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PESTICIDE APPLICATOR CERTIFICATION TRAINING

Category 3 Manual
Ornamental and
Turf Pest Control



EXTENSION DIVISION

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ORNAMENTAL & TURF PEST CONTROL

A Training Program for the Certification
of Pesticide Applicators

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INTRODUCTION

This training is intended to provide information that you may need to comply with EPA's Standards for Certification. It will help you prepare for the Certification examination prepared and administered by the Virginia Department of Agriculture and Consumer Services.

The emphasis of these standards and this training is on the principles of applying pesticides safely for man and the environment. It is not intended to provide you with all the knowledge needed. Additional information in the form of publications, short courses, field days, and professional meetings can be obtained from the local Co-operative Extension Service Office in your area.

BASICS OF PESTICIDES

It is not difficult to apply pesticides safely or to identify pests. There are scores of pests and pesticides, but, in reality, you must be concerned with only a few. You should learn these well, and then seek the experts' advice concerning the unusual. It is not essential that you understand or pronounce the scientific name of the pest or the chemical name of the pesticide. But it is important that you properly identify the pest, know which pesticide to use (or if one is needed at all), and completely understand all precautions concerning the pesticide.

Toxicity of Pesticides

All pesticides are poisonous -- at least to a certain degree. You have previously discussed the LD₅₀ value and its use in estimating the toxic effect of a pesticide. Another value of importance is phytotoxicity, or pesticide damage to plants. Phytotoxicity results in abnormal growth, leaf drop, and discolored, curled, and spotted leaves. If phytotoxicity is severe, the plant may die. Phytotoxicity often looks very similar to insect damage, plant disease, and response to poor growing conditions such as insufficient moisture, improper fertilization, etc.

Ornamental plants vary in nature from herbaceous to distinctly woody species. Generally, herbaceous plants are more susceptible to pesticide damage than woody ones; but even the woody plants are more susceptible when growth is young and tender. Greenhouses present a special problem because phytotoxic vapors tend to be trapped in the closed environment. Plant damage is more likely to occur with herbicides than with insecticides. Fungicides tend to be less hazardous to plants than herbicides or insecticides. The pesticide label is the best guide to safe use

of a pesticide on a specific ornamental plant or on an ornamental variety.

When To Use Pesticides

A pesticide should only be used to prevent or control a particular pest problem. To apply a pesticide just in case a pest might appear is certainly an extravagant waste in many situations. Pesticides are commonly combined for application and often at least one or two of these combination pesticides are of no value. Certain requirements must be met if pesticides are to be effective.

It is very important to use the right pesticide. Many pesticides are very specific and, therefore, you must know exactly what you need to control. Just because a material is labeled "broad spectrum" does not mean that it will kill or that it is good against all pest problems. For example, some weeds can easily be killed with 2,4-D. Many hard-to-kill weeds require herbicides such as dicamba. However, dicamba will not do a good job against weeds such as dandelions. Often, you can mix these two materials and kill a broad spectrum of the weed population. When buying these combination materials, make sure you read the label. Precautions for different pesticides within this combination may render the material ineffective or cause serious environmental or phytotoxicity problems.

Formulations

When applying a pesticide, make sure to apply the right formulation. A pesticide can only rarely be used as originally manufactured. The pesticide must be diluted with water, oil, air, or chemically inactive solids so that it can be handled by application machinery and spread evenly in the proper concentration over the area to be treated. Usually, the basic chemical cannot be added directly to water or mixed in the field with solids. The manufacturer must further modify a pesticide by com-

binning it with other materials such as solvents, wetting agents, stickers, powders, or granulars. The final product is called a pesticide formulation and is ready for use either as-packed or after being diluted with water or other carrier. Many common pesticides come in several formulations. It is important to know which formulation will be most effective in your situation. Always read the label.

Dusts - usually contain a pesticide mixed with finely ground talc, clay, or other such material. These materials must be uniform in particle size, and not become lumpy under storage conditions. Dusts should never be mixed with water. They should be applied only with special equipment designed for their use. Because of their fineness, dusts tend to be wasteful and are sometimes more hazardous than other pesticide formulations.

Granules - are dry, low-concentrate mixtures of pesticides and inert carriers. They are ready to use as purchased with no further mixing necessary. Because the particles are large and relatively heavy and more or less the same size, granules drift less than most other formulations. Also, there is little toxic dust to drift up to the operator's face and be inhaled by him. They can be applied with simple equipment such as seeders or fertilizer spreaders. However, granules are not always suitable for treating foliage because they will not stick to the leaves. Because of this problem, more of the active ingredient may be required per acre to do an acceptable job.

Wettable Powders - are similar to dusts in appearance but, unlike dusts, they contain wetting agents and are more concentrated. They can be mixed with water to form a suspension; however, agitation is required in the spray tank to keep the wettable powders from settling out. Wettable powders are generally abrasive to pumps and nozzles, but are less likely to damage sensitive plants than some other formulations.

Fumigants - are pesticides which produce toxic vapors. They are usually purchased as a liquid, but when released change into a gas. They are commonly injected into the soil or released under tarps when used.

Adjuvants - are a group of materials sometimes called additives, activators, synergists, spreaders, wetting agents, stickers, safeners, detergents, or soaps. An adjuvant is a material added to a pesticide to improve its effectiveness and/or safety. It does much more than just make the water wet better. Adjuvants can do the following: 1) Improve wetting--make the water more efficient. Water normally forms little balls or globules on waxy surfaces. Adjuvants cause water to spread and stick better on such surfaces, which is very important with the new low-volume sprays. 2) Reduce evaporation--this is important with mist blowers that make very fine droplets, or in aerial applications which may only use one gallon of spray solution per acre. Drift and uneven applications are reduced. 3) Aid penetration and translocation--this is very important with systemics. The pesticides must move into and within the plant. 4) Adjust pH--some materials are alkaline-sensitive (organic phosphates and carbamates) causing degradation. For example, malathion loses one-half of its concentration at pH 8 in one hour; at pH 7, in six and a half hours; at pH 6, in eight to nine hours. 5) Improve uniformity of spread--for instance, a contact fungicide will not control fungus if the deposit is not adequate. 6) Improve compatibility of mixtures when we want to apply more than one chemical. 7) Increase safety--this can be as important or more important than effectiveness. We do not want to injure desirable plants. There is no point in applying a pesticide to a plant if it does more damage than the pests it is intended to control.

Flowables - a finely ground, wetttable powder formulation which is sold as a thick suspension in a liquid. This makes its addition to water in the spray tank easier.

Solutions - usually contain only the pesticide and a solvent. The solvent is usually a petroleum product. One must be very careful to apply these pesticides only as directed by the label. The solvent or carrier of these preparations may damage or kill living plants.

Emulsifiable Concentrates - a liquid formulation of a pesticide which can be mixed with water to form an emulsion. An emulsion is one liquid dispersed throughout another liquid. Many pesticide active ingredients are not soluble in water but are soluble in oils. In emulsifiable concentrates, the active ingredient is often dissolved in an oil and an emulsifying agent is added so that the oily solution can be conveniently mixed with water to form a milky emulsion. They are non-abrasive, relatively harmless to equipment, and little agitation is required with emulsifiable concentrates. Some plants, however, are sensitive to the solvents or emulsifiers used in these formulations.

Compatibility

Pesticide compatibility refers to mixtures of pesticides that can be applied to a target pest without causing harmful side effects as a result of the mixture. Research concerning pesticide compatibility has not been extensive; there are infinite combinations of pesticides to study for compatibility and this becomes very expensive and sometimes unnecessary. Two or more pesticides can be used together in one application, but we must be concerned about compatibility. Pesticides that are not compatible may be as damaging to the environment as any other one thing.

Many times it is very convenient and more economical to apply two or more pesticides at the same time. Pesticides are

compatible: 1) if they mix and do not precipitate; 2) if results are the same as if they were individually applied; and 3) if they do not combine chemically.

Compatibility charts are being prepared and are available from Meister Publishing Co., Willoughby, Ohio. Also, other information can often be obtained directly from the pesticide manufacturer. Before mixing any pesticides, however, determine if you will get the best benefit from both pesticides. It's too expensive and time consuming, and possibly detrimental, to take unnecessary chances.

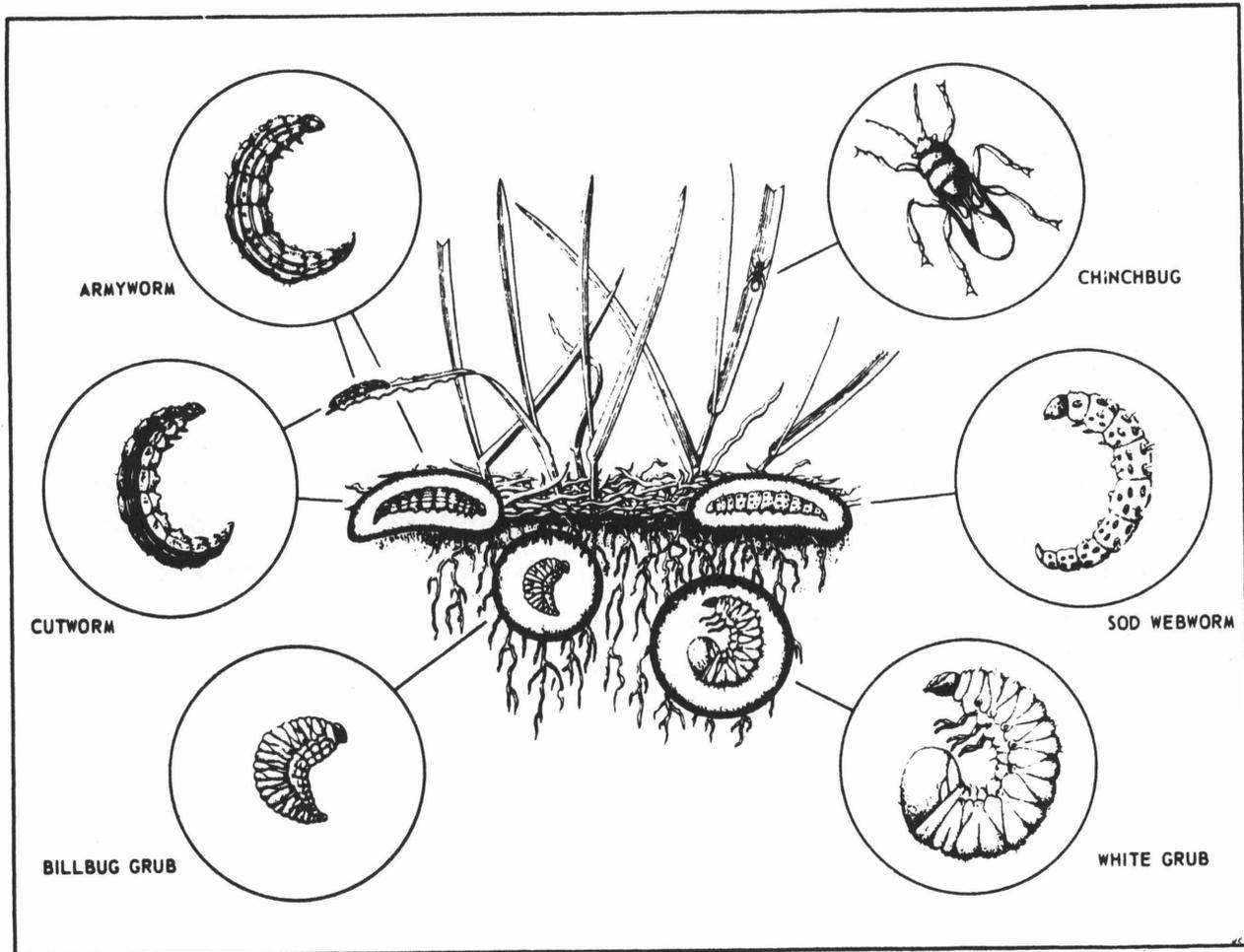
If pesticides are incompatible, then you have lost time and wasted the chemicals, and have either gotten no results, injured plants or animals, or maybe, have gotten less effective results. Read the label. The label may indicate incompatibility. Some pesticides are registered for pre-mixes or tank mixes.

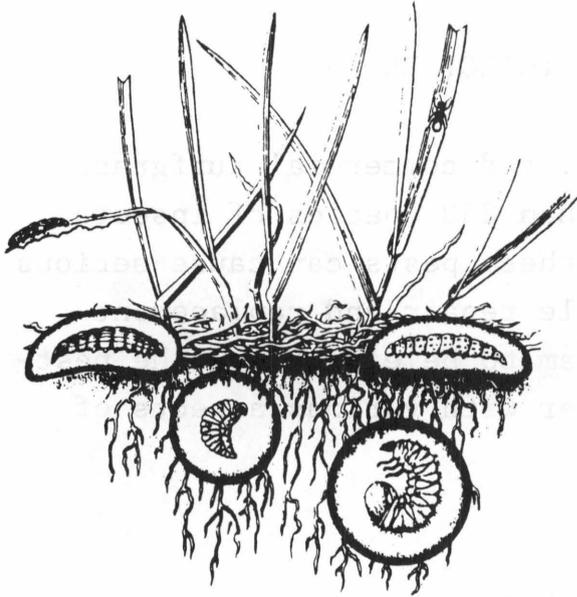
In order to check some aspects of compatibility, you can prepare the pesticides you intend to mix by diluting them to double the strength of your intended dilution, then mixing them. You should watch the mixture for at least one hour to determine if they have combined chemically or if they have precipitated. If at all possible, this combination should then be sprayed on a sampling of the intended host plant to determine if the effects are compatible or if any phytotoxicity develops.

