At higher rates of application, it may also suppress quackgrass. Diuron has been used in Michigan for several years to control annual weeds in apples, blueberries, brambles, grapes, and pear plantings. When applied at 2 to 3 lb/acre prior to the emergence of weeds, it will provide acceptable weed control for the growing season. There is no buildup of chemical in the soil from annual applications of this rate. Diuron is utilized successfully with paraquat to obtain season long control of most weeds.

Glyphosate (Roundup): This new herbicide is currently being developed for several uses in fruit plantings. At this writing it is labeled for use under nonbearing cherry and apple trees and has an Experimental Use Permit for grapes. Glyphosate is a translocated herbicide that is particularly effective for controlling perennial weeds. It has given excellent control of quackgrass, field bindweed, Canada thistle, horsenettle common milkweed, and numerous other perennials. In addition it knocks down emerged annuals. Although it readily moves through plants and kills the underground parts, it is rapidly inactivated upon contact with the soil. For this reason, a soil applied herbicide like simazine is still necessary to provide control of germinating annual weeds. To provide optimum kill on perennials, applications of glyphosate should be delayed until the weeds form a dense canopy of leaves. You should remember that the same characteristics that make glyphosate effective on perennial weeds also make it a threat to injure fruit trees or vines if it is improperly used. Precautions should be taken to avoid spray contact on leaves or new growth. Although contact on a few suckers through mid-June has caused no tree or vine damage, extensive sucker growth should not be treated. Applications on young nonbearing trees should be carefully directed toward the bottom 6 inches of trunk. Although newly planted peaches have been injured by trunk contact with glyphosate, the other tree fruits have adequate tolerance.

Paraquat (Paraquat CL): Paraquat provides rapid knockdown of annual and perennial weeds. It may be utilized under all trees and bush fruits. Paraquat has no action through the soil to prevent further weed growth and usually new weeds will be evident 30 to 40 days after application. Since this herbicide has no activity in the soil, it may be safely used on first year plantings. Bands 4 to 6 feet wide may be sprayed over sod prior to planting trees or the spray may be directed under the tree after planting. Care must be taken not to allow this chemical to touch the foliage or areas of the trunk where bark has not formed. If weed growth is heavy, apply at a rate of 1 pound of active ingredient per acre. On lighter infestations, 1/2 lb/acre is adequate. The addition of a wetting agent at 1 qt/100 gal of spray usually increases the effectiveness of the material. To eliminate weed competition for the entire growing season, two to three applications are necessary. Paraquat is extremely toxic, and the concentrate should be handled with utmost caution. Avoid contact with skin or eyes; and do not inhale mist of this chemical.

When trees have been established one growing season, paraquat may be used in combination with simazine or diuron in the spring to provide season-long weed control.

Simazine (Princep): Simazine is another very effective herbicide that has been utilized by Michigan fruit growers for several years. It is primarily effective on germinating annual weeds, but does provide some quackgrass suppression when applied in the fall as a granule or when applied in the spring in combination with paraquat. The use rate (2 to 4 lb/acre) varies with soil type. Injury may occur on stone fruit on extremely sandy soils when the rate of application exceeds 2 lb/acre. Simazine does not accumulate in the soil from annual applications of the above rates.

Simazine has been shown to directly stimulate the growth of apple and peach trees in some growing seasons. Where simazine is used for weed control, the rate of nitrogen application may often be reduced and adequate tree vigor still maintained. The chemical has clearance for all tree fruit, brambles, blueberries, and grapes. It has also been used successfully for weed control in established tree fruit nurseries. Do not apply to nursery stock planted on extremely sandy soil since injury may occur under these conditions.

Terbacil (Sinbar): This chemical is currently registered for use only on peaches and apples which have been established at least three years. It controls most annual weeds and quackgrass and will suppress the growth of some other perennial weeds.

Spring applications (April 15-May 1) of terbacil at 1 lb/acre have been sufficient to control annual weeds. Two to three pounds per acre are needed to control quackgrass, the lower rate being adequate on lighter soils. Terbacil may move quite readily in very sandy soils and tree injury manifested as veinal chlorosis of leaves has been observed from applying too much chemical on these soils. Do not apply terbacil on sandy or gravelly knobs or bulldozed areas where there is essentially no organic matter in the soil.

Herbicides for Strawberries

The herbicides now registered for strawberries are quite specific in the weed spectrum that they control. Rarely will one chemical handle all of the weed problems in a single planting. Research has revealed the following information about each chemical.