LAWN AND TURFGRASS INSECT PESTS

Ornamentals, plants, lawns, and commercial turfgrass are subject to injury by more than 250 species of insects and mites. If not controlled, these pests can cause serious damage and result in considerable repair and replacement expense. For any control program to be effective, the pesticide applicator must be familiar with various aspects of the pests, including:

- host preference
- seasonal abundance
- life cycle and feeding habits
- susceptibility to insecticides





Lawns and commercial turfgrass are subject to injury by a number of insects and mites. These pests can cause serious damage and result in considerable repair and replacement expenses. However, through the proper use of pesticides in a pest-management program, the economic damage caused by these pests can be reduced. For any pest-management program to be effective, the homeowner or commercial turf grower

must be knowledgeable in the biology and seasonal development cycle of the various pests.

This publication is intended to provide general biological and life cycle information on common lawn and turfgrass pests. Chemical control recommendations are not included here. The pesticides currently being recommended for controlling these pests are subject to sudden and constant changes. For current recommendations, consult the Virginia Tech Pest Management Guide 1.

Lawn and Turfgrass Insect Pests

It is helpful to divide lawn and turfgrass pests into two categories: above-ground pests, and below-ground pests. The division is made on the basis of where the adult or immature stages live. The insects (and mites) in these two groups have different feeding habits and life cycles, and usually require different control measures.

Chinch bugs
Sod webworms
Armyworms and Cutworms
Frit fly
Mites

Above-ground pests



White grub larvae
Poa beetle
Weevil or billbug groups
Ants, bees, and wasps

Below-ground pests

Above-ground pests. The above-ground pests feed on the blades of grass. Some, like sod webworm larvae, and armyworms cut off and eat the blades of grass. (The adult moths do no damage.) Others, chinch bugs, for example, suck the juice from the grass plants which often results in the plants turning yellow.

Some indicators of an infestation of above-ground insect pests.

1. Large number of birds feeding on the turf. They create holes in the grass as they search for insects.
2. Small moths are observed, especially in the evening, flying above the turfgrass.
3. Grass blades or complete plants chewed off just above the soil level.
4. Small and large brown patches appear in the grass.

Below-ground pests. Below-ground insect pests feed on the roots of turfgrass. In most cases, they are the immature stages of insects, and have chewing mouthparts.

Some indicators of an infestation by below-ground insects.

1. Grass roots chewed off just below the soil surface.
2. Individual plants can be easily pulled from the soil.
3. Turf can be rolled back like a carpet.

Pest Management Program for Lawn and Turfgrass Pests

The most effective way to control the insect and mite pests of turf is to use information on their life cycles, their feeding habits, a calendar, and the proper pesticides.

Life cycles and feeding habits. An understanding of the general life cycles of turf pests will help you know what, where, and when to expect them. You'll have a chance to plan your time and know what pesticides you'll need. Knowing the feeding habits and kind of mouthparts (chewing, sucking) will insure that you use the best insecticide formulation.

Calendar. A calendar is probably the most important tool for pest management. Set aside and use a "Pest Calendar" to manage turf pests. Record the first appearance of pest species, day of peak abundance, spray used, when applied, etc. Keep the calendars from year to year and you'll know what to expect.

Pesticides. Learn to use the proper pesticide, the best formulation, at the right time. Life cycle information and your calendar will help you make these decisions.

SOD WEBWORMS

Identification. Sod webworms are the larval or caterpillar stage of several species of moths, often called lawn moths. The caterpillar is brown or dusky-green colored, with a dark-brown head and several brown spots on each segment of the body. They are about 1/4" to 3/4" long.

The adult moth is small, grayish white, and about 3/4" long. The adults are attracted to lights at night. When at rest, the moth wraps its wings close to its body, giving it a tubular appearance.



Life Cycle. Sod webworms overwinter in the caterpillar and pupa stage. When the soil warms in the spring (above 50°F) the caterpillars become active and resume feeding on the grass. After a week or two of feeding, the caterpillar becomes full grown and forms a pupa. After about 10 days, the adult emerges from the pupa, has a short flight period, then mates. Adult females fly over the turfgrass in a jerky, zig-zag pattern, dropping eggs into the turf at random. The larvae hide during the day in silken tunnels built in the thatch. They come out at night to feed on the blades of grass. After feeding for several weeks, the caterpillar molt to a pupa. There are at least 2 generations of sod webworms in Virginia.

Damage Symptoms. Sod webworms damage turf by eating the grass blades, very often severing the entire plant at the crown. This damage appears as irregular areas of dead grass. An active webworm infestation may be noticed by the tunnels the caterpillars make in the turf. Birds often feed on the caterpillar in the grass and leave many holes in the grass and thatch.

Control. A pest-management program for sod webworms involves the use of a calendar, a pencil, and an insecticide. Begin looking for adult moths in late spring. They are attracted to outdoor lights at night (but so are a lot of moths - learn to identify sod webworm adults). Note on your calendar when you first begin seeing adults, and when the peak activity was noticed. There will be one or two nights when the moths will be very numerous. Count about 10 days after this peak -- then begin spraying. Ten days will allow for the adults to mate, lay eggs, for the eggs to hatch, and for the caterpillars to begin feeding. Apply an insecticide that will stick to the blades of grass (an EC formulation). Following this program will help you put the proper pesticide in the right place at the best time to get the maximum results. Repeat for second generation.

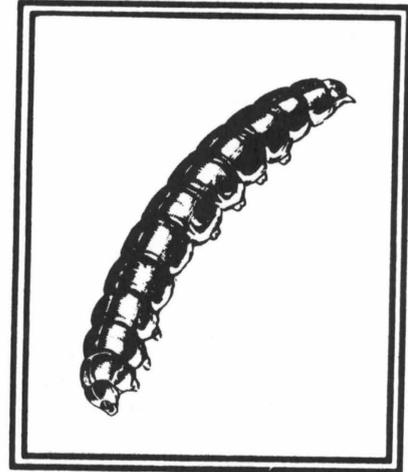
Notes:

CUTWORMS

Identification. Cutworms are the larval or caterpillar stage of several species of night - flying moths. The caterpillars are about 2" long (full grown), and have brown stripes along the length of the body. They are greenish-gray, brown, or black.

Life Cycle. Cutworms can have 1-4 generations per year, depending on location and species. In late spring the adult moths lay eggs on stems and grass blades. The eggs hatch into larvae which feed on the grass blades, usually at night, until fully grown. During the day they hide in the debris or thatch at the soil surface. At maturity, the larvae pupate in the soil. They overwinter as pupae.

Damage Symptoms. Damage can occur from spring through early summer and into fall. Cutworm larvae feed at night, chewing off and eating blades of grass close to the ground. Large numbers of cutworms are capable of causing extensive damage.



Control. To a certain extent, cutworms are controlled naturally by fungus-caused diseases and other insects. Chemical control should be applied whenever cutworms become numerous in the turf or adults appear in large numbers around lights at night.

Notes:

ARMYWORMS

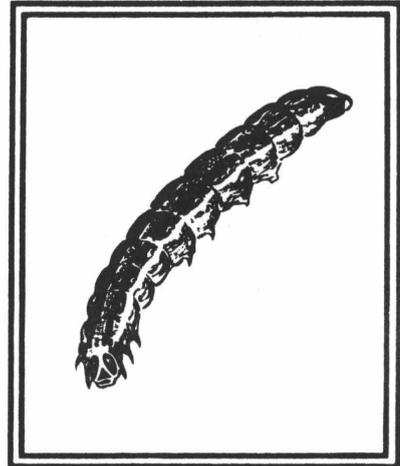
Identification. The adult armyworm is a large brown moth with a white dot in the center of each front wing. The larva of the armyworm is about 2" long (full grown). A yellowish-white midstripe runs the length of its back and ends in an inverted "V" on its head.

Life Cycle. The life cycle is similar to that of the cutworm. The overwintering larvae feed on the grass blades in early spring. They pupate in the soil below the thatch. Successive generations will continue to feed all summer long. Armyworms will feed during the day and night.

Damage Symptoms. Armyworms damage turfgrass by skeletonizing blades and severing entire plants at the crown. They may be numerous in one area and cause considerable damage.

Control. Armyworms breed continuously during the spring, summer, and fall. Therefore, control measures should be applied whenever the larvae becomes numerous. Constant surveying for larvae and/or damage is necessary.

Notes:



CHINCH BUG

Identification. Adult chinch bugs are small, black-bodied insects with white, folded wings. Another distinct characteristic of adult chinch bugs is the small black triangle on each side of their backs. The wingless nymphs are shaped like the adults. Young nymphs are red with white bands on their abdomens. Later, they change to orange and then black as they mature.



Life Cycle. In the spring, the overwintering adults move to rapidly growing grass plants. The adults feed and begin mating. Female chinch bugs deposit 15 to 20 eggs per day for about 30 days. It takes 35 - 90 days for the nymphs to pass through five stages and mature into adults. There are two generations per year in Virginia.

Damage Symptoms. Chinch bug damage often appears first as patches of dead or gradually yellowing turfgrass in areas where heat is radiated from sidewalks or driveways. These yellow areas may spread to other areas in the turf.

The chinch bug inserts its slender beak into the grass plant, injects a toxin and extracts plant juices.

Control. Chinch bugs are not usually a pest of turf in Virginia, but they do occur. Areas of gradually yellowing turf should be carefully inspected for the presence of chinch bugs. Treatment should be applied on an "as needed" basis.

Notes:

FRIT FLY

Identification. The adult frit fly is a small fly, about 1/8" long, with a shiny black body and yellowish markings on its legs.

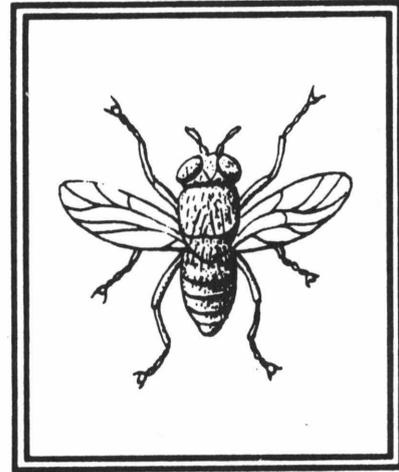
Although the adult frit fly does not damage turfgrass, its presence can indicate existing problems from frit fly larvae.

Frit fly larvae are small, yellowish maggots that feed in the stem of the grass plant. The plant turns yellow and dies when infested with a frit fly larva.

Life Cycle. The female frit fly lays her eggs in the axis of the leaf blades and inside the leaf sheath. The eggs hatch in a few days and the larvae penetrate the grass plant. The larval stage lasts about 10 days. The maggot usually drops out of the plant and forms a pupa in the thatch or soil. There are 2-3 generations per year. The overwintering stage is the pupa.

Damage Symptoms. Frit fly maggots damage turfgrass by boring into the stem and feeding in the plant. Heavily infested areas turn yellow then die.

Frit fly damage is heaviest when both day and night temperatures remain high, particularly if there is moisture stress to the grass.



Control. In places where frit flies are numerous, several adults will alight on a clean golf ball if it is rolled in the area. Control should be started immediately and repeated on a need basis.

Notes:

BILLBUG

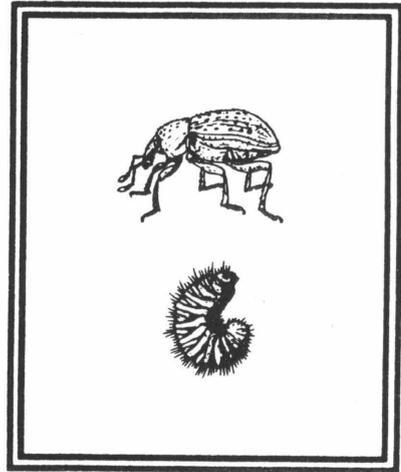
Identification. Adult billbugs are gray colored beetles, 1/2" to 3/4" in length. The adult has a long snout or bill. The billbug grub is legless, about 3/4" long, and white or cream colored.

Life Cycle. In May and June the adult females lay eggs in the stems of grass plants. The larvae burrow down through the stem into the soil. During the summer months the larvae feed on grass roots and stems. They form a pupa in the fall, adults emerge in September and October. The adults spend the winter in the thatch layer of the grass.

Damage Symptoms. Bluegrasses are quite susceptible to billbug injury. The damage is done by chewing near the crown and devouring roots slightly below ground level. Initial phases of injury appear as yellowing and browning of the turf in both circular and irregular patches. There may be some green grass present in the infested area.

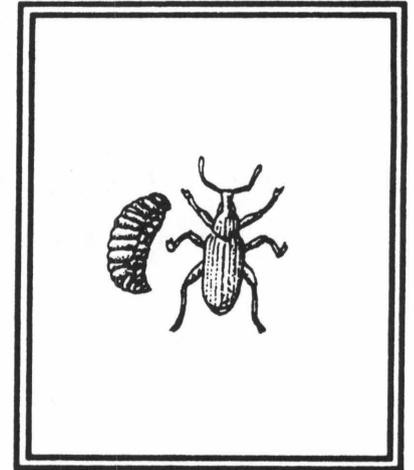
Control. The chemical control measures used for white grubs should help in controlling billbug grubs. Apply during the summer whenever damage appears.

Notes:



HYPERODES WEEVIL

Identification. The Hyperodes weevil is a relatively new turf-insect pest that has been found mainly in the northeastern U.S. Both adults and larvae damage turf. Adults are about 3/16" long and mottled brownish-black to black. The larvae are about 3/16" long, legless, and cream colored.



Life Cycle. The adult weevil lays two small eggs on the leaf blades of Poa annua grass plants. When the eggs hatch, usually only one of the larvae survives. It then burrows down through the stem and feeds just below the root collar. They will move from one plant to another. When the larvae are full grown, they burrow into the soil to pupate. Adults emerge in several weeks. They are first seen in March but are more abundant in the fall.

Damage Symptoms. The weevil seems to prefer Poa annua to other turfgrasses. The damage is caused by complete or partial severing of grass stems, often in areas about the size of a dime. This results in small bare spots.

Control. Chemical control should be considered in the spring to prevent egg-laying by the adults.

Notes:

POA BEETLE

Identification. The adults and larvae of this beetle are very small (about 1/8" long). The adults are oblong-shaped beetles, shining black, with reddish legs. The larvae are small, "C" shaped, and cream colored.

This beetle is a serious pest of golf course turf in Virginia. Larvae feed on roots of annual bluegrass, bluegrass, and bentgrass.

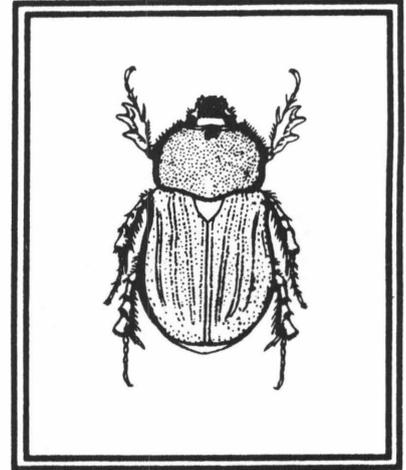
Life Cycle. The overwintering adults become active in the spring, laying eggs in the soil below the grass. The resulting larvae feed on grass roots. The larvae pupate in the soil. There are at least two generations a year. The adults from the second generation overwinter.

The adults may be seen in large numbers near lights at night.

Damage. The damage resulting from the larval feeding on the grass roots appears as small to mid-sized brown patches in the turf. Damage is more common in the spring.

Control. Chemical control should be applied in the spring, soon after the adult beetles are noticed. Control can be continued through the summer as needed.

Notes:



WHITE GRUBS

Identification. The turf-damaging insect known as the white grub may be the larval stage of several different beetles. Among others included in this group are the Japanese beetle, the May or June beetle, the green June beetle, and the European chafer.

White grubs are "C"-shaped larvae that are white to cream colored. They range from 1" - 1 1/2" long.



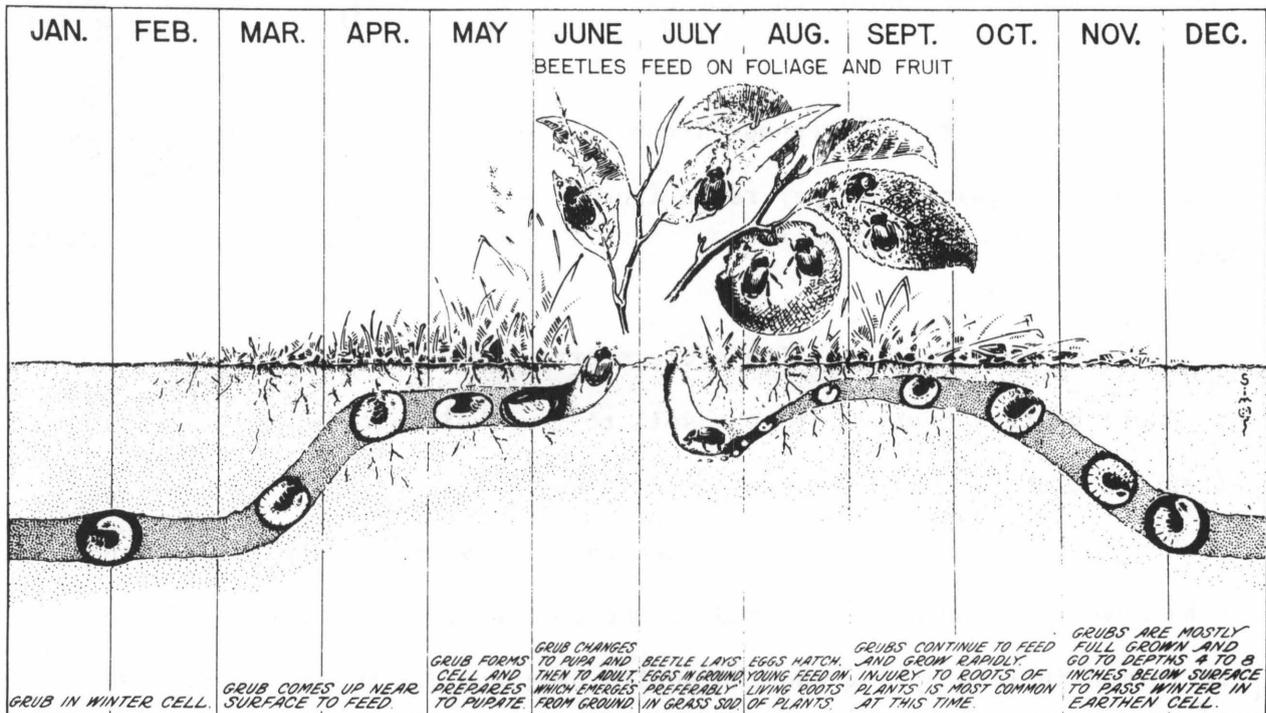
Life Cycle. The grub life cycle starts when the adult beetles burrow into the soil to lay their eggs (late summer). After the grubs hatch, they begin feeding on grass roots. They move deep in the soil to spend the winter. When the soil warms in the spring, the grubs move into the root zone and resume feeding on grass roots. Pupae are formed in late spring and the adults emerge a few weeks later. (See 1976 Packet.)

Damage Symptoms. The damage symptoms of an infestation of white grubs are:

- 1.) Irregularly-shaped patches of dead grass.
- 2.) Turf can be rolled back like a carpet.
- 3.) Birds, moles, and other small animals digging in the turf.

Control. Chemical control of white grubs should be centered on the time the grubs are feeding close to the soil surface - in the summer. Non-chemical control (milky disease) can be applied from spring till fall.

Notes:



BASICS OF COMMONLY USED INSECTICIDES

It is important that commercial pesticide applicators have an understanding of the commonly used insecticides. Specifically, they should be aware of the types of insecticides and their modes of action.

Types of Insecticides

Insecticides are classified into groups according to their chemical structure or their mode of action. It is particularly convenient to use chemical structures for this purpose. Following this plan, there are at least ten different groups which could be discussed. For practical purposes, however, a discussion of six or seven of these groups is adequate. The remaining groups contain either older or little-used compounds.

Group I - The Methoxychlor, DDT Insecticides

These are sometimes referred to as the Group I chlorinated hydrocarbon insecticides. They are important in that DDT was the pioneer synthetic organic insecticide developed during the period from 1940 to 1945. Chemically, chlorinated hydrocarbons are very stable. This is the main reason why they are a pollutant of the environment. They persist; they have a low vapor pressure and long residual activity. We refer to them as broad-spectrum insecticides because they have a lethal effect on many types of insects. They are relatively safe for mammals from the standpoint of acute toxicity. They are not soluble in water. Basically, they act as a nerve poison, causing tremors, bursts of activity in the sensory nerves, prostration, and eventually death. Their mode of action is not completely understood, but

they are believed to act by preventing the nerve membrane from reestablishing its normal resting stage.

Group 2 - The Cyclodiene Insecticides

In this group are the cyclodiene insecticides and lindane. They are often referred to collectively as the Group 2 chlorinated hydrocarbon insecticides. This is a fairly large group of materials with many of the compounds having similar structures. The chemical and physical properties of the cyclodienes are quite similar to those of DDT. They are very stable compounds and persist in the environment. They have a low vapor pressure with long residual activity, are broad-spectrum insecticides, and have variable toxicity to mammals. Some of them are quite toxic. Like DDT, they are not soluble in water. The cyclodienes are also active against the insect nervous system. They depress the activity of the affected insects and subsequently cause an extreme increase in respiratory rate. There are tremors and agitation associated with their action. Finally, paralysis and death result. The mode of action of this group of insecticides is perhaps the least well understood of any of the currently used compounds. About all that can be said at the present time is that they affect the central nervous system. Prominent materials in this group are isodrin, endrin, aldrin, heptachlor, toxaphene, and chlordane.

Group 3 - The Organic Phosphate Insecticides

In this group are the insecticides containing organic phosphorous. It is a very large group of poisons. A conservative estimate is that at least 100 organic phosphates (o.p.'s) have reached the commercial market. The materials in this group are quite different chemically from those previously considered. An important property

is that they are easily broken down under alkaline conditions. This means that they are not particularly stable chemicals and are often short-lived as insecticides. They have wide variability in their toxicity to mammals. Malathion, for example, is quite safe for use around mammals while others, such as parathion and methyl parathion, are extremely toxic to mammals.

Organic phosphate insecticides, as a group, are only slightly soluble in water. They are widely used for a variety of purposes including insecticides, acaricides, plant systemics, and others. The o.p. materials also act upon the insect's central nervous system. There is often a latent period after application in which nothing happens. Subsequently, there may be an increased activity followed by a deep depression. Finally, the insect dies. The mode of action of the organic phosphates is fairly well understood. They act by blocking part of the nervous system. The events resulting from damage of the nervous system which lead to death of the insect are not well understood. However, it is fairly obvious that trauma of this nature will eventually produce death. Other compounds in this group are: malathion, Guthion, Thimet, Di-Syston, DDVD, diazinon.

Group 4 - The Organic Carbamate Insecticides

This is one of the newer groups of insecticides. There are quite a few of these compounds in commercial use. All of these compounds are derivatives of the unstable carbamic acid.

Like the organic phosphate materials, the carbamates are quite easily broken down. For this reason they too are not particularly stable. They are considered to be narrow-spectrum insecticides with their toxicity often being restricted to certain selected groups of insects.

In general, they are quite safe for use around mammals, but a few of them are very toxic.

The carbamates attack the central nervous system of the insect in a way which is quite similar to that of the organic phosphate materials. The principle difference is that the effects of carbamates can sometimes be reversed by the insect nervous system. In practical experience this sometimes results in the insects recovering from carbamate treatment. In terms of mode of action, one can say that like organic phosphates, the carbamate insecticides block part of the insect nervous system.

Group 5 - The Dinitro Insecticides

This is a rather small group of materials which have found only limited use as insecticides. One of the better known of these materials is DNOC. It is a yellowish solid which is soluble in organic solvents but only slightly soluble in water. It is often applied as a dormant oil spray and is, of course, soluble in dormant oils. The symptoms of its action on insects are a large increase in oxygen uptake, restlessness, convulsions, paralysis, and death. Onset of symptoms and death is often quite rapid. This is a poison which does not involve the insect nervous system. It acts as a respiratory poison.

Group 6 - The Botanical Insecticides

The basis for classifying this group concerns the origin of the materials rather than their chemical structure. All of the materials in this group are derived from plants. Actually, a very large number of compounds could be listed in this group. For all practical purposes, however, about the only ones that are of any importance today are the pyrethrins, nicotine, and perhaps

rotene. Of these, pyrethrins is probably the most important in terms of current usage. Pyrethrins is a mixture of complex organic compounds which are at least four in number. It is a good insecticide with its principle asset being an extremely rapid knockdown. Indeed, it is almost instantaneous. This is the compound which is often used in combination with other materials in aerosol cans. Obviously, it is put in to show an immediate action with another material added to insure that the insect will be killed. The principle drawback of pyrethrins is that it is an expensive material and cannot be used economically on a large scale. Its mode of action is not completely understood. It is obviously a nerve poison since it produces paralysis almost immediately. Its action is often reversible, and the treated insect will recover.