Chloroxuron (Norex, Tenoram): This herbicide is most effective when applied to broad-leaved weeds in the seedling stage. It will knock down common weed species such as common chickweed, lambsquarters, pigweed, purslane, and wild mustard and prevent germination of these weeds for 40 to 60 days. Use 4 lb/acre applied 7 to 10 days after transplanting or in fall or spring on established fields for good results on the above weeds. Chloroxuron has not provided adequate control of grasses in our tests. However, a combination of 4 lb/acre with diphenamid at 4 lb/acre or DCPA (Dacthal) at 6 lb/acre has allowed control of both broad-leaves and grasses when applied pre-emergence. Chloroxuron may not be used within 60 days of harvesting the crop.

DAPA (Dacthal): Dacthal provides good control of annual grasses such as crabgrass and foxtail when used at 8 lb/acre on sandy soils. It has been much less effective on heavier soils and has not consistently controlled broad-leaved weeds. Dacthal should be used for grass control in new and established plantings before emergence of the weeds. It is more effectively used in combination with chloroxuron to obtain control of broad-leaved weeds also.

Diphenamid (Enide): Diphenamid is also more effective on annual grasses than on broad-leaved weeds, but will provide acceptable control of several common broad-leaves if irrigation is utilized soon after application. Diphenamid has inhibited rooting of runner plants on light sandy soils. Consequently, we do not recommend its use on new plantings located on these soils. It may be used safely on established plantings at 4 lb/acre on light soils and 6 lb/acre on heavier soils. One application will control weeds for 6 to 10 weeks. When applied in the fall prior to mulching, it controls germinating grain. Do not apply within 60 days of harvest. Combinations of diphenamid with chloroxuron also look very promising.

<u>2, 4-D Amine (Formula 40)</u>: 2, 4-D has been effectively used in the renovation program for established strawberry plantings. When utilized immediately after harvesting, at 1 lb/acre, it provides good control of annual broad-leaved weeds. It also provides control of some fleshy-rooted perennials not controlled with other chemical treatments. Do not apply 2, 4-D at other times during the growth of the strawberry plant or injury and yield reduction may occur.

PRINCIPLES OF HERBICIDE USAGE

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

Foliage Applications

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

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

By translocation: This treatment kills the entire plant because the herbicide moves within the plant. For example, when applied to the leaves the herbicide is translocated to the roots. It may also move from older leaves to young growing points. Therefore, herbicides of this type are used on perennial plants as well as annuals. 2, 4-D is a translocated herbicide that is widely used to kill broad-leaved weeds such as dandelions in apple orchards.

Soil Application

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

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

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

The tolerance of fruit crops to most soil-applied herbicides is to some extent on keeping the herbicide placed on the upper 2 or 3 inches of soil. If there is excessive leaching of the herbicide into the root zone of trees or bushes, injury can result. For this reason, less herbicide should be used on coarse-textured sandy soils that are low in organic matter or clay content.

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

Preventing Herbicide Injury

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

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

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

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

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

For tree fruits, 80- or 110-degree angle nozzles are preferred because they allow the boom to run closer to the soil surface. Drive down the row in one direction; never go in a circle around the trees, since this concentrates the spray at the base of the tree.

Apply the spray as a complete row treatment or as squares under the orchard trees. It is usually best to spray a strip on one side of a row going in one direction and on the other side coming back. In vineyards, the entire band (under a row) may be sprayed with a 45-degree angle TOC nozzle on a gun or boom. The width of the band will be determined by the age of the plants and desires of the grower.

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

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

A good way to calibrate a sprayer is to:

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

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

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

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

When cleaning a sprayer, thoroughly rinse the whole sprayer with water before you add the cleaning agent. Keep the pump running so that the cleaning solution will circulate throughout the sprayer. Do not leave corrosive cleaning agents in the tank or spray system more than 2 hours.

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

SELF-HELP QUESTIONS

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

1. Why is control of 90-95 percent of the vegetation under trees considered to be best?

2. Explain the difference between summer and winter annuals.

3. List at least two examples of biennial weeds.

4. Explain the difference between simple and creeping periennials.

5. On what type of soil are trees most likely to be susceptible to soil applied herbicides?

6. List at least three systemic herbicides.

7. List at least two herbicides that provide good control of annual grasses.

8. List at lease three herbicides that give effective control of perennial broadleaved weeds.

9. List two herbicides that provide good control of annual grasses in strawberry fields.

10. How do translocated herbicides kill the entire plant?

11. Can contact herbicides indirectly cause the death of noncontacted parts?

12. Do most soil applied herbicides require surface moisture after application in order to be effective?

13. Can the selectivity of a herbicide be affected by environmental conditions?

14. What type of nozzles should be used for herbicide application?

15. Outline a good way to calibrate a sprayer.

16. What is the maximum amount of time that corrosive cleaning agents should be left in the tank or spray system?

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