Nicotine produces excitation in insects when used at low concentrations. However, at high concentrations, it will result in death. It is a nerve poison.

Group 7 - The Biological Insecticides

The materials in this group also do not fit the classification scheme. The materials involved are toxins of bacterial origin, most commonly from Bacillus thuringiensis. These materials are proteinaceous in nature and must be ingested by the insect. They are often quite specific and work on only one species or one group of insects. Apparently, they have to be ingested in fairly large quantities in order to be effective. Their mode of action seems to be an interference with the insect gut. Use of this kind of an insecticide represents a form of biological control of insects. Because the pathogens or their toxins seem to be specific for insects, they do not constitute an environmental pollution hazard.

NATURE AND CHEMICAL CONTROL OF ORNAMENTAL DISEASES

Each and every plant species is subject to its particular disease. Plant pathology is the science of plant diseases. The estimated average annual loss to plant diseases in the U. S. is over \$4.5 billion including the cost of control measures. There is clear evidence that diseases vary in their incidence and severity from year to year due to environmental influences. Over a period of many years, naturally occurring plant pathogens and their natural host plants establish a balanced relationship or coexistence. When a large number of turfgrass plants or ornamentals are deliberately crowded together, as they are in modern agriculture, conditions become optimum for attack and destruction by plant pathogenic fungi or bacteria. The pathogens, or causes of plant diseases, that are susceptible to control with chemicals are bacteria, fungi, and nematodes.

Bacteria, Fungi, and Nematode Pathogens

Bacteria causing disease of plants number approximately 200. Several different species attack ornamentals, but they have a generally insignificant affect on turfgrass species. Bacteria differ from the other pathogens in that they do not have a nuclear membrane. Because some of them have the ability to form highly resistant cells or spores, they are capable of surviving exposure to high temperatures or long periods of dryness. They also have the ability to multiply in large numbers in only a few hours. Some of the best known examples in ornamentals are crown gall of willow, fire blight of pyracantha, and bacterial canker of flowering cherry.

The largest number of diseases of ornamentals and turfgrass are caused by fungi. The typical fungus has a very fine filamentous structure known as the mycelium. On the surface of the host plant it may appear as a delicate, whitish,

cobweb-like thread, or as powdery mildews, or as sooty-brown or black threads as in Rhizoctonia blight. In addition to the mycelium, the fungi produce spores which vary greatly in size, shape, color, and method of reproduction. Millions of spores may be produced by a single fungus, and a single spore under favorable conditions is capable of developing into a new fungus. Spores are spread by air currents, water, and other means. If they happen to land on susceptible plants when environmental conditions are favorable, infection occurs and the plant becomes diseased. Some fungi survive in plants and in the soil as sclerotia. They can endure extreme drying and long periods of high temperature or extreme cold. Although the presence of slime mold fungi on turfgrass does not indicate parasitism, they can cause a severe disease problem because sufficient light is excluded to reduce photosynthesis, resulting in loss of leaves, crown, and roots.

Nematodes cause a large number of important plant diseases. Nematodes are tiny round worms that may cause swelling of plant tissues. They attack roots causing stolon and crown rots, bulb rots, and leaf destruction. The majority of nematodes are microscopic varying from one-sixty-fourth of an inch to one-eighth inch in length. With a few exceptions, plant damage by nematodes is dependent upon large quantities of the parasites. If they are unable to reproduce on the plant tissue, little damage will result. Susceptible plants are those that allow a normal reproduction of the nematode. Nematodes are grouped into the ectoparasites and endoparasites. The ectoparasitic ones feed on the root surface and normally do not enter the root tissue, while the endoparasitic nematodes invade, feed, and may or may not become established in the root tissue or permanently attach themselves to it. The root-knot nematode, during feeding, causes the host cells to enlarge resulting in large galls

as frequently seen on rose, Japanese holly, and periwinkle. Woody shrubs, like boxwood, that are attacked by the root lesion nematode suffer root destruction, while the stunt nematode that attacks azalea may cause a severe reduction in top growth.

Factors Affecting Disease Development

In order for an infectious disease to occur, there must be a susceptible host available in a vulnerable state; the pathogenic causal agent must be present and in a condition capable of inciting infection; and the environment must be favorable for the infection and establishment of the pathogen in the host. The environment then is a requisite factor for the development of an infectious disease.

There are two areas of environment: above ground and below ground; or, the aerial environment and the soil environment. A plant is exposed to both areas and, therefore, both have a direct influence on the plant. The aerial environmental factors are: temperature, humidity, light, rain, hail, snow, and wind. The soil environmental factors are the physical and chemical composition of the soil, temperature, and moisture. The pH of the soil solution and the compaction of the soil are also important.

In any particular region there is a rainfall and temperature average for each season of the year. This mainly determines the climate of that region. Variations in the average are generally responsible for severe epiphytotics of disease such as pyracantha scab, azalea leaf gall, and juniper twig blight. Above-average rainfall in the spring usually results in outbreaks of fungus leaf spots, and heavy rains in the summer will promote Phytophthora root rots of azalea and boxwood.

The environment may predispose a plant to infection; that is, make it more vulnerable. A predisposed plant is one that has been weakened or is unable to adjust its defense mechanism in a normal manner. For example, a plant may

fail to grow new roots to compensate for the roots destroyed by a root knot fungus. Under conditions ideal for plant growth, the plant is often able to tolerate a certain degree of infection without apparent ill effect. However, under conditions that are less than ideal for plant growth, the plant is generally predisposed to infection and is less able to tolerate infection. Such a situation exists when plants are placed under a moisture stress which may be caused by too little or too much water, and the longer the plant is under the stress, the more susceptible it is to becoming diseased.

The critical environmental factor influencing bacterial and fungal pathogens just prior to infection is moisture. Most bacterial and fungal foliar pathogens require free surface moisture in order to enter their hosts. Splashing, as occurs during a wind-blown rain, is undoubtedly responsible for driving bacterial pathogens through natural openings in the leaves.

The temperature range for infection is quite broad and may extend down to freezing, as is the case with the crab apple scab fungus, but moisture is more often the limiting factor of infection. For both the aerial and the soil environments, temperature and moisture are the main factors influencing the development of most infectious diseases.

Many parasitic nematodes are capable of surviving within a wide range of soil temperatures. In the southern U. S. where the soil never freezes, high populations of nematodes may abound the year around. In the northern states, the freezing of the soil reduces the population each winter.

The physical structure of the soil may be a limiting factor in the ultimate nematode populations. For example, clay loam and silty clay loam soils cannot maintain as high a nematode population as sandy soils. This is because the nematodes exist in the pores between the soil particles. If the pore size is smaller than the diameter of the bodies of the nematodes, the nematodes are trapped and become prisoners

in their own environment. This is what occurs in the clay loam and silty loam soils.

Except for resting forms, nematodes cannot survive long in dry soils or flooded fields. Soil moisture sufficient for good plant growth is about optimum for most soil nematodes.

Selection of the Correct Control Measures

Accurate and early diagnosis is the most important phase of a successful turfgrass or ornamental disease control program. An incorrect diagnosis could easily lead to loss of all, or of a portion, of both turfgrass and ornamentals, even though control measures of a sort were being attempted. The commonly tried approach of treating symptoms, rather than causes, is one of the primary reasons for sporadic failure in disease control.

In a carefully planned turfgrass or ornamental management program accurate diagnosis is an absolute necessity for the selection of the proper fungicide, bactericide, or nematicide. The following factors should be considered in selecting fungicides: a) provide a high level of disease control; b) be comparatively low in cost; c) not be readily harmful to either the user or the environment; d) not be phytotoxic at dosage levels of at least two times the recommended rate; e) be compatible with a wide range of insecticides, herbicides, and other fungicides; f) be easily dispersed in the diluent and not clog the outlets of application equipment; g) not leave an objectionable appearing residue on the host; h) have a long shelf life; i) be readily obtained in large quantities when necessary; and j) be conveniently packaged.

Methods of Fungicide Application

An effective disease control program is dependent on selection of the correct fungicide and careful, uniform distribution. The specific method of application is determined by the particular type of fungicide formulation being used and the size of the

turfgrass area being treated or the number of containers or acres of ornamentals involved.

The various commercially available fungicides are packaged either as dusts, wettable powders, water soluble powders or liquids. The most numerous group is wettable powders. These usually have dust counterparts, but are seldom marketed as water soluble powders or liquids.

Mechanism of Plant Protection with Chemicals

Plant protectant chemicals may either: 1) reduce plant pathogen inoculum; 2) provide protection before the pathogen is able to contact a host plant; or 3) provide therapy after the pathogen has invaded the host. Soil fumigant nematicides are examples of chemicals that reduce the quantity of the pathogen.

Most foliar fungicides serve to protect plants by forming a chemical barrier between the pathogen and the plant. Therefore, they are often referred to as protectant or protective fungicides. Some fungicides are active against a large number of fungi and are described as possessing a broad-spectrum of activity. Others have a narrow-spectrum of activity and are only effective against a few fungi. Most fungicides are non-systemic, meaning that they are not absorbed by the plant and translocated within the plant. A few fungicides are systemic. These are absorbed and translocated throughout the plant. This type of chemical has a two-fold advantage in that it will eradicate fungi that are colonizing the plant and provide uniform, long term protection of all plant organs against future infections.

Protectant fungicides are usually effective for 7 to 10 days, an occasional fungicide may be effective for 3 weeks if it is applied at a dosage rate of 2 to 3 times the normal application rate. The length of time a fungicide remains effective is usually dependent upon the weather. Frequent and hard rains reduce the concentration of even the best fungicides.

RELATIVE TOXICITY TABLE

<u>Commonly Used Name</u>	<u>Toxicity to Humans</u>	<u>Commonly Used Name</u>	<u>Toxicity to Humans</u>
Agrimycin	Low	Formaldehyde	Very High
Actidione PM	High	Furadan	Very High
Allyl alcohol	High	Hypochlorites	Medium
Banrot	Low	Lime Sulphur	Low
Benlate (benomyl)	Low	Maneb	Low
Binapacryl	Low	Mercury compounds: inorganic salts, except calomel	Very High
Bravo (Daconil 2787)	Low	Methyl bromide	Very High
Brozone	Very High	Mocap	Very High
Botran	Low	Nemacide (VC-13)	Very High
Cadmium	Very High	Nemacur	Very High
Captan	Low	Nemagon	High
Carbon disulfide	Very High	PCNB (Terraclor)	Low
Chloropicrin	Very High	Pentachlorophenol	Medium
Chloropropene (mixed)	High	Phaltan (Folpet)	Low
Copper compounds	Low	Phenyl mercuric acetate	Very High
Dikar	Low	Polyram	Low
DD - Mixture	High	Quaternary ammonium compounds	Medium
Dexon	Low	Sulfur	Low
Dichlone	Low	Telone C	Very High
Difolatan	Medium	Terrazole (ethazol)	Low
DiSyston	Very High	Thiram	Low
Dodine (cyprex)	Low	Triforine	Medium
Dowfume MC-2	Very High	Truban (ethazol)	Low
Dyrene	Low	Zineb	Low
Ethylene dibromide	Medium	Ziram	Low
Ferbam	Low	Vitavex (carboxin)	Low

WOODY ORNAMENTAL DISEASES

Phytophthora Root Rots and Wilt of Rhododendron, Azalea, and Related Ornamentals

Root rot and wilt of rhododendron and azalea are symptoms of a disease caused by the soil inhabiting fungus Phytophthora cinnamomi. Other species of Phytophthora have been reported to cause similar symptoms, but their importance in Virginia is not clear. In addition to Rhododendron, several varieties of Azalea, Pieris, Kalmia, heather, Kinnikinnik (Arctostaphylos), blueberry, Camellia, Taxus (English and Japanese yew), and several species of heath (Erica sp.) have been reported to be susceptible.

Factors Favoring Disease

Disease development is favored by high soil moisture and high soil temperature of 80^oF and above. Infected plants growing on sandy soils are generally not as seriously affected by the disease, while those on poorly drained soils wilt and die. Plants do not recover from wilt if the soil is maintained wet. The normal tendency is to apply more water when wilt appears. On well-drained soils only feeder rootlets are rotted. Leaves and branches of such plants often are infected by leaf-spotting fungi.

Phytophthora cinnamomi is common in soils of several different regions of the United States where Rhododendron, Taxus, and azaleas are grown in the field. Too often, susceptible plants purchased in either western, New England, or southern states are diseased when brought into Virginia. These diseased plants appear healthy when received, but die from root rot when exposed to high moisture and high temperature conditions. Feeder roots of such plants are commonly infected with Phytophthora, but not extensively enough to result in obvious foliage symptoms. Rhododendron root rot has been spread in this fashion.

Symptoms

In early stages of disease, the symptoms consist of retarded growth and "off-color" yellow foliage. Infected broadleaf species wilt during the day and recover over night. On coniferous species the wilting is less obvious, but is followed by yellowing and dieback. When the roots are infected, they become dark colored and die. Dark streaks soon extend up into the wood of the lower stem. Discoloration of the wood extends well up into the main stems, even to the buds. Infected plants wilt and die in the field during the heat of the summer. In species of Taxus, newly infected tissue is lightly streaked with black.

Dogwood Spot Anthracnose

The fungus Elsinoe corni causes the disease, spot anthracnose. White varieties of dogwood are most seriously affected, but pink varieties may be attacked also. Damage from the disease appears as malformed blooms, ragged leaves, and scabby young shoots and berries. If the disease is not controlled, it may become so severe that flower buds never open. Leaves and twigs may be so heavily diseased that the tree is weakened so that flower and foliage production is poor.

Symptoms

Spots appear on infected flowers, leaves, stems, and fruit. The spots on bracts are reddish-purple and may be as large as 1/10" in diameter. They are circular to elongate in shape. The center of the spot becomes a dusty yellow while the margin remains dark in color. The spots on the leaves are usually circular, although they may be somewhat angular to elongated. They are dark purple, but the centers may turn pale yellowish-gray and drop out, leaving holes in the leaves. Heavily infected leaves are reduced in size and often are killed outright. Infected berries

also have scabby spots with purple margins. Severely infected berries may be badly deformed.

Disease Cycle

The fungus overwinters on infected berries, buds, shoots, and leaves. Spores produced in the infected plant parts are blown to healthy buds causing new infections.

Rusts of Ornamentals

Three species of the fungus Gymnosporangium-- G. juniperi-virginianae, G. globosum, and G. clavipes-- cause diseases of ornamental crab apple, hawthorn, and quince. The rust fungi have as their alternate hosts red cedar and certain other Juniperus species. Damage to the crab apple, variety Bechtel's, may be very serious, resulting in death of branches or of the entire tree.

Symptoms on Crab Apple, Hawthorn, and Quince

Orange areas 1/8 - 3/4" in diameter appear on the leaves and fruit of crab apple and hawthorn in the summer. The upper surfaces of these areas are covered with minute black dots within reddish circles. On the under surface of the leaves and also on the fruit, the orange spots may have many small, cup-shaped structures with fringed edges.

Infected quince leaves have grey to brown spots on their upper surface. The undersides have brownish horn-shaped fruiting bodies. Fruit also may be infected and covered with the same brownish horn-shaped fruiting bodies.

Disease Cycle - (Ornamental crab apple)

During rainy periods in April and May, the galls on red cedar and junipers that were formerly hard, develop bright-orange jelly-like bodies called "spore-horns". Spores of the fungus G. juniperi-virginianae produced on the "spore-horns" are carried by wind and insects to leaves or fruit of apple and ornamental crab apple within a radius of 4 to 5 miles from

the infected junipers. The galls of cedar-apple rust develop from infections on the cedar which occurred 1-1/2 years earlier. The galls die following the period of spore discharge, which usually occurs over a period of only a few weeks. During some years, however, the gall may remain active to mid-summer. The cedar must be reinfected every year for the infection to persist. This is not true of quince rust galls, which are perennial in nature.

Crab apples that are infected by the spores from junipers have orange areas 1/8 to 3/4" in diameter on the leaves and fruit. On the under surface of the spots on leaves, cup-shaped structures with fringed edges are produced. Spores produced in these structures blow to junipers and cause an infection; thus, the cycle is completed.

Juniper Twig Blight

Juniper twig blight, also known as *Phomopsis* twig blight, caused by the fungus *Phomopsis juniperovora*, infects twigs of junipers and occasionally *Cryptomeria*, *Chamaecyparis*, and *Thuja* (*arborvitae*). The fungus seldom causes significant damage unless weather conditions become favorable for disease development. It is very destructive in seedbeds, cutting beds, and lined-out stock in nurseries.

Symptoms

The visible symptoms are a browning and die back of the young leaves and twigs. With the aid of a hand lens or microscope, very small black fruiting bodies of the disease fungus may be seen at the base of the brown or blighted plant tissue. The blighting of a young shoot tip occurs in early May in Virginia. On highly susceptible hosts, the fungus may invade and girdle larger stems, resulting in browning and death of major branches. In very severe cases, entire plants may be killed.

Disease Cycle

During prolonged wet, cool periods as occur in the spring, spores which ooze from the black fruiting bodies in long threads are spread chiefly by rain and overhead irrigation to other branches and adjacent healthy plants. These spores germinate and invade healthy twigs. The blight fungus penetrates young tissues rapidly and usually kills infected first-year seedlings.

Azalea Leaf and Flower Gall

Although the disease is more alarming than damaging, the fungus Exobasidium vaccinii causes concern to many Virginia home gardeners each year. Under very humid conditions, as may occur under glass, the galls may become so abundant as to cause considerable harm to nursery plants if control measures are not implemented. Closely related species of the fungus Exobasidium cause the same type of gall formation on plants such as Arbutus, Blueberry, Camellia, Ledum, Leucothoe and Rhododendron.

Symptoms

The disease causes the leaves to become swollen, curled, and fleshy. They are pale green to white or pink in color during the early stages of the disease, and turn brown and hard as the season progresses. Infected flowers are fleshy, waxy, and swollen. These galls are made up of abnormal tissue. Lower leaves on plants are usually the most seriously damaged portion, but under humid conditions and in shaded locations, galls may occur at the ends of top branches. Flowers of other plants are also frequently affected, especially the petals of evergreen species of rhododendron. The galls which are formed from the swollen, distorted tissue become covered with a whitish mold-like growth during periods of high humidity.

Disease Cycle

The occurrence and intensity of the disease is dependent upon weather conditions and upon a source of the casual fungus. Spores produced in the whitish mold on the surface of the galls blow and are washed to leaf and flower buds causing infection.

Rose Blackspot

Both the leaves and canes of susceptible roses are infected by the blackspot fungus Diplocarpon rosae resulting in almost complete defoliation of bushes by early fall. During the dormant period of the year, the fungus survives in the diseased canes and leaves. If blackspot is uncontrolled and early defoliation occurs, bushes are weakened and cane dieback the following spring will be severe. Weakened plants will continue to die, even after the bushes leaf out.

Symptoms

On roses grown out-of-doors, the leaves are infected in the summer. Small round spots ranging in size from 1/16" to 1/2" in diameter appear, generally on the upper side of the leaves. Leaf tissue adjacent to the spot turns yellow. Infected leaves characteristically turn yellow and fall prematurely. The disease is distinguished from the other leaf spots by the generally fringed margins and also by the darker and consistently black color. Spots on the canes are reddish-purple in color. Blackspot is indirectly responsible for a pale flower color often occurring in many varieties.

Disease Cycle

The spores of the blackspot fungus are spread by splashing water, and infection takes place only when water remains on the leaves for several hours. Therefore, the disease is most serious in regions of high rainfall and high humidity. Overhead irrigation or syringing the plants during dry periods should be avoided.

Sanitation

A preventive program for blackspot should begin in the fall with a thorough clean-up program. Diseased leaves on the ground should be raked and burned. All diseased canes should be pruned off, cutting several inches back into healthy wood. These precautions reduce the amount of overwintering fungus.

Fire Blight of Ornamentals

Fire blight caused by the bacterium Erwinia amylovora is a serious disease on many different ornamentals and can be very destructive to members of the Rosaceae family. Certain varieties of apple, flowering crab, pear, pyracantha, and quince are highly susceptible. Other plants like hawthorne, Japanese Quince, mountain ash, rose, cotoneaster, spirea, loquat, and amelanchier may be damaged.

Symptoms

Blossom, young fruits, small twigs, leaves, and water sprouts are infected. Blossoms and leaves suddenly wilt, turn dark brown, shrivel and die, but usually remain attached. Cankers on limbs are characteristically shrunken, dark brown to purplish in color. Secondary infections start in the small twigs, progress down the stem and may involve whole branches. A characteristic symptom of twig-blight is the bending of the blighted terminal which resembles a shepherd's crook. Dark streaking of the wood extends several inches beyond any outwardly diseased area.

Disease Cycle

The bacteria overwinter in cankers. Frequently an orange bacterial gum or slime oozes from the cankers and the bacteria are disseminated by wind-blown rain, insects, and pruning tools.

Sanitation

During the late summer, all infected, twigs and branches should be cut off and burned. The cut should be made through healthy wood 6 to 8" below the point of visible infection because the bacteria are usually found somewhat in advance of the obviously diseased tissue. Cankered areas on large branches and trunks should be cut out during the dormant season. Pruning tools should be sterilized frequently in alcohol or diluted household bleach (1-10) during this operation in order to prevent carrying the bacteria to new areas. A chemical wound dressing containing a disinfectant should be applied to the fresh cuts.

Scab of Crab Apple and Pyracantha

Certain varieties of crab apple such as Almey, Hopa, Jay Darling, and Strathmore are very susceptible to scab caused by the fungus Venturia inaequalis. Foliage and fruit are often severely diseased. Pyracantha grown in the landscape and in containers is also very susceptible and is damaged similarly by a closely related fungus, Fusicladium pirinum var. pyracanthae.

Symptoms

Symptoms on flowering crab include spotting of leaves, premature defoliation, and unsightly scabby spots on the fruit. Scab first appears on the underside of new leaves as olive-green spots. These spots become progressively olive, brown, and velvety in appearance and then leaves turn yellow and drop prematurely. Fruit may become infected at any time it is developing from blossom to maturity. Typical fruit lesions are distinct, almost circular, olive-green spots that later become brown or black.

Symptoms on pyracantha resemble those on crab apple. Fruit of pyracantha has scabby spots and is shriveled. The leaves are covered with dark, sooty areas.

Disease Cycle

The scab fungi overwinter in infected fallen leaves. In the spring, crab apple leaves and fruit are infected by spores produced in the fallen leaves. Spores will germinate only if they are kept continuously wet over a period of time which varies according to temperature. At 46° F., which is the lowest temperature for spore germination, spores must remain wet for about 20 hours. At 70° F., the optimum temperature for germination, only 9 hours of continuous wetting is required.

Powdery Mildew of Roses

The fungus disease powdery mildew occurs on both greenhouse and out-of-door rose varieties, but some are more susceptible than others. Certain climbers are highly sensitive.

Symptoms

In the spring, the leaves, buds, and stems are covered with a white powdery coating. On highly susceptible varieties the new growth is stunted and curled and may become dry and drop; the buds are frequently malformed and may fail to open properly.

Disease Cycle

The white fuzzy growth on the leaf surface contains spores of the fungus Sphaerotheca pannosa. The spores are carried by the wind to young leaves, causing more infections. Although it appears to be confined to the surface, the fungus has root-like organs in the cells of the leaflets. Only roses are infected by the fungus Sphaerotheca pannosa. Mildew diseases of other plants do not spread to roses. Unlike most fungi, the mildew spores do not germinate readily when wet. However, the disease develops rapidly during warm, humid weather.

Cylindrocladium Root Rot

Cylindrocladium root rot caused by the fungus Cylindrocladium has been a problem of significant importance in

Virginia nurseries, especially in azalea culture. The causal fungus has a very broad host range, attacking many different ornamentals. Among these are Ilex vomitoria cv. Nana compacta, Ilex cornuta cv. Burford, Ilex crenata cv. Helleri, Ilex opaca cv. Savahanah, Rhododendron obtusum cvs. Coral Bell and Hinodigiri and Juniperus chinensis cv. Blue Vase. The fungus may attack the leaves, stems, and roots of susceptible plants. Heavy losses have been experienced by certain Virginia nurserymen who obtained infected azaleas from other states.

Symptoms

Symptoms vary widely, depending on the affected plant species. The fungus may cause leaf spot in holly, a stem canker or crown rot in rhododendron and rose, damping-off or root rot of red bud, a leaf spot, stem canker, root rot and quick wilt of azalea. Damping-off, needle blight, stem canker, and root rot may occur in white pine.

The outer or cortical tissues of the roots are diseased and the vascular cylinder of azalea roots becomes discolored. In some situations, the vascular discoloration extends into the stem; however, discoloration does not usually appear more than an inch or so above the soil line. Latent root infections in which the fungus progresses slowly are believed to account for the late sudden wilt of plants which are several years old.

Environmental Factors Affecting Disease Severity

The key environmental conditions for the leaf spot phase of the disease are high humidity and temperature. Azalea variety Rentschler's Rose has been found equally susceptible at temperatures from 60-75° F. Abundant free moisture on leaves is believed important in order to prevent spore desiccation and also to wash conidia to other leaves. Under conditions of high atmospheric humidity, two-year-old white pine seedlings have been reported susceptible to needle blight.

Crown Gall of Ornamentals

Crown gall is a widely prevalent and destructive disease that occurs on a wide variety of plants in Virginia. *Pyracantha* and certain ornamental stone and pome fruits and roses are most susceptible; however, chrysanthemum, dahlia, daisy, euonymus, poplar, and willow are frequently infected.

Symptoms

Two general types of abnormal growth are characteristic of crown gall: (1) typical overgrowths or tumors, true galls of varying form and size, located in the crown, roots, stems, or leaves, and (2) excessive or abnormal development of organs, either with or without an accompanying swelling. The tree galls on fruit trees are so commonly found at the base of the trunk just below the ground level, on the part called the crown, that the common name "crown gall" was suggested, and this name is frequently applied to the tumors found on other parts of the host. These galls may be irregular, globular, or elongated in form, with more or less convoluted surface, the size varying somewhat with the size and vigor of the structure from which they originate, sometimes exceeding this six to ten times in diameter. In actual size they vary from that of a pea to gigantic overgrowths weighing 50 to 100 pounds, although this maximum size is uncommon.

Cause

The bacterium, *Agrobacterium tumefaciens*, is the cause of crown gall. Infection may occur on the grafting bench (the bacteria passing from diseased to healthy trees on the grafting tool or carried inside from the surface of infected roots) as the graft is made. Many native soils are already infested with crown gall organisms, and healthy plants can readily contract the disease in such soil. In most cases, the bacteria appear to survive no more than two years in soil in the absence of host plants. Crown gall is likely to be more serious on limed soil than on more acid soil.

Damage

Crown gall is a primary cause of condemnation of nursery stock. The injury from crown gall varies with (1) the host (2) the age of the host at time of infection, (3) location of the tumors, (4) number of infections, and (5) the type of host response. In some cases, the following effects have been recorded: retarded growth and dwarf development with undersized, chlorotic foliage; the killing of branches, canes, or roots from the presence of localized cancerous lesions; and, more rarely, the death of the entire plant. Galled trees grow more slowly than normal ones, with reduction in trunk diameter and in number, length, thickness and weight of twigs.

General Sanitation

Do not plant ornamentals with galls on roots or stems. If diseased plants are found among healthy ones, rouging-out and destroying infected plants are recommended. Avoid wounds of any kind. If pruning or other cutting tools are necessary, sterilize tools frequently with denatured alcohol and flame. Observe strict sanitation measures in handling and storing cuttings, including keeping branches and floors clear of trash and plant debris, washing all tools, boxes, benches, preparation and storage areas with soap and water, followed by a 0.5% sodium hypochlorite spray, and not allowing traffic between field and cutting rooms. Additional protection can be had by immersing cutting wood in 0.5% sodium hypochlorite solution before preparing cuttings.

TURFGRASS DISEASES

Melting-Out

Melting-out is one of the more serious diseases of Kentucky bluegrass (Poa pratensis) in the cool, humid areas of North America and Europe.

Symptoms

The disease occurs on all plant parts. On the leaves, it is first seen as minute, water-soaked lesions. These soon enlarge into dark, purplish-red, ovular areas 1/4 inch to 3/8 inch long and 1/16 inch to 1/8 inch wide - the width being limited by size of the leaf. As the infected areas enlarge, the color of the centers changes to brown, and finally a dull white.

Although any area of the leaf may be attacked, infection is usually more severe on the sheath. Lesions on the leaf sheath are generally not as regular in outline as those on the leaf blades. In addition, the lighter colored center is usually missing. Infection of the sheath is often so severe that the leaf is girdled at this point and drops from the plant. It is this leaf dropping phase of the disease that has given rise to the name "melting-out."

Occurring in conjunction with infection of the leaves is an invasion of the crowns, and, ultimately, the roots and rhizomes. The disease in these plant parts is a rot, appearing at first as a reddish-brown decay and finally turning dark brown to black as bacteria and other fungi begin to colonize the tissues. It is not unusual for the diseased plants to wilt under soil moisture conditions that would normally seem adequate for growth.

The Fungus

* Helminthosporium vagans

Disease Cycle

Melting-out of Kentucky bluegrass is characterized by two phases of development. In the cool, wet months of spring

and late fall, the more striking, and better known, leaf spot phase is evident, while during summer months, a crown and root rot phase predominates.

Helminthosporium vagans survives the winter months in diseased Kentucky bluegrass crowns, roots, and rhizomes, and in debris formed from infected leaves. Older leaves appear to be more susceptible than younger ones.

Prolonged periods of cool air temperatures, high atmospheric humidity and overcast weather are more favorable for leaf infections.

Infection of crowns and roots of new plants also occurs in the spring. With the advent of warm, relatively dry summer months, the fungus is restricted primarily to the crowns and roots of diseased plants. However, if cool, wet weather develops during this time, the disease can break out on leaves again.

Helminthosporium Leaf Spot

Helminthosporium leaf spot, incited by Helminthosporium sorokinianum, is a serious disease of turfgrasses throughout the northern regions of the United States.

Symptoms

The leaf lesions characteristic of this disease are quite similar to those of the leaf spot phase of melting-out. They are first seen as small purplish spots. As these diseased areas increase in size, the centers turn brown, and finally fade to a light tan with purplish brown borders.

Infection of the leaf sheath is not as common as with melting-out. The principal damage inflicted by H. sorokinianum is actual blighting of the lamina. This blighting is manifested by a sudden collapse and drying of the leaf blade - after which the leaves blanch to a light straw color. During warm, humid weather of mid-summer, leaf blighting may occur within a period

of 4-5 days from the time of initial infection. In overall view during this period, the disease pattern is seen as a brownish fading-out of irregularly shaped turfgrass areas of various sizes.

Disease Cycle

Helminthosporium sorokinianum survives the winter as dormant mycelium in infected plants and infested debris from the previous year's stand.

The first leaf lesions usually appear in late spring, with disease severity increasing with the onset of warm, wet weather, and decreasing with the advent of cooler, fall weather.

In conjunction with the leaf-lesion phase of the disease, there is frequently a severe crown and root rot, which appreciably reduces the vigor and drought tolerance to the plants.

Degree of severity of the foliar phase of the disease has been shown to be directly related to atmospheric temperatures. At 68° F., the leaf spotting occurs, with no leaf blighting; at 75° F., leaf spotting predominates, with a slight degree of blighting; at 85° F., leaf blighting is heavy, with very little leaf spotting; and at 95° F., leaf blighting is severe, with no leaf lesions being produced.

Red Leaf Spot - Bentgrasses

First reported on redtop, red leaf spot is known to occur on all of the commonly cultivated bentgrasses.

Symptoms

Leaf lesions are circular to ovular, straw-colored, and surrounded by reddish-brown borders. On occasion, the characteristic lighter colored centers may be either extremely minute, or entirely absent. During periods of prolonged, wet weather, many of the lesions may be further surrounded by a belt of water-soaked tissue. Under conditions favorable for disease development, lesions may overlap, producing pseudozonate patterns and giving the affected area a reddish cast.

Heavy infection is often accompanied by withering of the leaves. As a result, a diseased stand of bent grass may have a drought-stricken appearance, even though soil moisture may be adequate for plant growth.

The Fungus - Helminthosporium erythrospilum

Disease Cycle

A warm-wet-weather disease, red leaf spot is usually first seen in late spring. Disease incidence and severity increases with the advent of warmer weather, usually reaching its peak in late July and August. The leaf blighting and subsequent overall "drought-stricken" phase of the disease is usually evident during this period, particularly following periods of prolonged wet weather.

Helminthosporium Blight (Netblotch) Fescues

Long recognized as a disease problem of meadow fescue (Festuca elatior) and tall fescue (F. arundinacea), it has been recently shown that Helminthosporium blight is also a disease of the commonly cultivated forms of red fescue (Festuca rubra). Also, in certain sections of the United States, the disease has been reported to cause moderate to severe damage to Kentucky bluegrass.

Symptoms

The common name of netblotch stems from the lesion pattern of development commonly associated with the disease on the more broad-leaved tall and meadow fescues. On these species, the disease appears first as short, irregular, dark-brown, transverse bars, which resemble short strands of dark thread drawn across the leaf. These bars eventually combine with short longitudinal streaks of brown tissue - producing a very finely developed network. Under conditions optimum for disease development, these net-like patterns aggregate, fusing into

dark-brown, solid spots, measuring 1/4 - 1 inch long and 1/16 - 1/8 inch wide. Heavily infected leaves ultimately turn yellow and die-back from the tips.

In the warmer part of the summer, heavily diseased stands of red fescue go off color - at first becoming yellow, and finally fading into a light brown. At this time, characteristic "pockets" of dead turfgrass, ranging from 1 - 3 feet in diameter, may develop.

The Fungus - Helminthosporium dictyoides
Disease Cycle

The cycle of development for Helminthosporium blight is similar to that for melting-out of Kentucky bluegrass. The pathogen survives the winter months in diseased fescue crowns and roots and in debris formed from infected leaves. In early spring, leaves of the current season's growth are infected by conidia produced in these zones of overwintering. Conidial dissemination is accomplished by wind and splashing water. On the red fescues, the leaf lesion phase of the disease is usually not too conspicuous, and, except in cases of very high incidence, may go unnoticed.

Infection of crowns and roots of new plants also occurs in the spring. The activity of the fungus in these areas later in the summer creates the most important aspect of the disease. With the advent of warmer, drier weather, the leaf lesion phase of the disease decreases and severity of the crown and root rot phase increases. During late July and August, it is not uncommon for entire stands to be rendered useless due to the magnitude of the crown and root rot phase of this disease. In many cases, Helminthosporium blight is one of the primary causes of the summer "browning-up" problem of red fescue.

Brown Blight - Ryegrass (Lolium spp.)

Symptoms

Leaf lesions are of two types. The first are seen as small, ovular, chocolate-brown spots, which eventually develop white centers. These may be quite numerous, numbering as high as 100 per leaf. This large population of lesions at many times may appear similar to the net blotch effect on tall and meadow fescues caused by Helminthosporium dictyoides; however, the characteristic transverse markings of the latter disease are absent. The second lesion type takes the form of dark brown streaks 3/8 inch or more in length. Both lesion types may appear concurrently on the same leaf blade. Heavy infection usually causes the entire leaf to become blighted. This withering process begins at the tips of the leaves as a yellow discoloration, and progresses toward the sheath.

The Fungi - (a) Helminthosporium siccans Drechsler;
Pyrenophora lolii

(b) Helminthosporium dictyoides

Disease Cycle

Carried on seed harvested from diseased plants, the pathogen also survives its adverse season as dormant mycelium in infected plants and in debris from the previous season's growth. The leaf lesion phase of brown blight appears first during the cool, wet weather of early spring. At this time, infection of crowns and roots of new plants also occurs. Secondary spread from plant to plant is accomplished by wind-borne conidia. During the warm summer months, leaf spotting subsides and the severity of crown and root rot increases. With the advent of cooler, fall weather, leaf lesioning may again become important.

Fusarium Patch (Pink Snow Mold)

Symptoms

Active under the snow cover during winter months, Fusarium patch is usually readily apparent with the first spring thaw.

At this time, it is evidenced as areas of pale yellow grass, irregularly circular in outline and ranging from 2 inches to 1 foot or more in diameter. Under conditions conducive to disease development, coalescence of the affected areas may occur, thus involving large areas of turfgrass. As the disease progresses, the affected areas change in color to a whitish gray, with the individual leaves having a bleached appearance and feeling slimy when wet.

Under a snow cover, or during prolonged, cool, wet weather, the diseased patches may be covered with a mat of aerea mycelium which is at first white, and then turns to a faint pink color with longer exposure to light. Usually, only leaves are attacked, but, under severe disease conditions, the pathogen may infect crowns, inciting a rot that may lead to complete killing of the plant.

The Fungus - *Fusarium nivale*

Disease Cycle

Although *Fusarium* patch is generally regarded as a disease of late fall, winter, and early spring, under the proper combination of atmospheric humidity and temperature it may occur at any time of the year. Optimum conditions for development of the disease are periods of high humidity and an air temperature range from 32° F. to 45° F. Disease development of economic importance will occur, however, at temperatures up to 65° F., with the fungus becoming dormant at 70° F. and above. Under winter conditions, snow falling on unfrozen ground is most conducive to disease development.

Fairy Rings

World-wide in distribution, the distinctiveness of fairy rings in one region as opposed to another is marked not so much

by different levels of economic importance as by the degree of supernatural phenomena that has been attached to them by the local citizenry.

Symptoms

In overall view, fairy rings are the result of fungus activity and are seen as more or less continuous circles, formed by bands of turfgrass that is darker green and faster growing than the adjacent plants of the same species. These bands of stimulated grass may range from 4 - 12 inches wide, with the diameter of the circles varying from 3 - 200 feet. Frequently, several distinct rings will occur in the same area. In these cases, as they converge on each other, fungus activity ceases at points of contact, and, as a result, the concentric shape of the original rings may give way to a scalloped effect.

A characteristic feature of fairy rings is the presence of fruiting bodies of the associated fungi in the band of stimulated turfgrass. Commonly referred to as "mushrooms," "toadstools," and "puffballs," from time to time, under conditions of high soil moisture, these structures may be abundant throughout the circumference of the rings.

The Fungi

Many species of Basidiomycetous fungi have been found associated with fairy rings.

Hosts

All commonly cultivated turfgrasses are affected by the fungi causing fairy rings.

Disease Cycle

Beginning from transported bits of mycelium, or less rarely, from germination of basidiospores, the fairy ring is generally first seen as a cluster of sporophores. As the mycelium progresses outward from the point of origin, formation of the circular pattern of fungus fruiting bodies of Type III

ring becomes apparent. Two to three years from the time of inception are usually required for zonation characteristic of Type II and Type III rings to develop.

The cause of outward movement of fairy ring fungi, and the reasons for growth stimulation, and ultimate death, of grass in Type I and Type II rings appear to be inter-related. Through the saprophytic action of the fungus mycelium, the protein portion of non-living organic matter in the soil is reduced to ammonia. This unites with other compounds or is changed by bacteria to nitrates, and ultimately by other bacteria into nitrates. Eventually the fungus grows into new soil and the old mycelium dies and is also decomposed by other soil flora and fauna. The original fungus mycelium in the area then, in turn, serves as an additional source of nitrogenous compounds. It is this accumulation of nitrogen in the soil, in a form that is readily available to higher plants, that brings about the typical growth pattern of conspicuous bands of taller, darker-green plants.

Sclerotinia Dollar Spot

Generally recognized as a wide-spread and serious disease problem of bentgrass (Agrostis spp.) putting greens, Sclerotinia dollar spot may also be severe on various turfgrass species used in home lawns, park lawns, golf course fairways, etc.

Symptoms

Affected individual leaves at first show yellow-green blotches, which progress to a water-soaked appearance, and finally bleach to a straw-colored tan. Entire leaves are commonly blighted, but in some cases, only portions of leaves may become necrotic.

The Fungus - Sclerotinia homoeocarpa

Disease Cycle

Sclerotinia homoeocarpa overwinters in the form of sclerotia and as dormant mycelium in the crowns and roots of infected plants. When the micro-climate temperature reaches 60° F., the organisms resume growth, and reach the peak of activity when the temperature in this region ranges from 70-80° F. and the atmosphere is moisture-saturated.

Turfgrass growing under low soil moisture conditions is more susceptible to S. homoeocarpa than that which is maintained at field capacity.

Rhizoctonia Brown Patch

Rhizoctonia brown patch is one of the major fungus foliar diseases of turfgrasses in those areas of the United States characterized by extended periods of high temperatures and high atmospheric humidities. Involving a very wide range of grass species, under proper environmental conditions the disease can completely destroy both the aesthetic and service qualities of a stand of turfgrass within a very short time.

Symptoms

With the conditions of close mowing, as practiced for putting greens and bowling greens, Rhizoctonia brown patch appears as irregularly-shaped patches of blighted turfgrass. Ranging from a few inches up to 2 feet in diameter, the overall coloration of these patches is usually first a purplish green, which rapidly fades to light brown as the withered leaves dry out.

The chief field diagnostic feature of Rhizoctonia brown patch is evident during periods of warm, humid weather. At these times, dark, purplish "smoke rings," 1/2 - 2 inches in diameter may border the diseased areas. Usually more prominent in the hours of early morning, these "halos" may fade as the day progresses.

The Fungus - *Rhizoctonia solani* Kuhn; *Pellicularia filamentosa*
Disease Cycle

Rhizoctonia solani survives the winter months in the form of sclerotia, either embedded in plant tissue or on the surface of the soil. The organism is also capable of existing for long periods of time in the absence of suitable host plants as a soil saprophyte.

When the average daily air temperature reaches 73° F., fungus penetration of the leaves occurs. Initial invasion of the leaf tissue is accomplished by entry through stomates and wounds produced by mowing. This subdued level of parasitism persists until the air temperature reaches 80-85° F. In this temperature range, particularly in the presence of a moisture-saturated atmosphere, R. solania may completely blight a large stand of turfgrass within a period of 6 - 8 hours. When the air temperature reaches 90° F., parasitic activity of the fungus virtually ceases.

Red Thread (Pink Patch, *Corticium* Disease)

Red thread is capable of causing severe damage to practically all commonly cultivated turfgrass species in the cooler, humid areas of North America.

Symptoms

In overall view, red thread is seen as irregularly-shaped patches of blighted turfgrass, ranging in size from 2 inches to 3 feet in diameter. In large areas of grass, the patches have a general "ragged" appearance due to a fairly high population of unaffected leaves.

The disease is confined to the leaves and leaf sheaths only. At the points of infection, there appear small, water-soaked spots which rapidly enlarge - covering a large portion of the leaf or leaf sheath. With the enlargement of these

water-soaked lesions, there begins a general drying-out of the affected tissue, and subsequently, a gradual fading to a tan color that eventually involves the entire leaf. Under favorable weather conditions, the leaves may be completely covered with the pink gelatinous growth of the pathogen.

The Fungus - Corticium fuciforme

Disease Cycle

Corticium fuciforme overwinters in the form of stroma and as dormant mycelium on the leaves and in the debris of previously infected plants. In either of these forms, the fungus is comparatively long-lived, remaining viable for at least two years.

Disease development is favored by air temperatures in the 68-75° F. range, coupled with prolonged periods of moisture-saturated atmosphere. The pathogen enters the leaves through stomata and spreads rapidly through the various tissue groups. Water-soaked lesions are usually macroscopically visible 24 - 48 hours after leaf penetration has been accomplished.

Pythium Blights (Grease Spot, Cottony Blight)

Among the most destructive of turfgrass diseases, Pythium blights are capable of entirely destroying established stands within 24 hours from the onset of environmental conditions favorable for disease development. In the aftermath of a severe outbreak of Pythium blight, it is frequently necessary to completely re-establish the desired turfgrass species.

Symptoms

In overall view, Pythium blight is first seen as small, irregularly-shaped spots ranging from 1/2 - 4 inches in diameter. Water-soaked in appearance at first, as the leaves shrivel, the color of these patches fades to a light brown.

As the disease progresses, the groups of affected patches frequently coalesce to envelop sections of turfgrass ranging

from 1 - 10 feet in diameter. At times, the shape of the affected areas more closely resembles elongate streaks, rather than irregularly-shaped spots. These streaks may or may not be serpentine in outline. Development of this pattern of blighting is apparently the result of the pathogen being washed over the surface of the soil.

Diseased individual leaves are at first water-soaked, soft, and slimy. When disturbed, they mat together. If the growth of the pathogen is checked before the entire leaf is blighted, distinct, straw-colored lesions of varying size develop. In general appearance, these lesions are not unlike those incited by the *Sclerotinia* dollar spot pathogen - with the exception that the reddish margins characteristic of the latter disease are absent.

The Fungi - (a) *Pythium aphanidermatum* and (b) *Pythium ultimum*
Disease Cycle

Both species of *Pythium* are capable of surviving as soil saprophytes. In a stand of turfgrass already diseased, however, dormant mycelium in plants infected the previous season serves as the chief source of primary inoculum.

The pathogens spread locally, primarily by growth of mycelium from plant to plant. Under conditions favorably for disease development, the rate of this movement can be extremely rapid. Dissemination over great distances is accomplished by transport of either diseased turfgrass plant parts or infested soil on maintenance equipment and by surface movement of water.

Pythium blight is characteristically a warm-wet-weather disease problem. Both *Pythium* species are most aggressive at air temperatures of 85-95° F. and in a moisture-saturated atmosphere.

Fusarium Blight

Symptoms

In overall view, affected turfgrass stands first show scattered light green patches 2 - 6 inches in diameter. Under environmental conditions favorable for disease development, the color of these patches changes in a 36 - 48 hour period to a dull reddish brown, then to tan, and finally to a light straw color. Initially, the shapes of the patches are elongate streaks, crescents, or circular patches.

The most characteristic feature of the gross symptomatology is seen in the later stages of disease development. At these times, there are present more or less circular patches of blighted turfgrass 1 - 3 feet in diameter. Light tan to straw colored, they often have reddish brown margins 1 - 2 inches wide and contain center tufts of green, apparently unaffected, grass. This combination produces a distinctive "frog-eye" effect. When optimum conditions for disease development exist for an extended period of time, these affected areas coalesce. As a result, large areas of turfgrass may be blighted.

Turfgrass plants affected primarily by the root rot phase of the disease are stunted, pale green in color, and do not readily recover from mowing or adverse weather conditions. Their roots are characterized by a brown to reddish-brown dry rot. As the disease progresses, these roots become darker in color due to the colonization of soil saprophytes.

The Fungi - (a) Fusarium roseum f. sp. crealis and
(b) Fusarium tricinctum

Disease Cycle

Both species of Fusarium have been reported to be transmitted on turfgrass seed, and are known to be capable of surviving as soil saprophytes. These two sources constitute the main reservoirs of primary inoculum for the development of the disease

in newly seeded stands of turfgrass. In established turfgrass, the main sources of inoculum are dormant mycelium in plants infected the previous season and thatch that has been colonized by the pathogen.

The most common area of penetration of foliage by the pathogens appears to be the cut ends of the leaves. With both direct penetration and entry through cut leaf tips, mycelial movement is direct intercellular over an area of 12 or more cells and then it becomes intracellular.

Certain isolates of F. roseum and F. tricinctum have been shown to vary in their temperature requirements for optimum pathogenicity. As a general rule, however, the foliar phase of Fusarium blight is most severe during prolonged periods of high atmospheric humidity with daytime air temperatures of 80-95° F. and night air temperatures of 70° F. or above.

Powdery Mildew

Although not generally considered a major turfgrass disease, under conditions of dense shade, powdery mildew can cause either severe damage or death to the affected plants.

Symptoms

The signs of the fungus are usually evident before the appearance of macroscopic symptoms of powdery mildew.

The fungus is usually first seen as isolated wefts of fine gray-white, cobwebby growth, confined for the most part to the upper surface of the leaves. This growth rapidly becomes more dense, and may involve the entire leaf surface. After this, the individual leaves assume a gray-white appearance.

The Fungus - Erysiphe graminis

Disease Cycle

The pathogen survives the winter months as cleistothecia on debris from the previous season's growth, and as dormant mycelium in host tissue. Consequently, conidia, ascospores, or both spore forms, may serve as primary inoculum.

After the death of diseased leaves in late fall and early winter, cleistothecia are produced on their surface, and the cycle of fungus development is completed.

Optimum environmental conditions for the development of powdery mildew include (a) reduced air circulation, (b) high atmospheric humidity, but not visible free water on the surfaces of the leaves, (c) low light intensity, and (d) an air temperature of 65° F.

The importance of reduced light intensity in the development of powdery mildew is illustrated by the fact that the disease is usually more severe in turfgrass growing in shaded areas than in full natural light. This is probably due to reduced air temperatures from shading.

Rusts

With the introduction of the highly susceptible Merion variety of Kentucky bluegrass, the newer fine-leaved perennial ryegrasses, zoysia, and certain varieties of Bermudagrass, rust has become a very serious turfgrass disease.

Symptoms

Early leaf lesion development is seen as light yellow flecks. As these lesions enlarge, they may become somewhat elongate, and in cases of high incidence, show definite orientation in rows parallel with the veins of the leaves. Finally, with the rupture of the cuticle and epidermis, the lesions develop into reddish-brown pustules. As these maturing pustules enlarge, the cuticle and epidermis that formerly covered each is pushed back to produce a characteristic collar-effect.

In cases of high disease incidence, the leaves of the affected plants turn yellow, beginning at the tips and progressing toward the sheaths.

The Fungi - (a) Puccinia coronata, (b) Puccinia crandalli, and
(c) Puccinia cynodontis

Disease Cycle

The cycle of development of this group of diseases is highly complex, owing to the fact that of the 13 species of rust fungi reported parasitizing turfgrasses of economic importance, all but 3 (Puccinia piperi, P. poae-sudeticae, and Uromyces jacksonii) go through 5 morphologically distinct spore stages.

The pathogen overwinters as dormant mycelium in infected turfgrass plants as teliospores. Survival as dormant mycelium in the crowns of infected plants is more common in regions characterized by mild winters of short duration.

Smuts

The various smut diseases affect leaves, stems, and seed heads of turfgrasses. Those involving the vegetative portions of the plants can be very destructive in that the rupture of the long sori in the leaves and leaf sheaths results in the shredding and death of these organs.

Symptoms

Turfgrass plants infected with the stripe smut organism usually make slow vegetative growth. In addition, the inflorescences may be stunted or entirely absent. Long, yellow-green streaks develop on the leaves of the affected plants, and, as the disease progresses, these streaks become gray in color. In final stages of disease development, the cuticle and epidermal cells covering these streaks are ruptured, exposing the underlying, black spore masses of the pathogen. With this, the leaves split into ribbons and curl from the tips downward. The leaf blades then turn light brown, wither, and die.

Symptom expression is more readily apparent in late spring and early fall. Plants grown at 90° F. for prolonged periods usually do not show symptoms. On the other hand, extended periods in the 50-60° F. range are very conducive to symptom expression.

The Fungus - Ustilago striiformis

Disease Cycle

The pathogen survives winter months as dormant mycelium in infected plants and as chlamyospores in the soil or on seed.

Infection of young turfgrass seedlings occurs through coleoptiles, while with other plants, tillers probably serve as the chief avenues of entry of the pathogen. After penetration has been accomplished, the mycelium grows systemically throughout the host. Ultimately, the leaves and stems are colonized to the extent that the massing chlamyospores force a rupture of the cuticle and epidermal cells - producing the chief field diagnostic feature of the disease.

Diseases of Turfgrasses Caused By Pathogenic Nematodes Requirements for Pathogenicity

In order for a nematode species to be pathogenic to a given grass host to the extent that visible stress is evident in the vegetative portion of the plant, it must not only feed on the root system, but, in the process, increase in numbers sufficient to initiate an extremely high incidence of sites of feeding. Macro-pathogenicity, then, is determined to a very large extent by an ability to feed, population pressure, and the initial vigor of the grass. This is an important point to remember, for the reduction in nematode-incited disease severity in established stands of turfgrass with presently available nematicides is brought about by reduction in population pressure, not by complete elimination of the nematode species from the soil.

Life Cycles

In general, the life cycles of plant pathogenic nematodes are comparatively simple.

Methods of Feeding

Plant pathogenic nematodes feed only on living host cells. On the other hand, many of them are not too selective as to host species.

Symptoms

With the root-feeding nematodes, the above-ground symptoms vary somewhat with the turfgrass and nematode species involved. In general, foliar symptoms are those caused by an improperly functioning root system. The affected plants may show various shades of light green to yellow, with the overall areas varying in shape from serpentine streaks to sharply defined patches, and in size from a few inches to several feet in diameter. Affected plants lack vigor, and consequently, have a reduced ability to withstand drought, low fertility, extremely high air temperatures, and other adverse growing conditions.

USING HERBICIDES PROPERLY

Description of Weed Pests

Plant Classification

There are many thousands of plants of various types. In order to recognize them, they are grouped into large groups called divisions. Plants within a division are broken down into families and genera. A genera would then be composed of several very closely related but distinctly different plants called species. This enables us to discuss a particular plant and know that we are referring to that plant and no other plant. Each plant is given a scientific name by genus and species. It is not necessary to know scientific names as long as recognized common names exist. Common names vary from locality to locality and many weeds have several common names. As herbicides are often quite selective, it is imperative that one recognize several of the common weeds and be able to match the common name with the list of susceptible weeds on a product label.

The plants that we are primarily interested in are flowering plants (those which produce seeds). Two distinct types of flowering plants are the grasses and broadleaf plants.

Life Cycles

Chemical control varies with the nature of the weed involved and its life cycle. Annual weed seeds germinate to form seedlings, grow, flower, produce seed, and die within a year. These weeds are often controlled with preemergent herbicides applied prior to seed germination. Annual weeds may germinate in the spring or summer (summer annuals) or germinate in the late fall and grow throughout the winter (winter annuals). Crabgrass and lambsquarters are summer annuals and many of the mustards are winter annuals.

Biennials require two years to complete their life cycle. The musk and curled thistles belong to this group. The seed germinates in the fall and the plant grows vegetatively forming a large rosette during the first growing season. During the second growing season the plant sends up a stalk, produces flowers and then dies. The ideal time to control this plant is during the rosette stage.

Perennials live for indefinite periods, usually several years. They are difficult to control because they have large fleshy underground food reserves. Johnsongrass and bermudagrass (wiregrass) are examples of perennial weeds.

Reproduction of Weeds

Weeds commonly reproduce by forming an abundant seed crop. Many species of weeds produce seeds covered with thick coats and some may remain viable in the soil for periods of 20 years or more. This accounts for the saying that "one year's seeds brings seven years weeds."

Perennial weeds, in addition to producing abundant seed crops, reproduce by vegetative means. This type of reproduction is called vegetative, or asexual, because the new plant is identical in every respect to the parent. There are several types of vegetative reproduction. Johnsongrass reproduces by rhizomes (fleshy underground stems); Canada thistle reproduces by spreading roots; nutgrass reproduces by tubers (tiny potato-like roots); wiregrass reproduces by stolons (above-ground runners which root); and, wild garlic reproduces by aerial bulblets and underground bulblets.

Plant Metabolism

Plants, like all living organisms, undergo vital processes that are necessary to sustain life. To interfere with one or more of these processes will cause the plant to die. Many

herbicides work by interfering with one or more of the plant's vital processes. Photosynthesis is the process by which green plants convert light energy into food energy. Several herbicides interfere with photosynthesis and ultimately the plant runs out of food energy. The utilization of food energy is called respiration. Certain herbicides are able to uncouple and waste the energy resulting from digestion of food by the plant. Again the plant starves. Other herbicides may interfere with protein synthesis or cell division. Paraquat, a contact herbicide, causes rapid destruction of cell membrane. There is no standard method by which an herbicide kills a plant, and the method will vary with the manner in which a given herbicide affects the vital plant processes.

Herbicide Classification

Herbicides can be classified in various manners. Based on chemistry, those which are chemically similar are placed together. The 2,4-D and related compounds are called phenoxy herbicides. Simazine and atrazine belong to the triazine group.

A practical classification is based on the manner in which we use the compounds. Preemergent compounds are applied prior to the emergence of the weed and interfere with the metabolism of weed seed after it germinates. They do not affect dormant seed in the soil. They are usually effective for periods ranging from one month to the entire growing season. Certain preemergent herbicides are volatile and will be lost if allowed to remain on the soil surface. To prevent loss of activity, these materials are applied preplant and incorporated.

Materials applied after the weeds and crop emerge are called postemergent herbicides. Postemergent herbicides may work through a contact action, such as with paraquat; or their action may be systemic, as with 2,4-D.

Soil fumigants are materials that have a broad action, killing weed seed in the soil in addition to disease organisms, insects, and nematodes. The most common type utilizes methyl bromide gas which requires a plastic tarp to prevent escape of the gas. The fumigants are quite toxic and extreme caution must accompany their application. Also, they dissipate rapidly from the soil and new weed seed transported into the area may grow immediately.

The soil sterilants are designed for use when long-term permanent vegetation control is desired. They may persist in the soil for three years or more, depending upon the material and rate of application. They must not be used near desirable vegetation.

Chemical Nature of Herbicides

Herbicides have diverse chemical structures. There are more than 150 different basic herbicides on the market. They are formulations and in various combinations with other herbicides and sometimes with fertilizers and insecticides. It is important to recognize the designated common name because there may be many trade names for the same basic ingredient. Most herbicides are relatively non-toxic to the applicator. The LD₅₀ of most herbicides is in excess of 500 which means they can be safely handled with a minimum of precaution. Certain herbicides, such as paraquat, are toxic enough to bear the skull and crossbones and require special handling requirements. These requirements are elaborated on the chemical label.

Several plants such as grapes, tobacco, tomatoes, and many ornamentals are extremely susceptible to growth regulator herbicides. Special precautions must be observed to prevent injury to these plants. Many cases of injury have resulted from spray drift or from contaminated sprayers.

Presently-used herbicides are biodegradable. Many of them are broken down within weeks and used as a food source by bacteria in the soil. Others, such as some of the sterilants, are much more resistant to breakdown and many remain in the soil for years. Some herbicides are quite mobile in the soil and may move down to a considerable depth while others remain where they are placed at or near the soil surface. A general knowledge of all of these factors must govern the use of these materials. Any one of the presently used herbicides can cause problems if used improperly.

SAFE USE OF PESTICIDES

Turf and ornamental pesticides must often be applied in environments frequented by humans, pets, and other domestic animals. The pesticide applicator must be constantly alert to the hazard associated with this situation. The problem is very complex: 1) he must prevent hazardous amounts of pesticides from drifting into non-target areas; 2) he must prevent humans, pets, and other domestic animals from contacting hazardous amounts of pesticides within the treated area; 3) he must apply the correct amount of pesticide evenly over the entire area to maintain effectiveness and reduce phytotoxicity problems; 4) he must be able to handle his materials within these environments before, during, and after the spray application.

Drift Problems

The proximity of a diversity of plants with greatly different susceptibility to pesticides requires that you must be especially aware of drift problems. There are several steps that you can take to prevent damage to non-target plants. You can search for a pesticide that is safe for both the target and non-target plants. You may place a barrier in front of the target plant, you may remove potted plants from the area, or you may decide not to apply pesticides to the target plant because the benefit does not justify the hazard to nearby plants. Where several pesticides are available, the applicator should strongly consider the toxicity of the active ingredient in making the choice. He should use formulations and methods of application that will result in minimum drift.

Air blast sprayers should never be used in the usual environment associated with ornamental and turf pest control unless absolutely necessary and unless very safe pesticides are used. Air blast sprayers should never be used to apply herbicides.

Two types of drift are associated with pesticides. The most common (drift of spray droplets or dust particles) is directly effected by such things as spraying pressure, nozzle opening size, wind velocity, and pesticide formulations. Vapor drift is related directly to the chemical properties of the pesticide. Vapors or gasses can drift in harmful concentrations, even in the absence of the wind. Fumigants, such as methyl-bromide, must be confined so that they will not drift from the treated area. Some pesticide products are volatile or are capable of vaporizing from the soil and leaf surfaces in potentially harmful concentrations after application. Herbicides are often available in both a volatile (for example, esthers of phenoxy herbicides) and a non-volatile (for example, amines or acids of phenoxy herbicides) form. Herbicide vapor can severely damage or kill desirable plants.

Protecting humans, pets, and domestic animals from hazardous residues within the treated area

Before applying a pesticide, you should see that the application site is clear of such things as toys, pet food dishes, bird feeders, and other articles upon which pesticide residues can be a hazard after application. Animals and humans should be kept from the area during pesticide application, at least until the spray has dried or until the dust has settled. This is true with the least hazardous pesticide. Some pesticides may be hazardous for a longer period of time and the label directions should be closely adhered to concerning re-entry. Recently sprayed ornamental plants that

contain showy flowers or edible fruits present a special hazard because they are likely to be handled or consumed, especially by children. It is essential that pesticides and pesticide containers be made inaccessible to everyone except the spray applicator and that all pesticides and pesticide containers be removed from the premises upon completion of the job.

Calibration

Remember the basic facts behind calibration and it will become simple and easy. A calibrated sprayer makes for an effective job and saves materials and money. Even if you have the right mixture in your spray tank, you can still apply the wrong amount of pesticide. You need to know at what rate your equipment is applying the pesticide to the target.

In calibrating a sprayer, you must first find out how much material is being applied per unit area per time. If your sprayer is delivering less or more spray to each acre than you want it to, you can change the rate by either changing the pump pressure, changing the speed of your sprayer, or changing the discs or jets in the nozzles to change the amount each nozzle delivers. The larger the hole in the disc, the more spray delivered. The rate of application of a pesticide will vary with the following factors:

- 1) Ground speed;
- 2) Pressure;
- 3) Type or size of nozzles;
- 4) Density of the liquid.

Regardless of the method of calibration used, do it right.

Disposal

Safely dispose of surplus pesticides and empty pesticide containers. There are several ways in which you may end up with surplus pesticides. The government may cancel registration, you may buy more pesticide than you really need, some may be

left in the tank, water from cleaning operations may be present, the pesticide may have lost its strength in storage, its container may be damaged, or the label may be missing.

When at all possible, return the empty container or surplus pesticide to the manufacturer. If not possible, try to apply any extra tank mix or rinse water on the same type area in which you used the pesticide.

Empty pesticide containers are not really empty. Even after they have been rinsed out properly, a large amount of the pesticide may be present. Containers that have contained mercury, lead, cadmium, arsenic, or inorganic pesticides should be disposed of very carefully. For example, metal containers can be crushed and kept in the pesticide storage area for disposal. An empty 55-gallon drum makes a good storage container for smaller empty containers. Incapsulation may be necessary for their safe disposal. This means to seal the pesticide and empty container in a sturdy, waterproof container so that the contents cannot possibly get out. Burning pesticides in containers in special high temperature pesticide incinerators is one safe method of disposal of some pesticides. Pesticides are reduced to harmless gasses and solid ashes. This method may not be used, however, for those containers containing mercury, lead, cadmium, arsenic, and inorganic pesticides. When burying pesticides in containers, be careful that surface and underground water systems are protected. Special pesticide landfills may be available. But again, do not bury mercury, lead, cadmium, arsenic or inorganic pesticides, unless special precautions are taken. Never burn containers that hold 2,4-D type weed killers. The smoke from such a fire could cause serious damage to nearby plants and trees. Take the extra time and effort to dispose of surplus pesticides and empty containers safely. It is well worth your while.

Storage

Make a habit of storing all your materials safely before you clean up and go home or on to the next job. Consider wearing gloves even if they were not recommended on the label. Choose a good site for your storage area. A separate building is the best, but if only one building is available for all of your maintenance, then choose a clean corner on the first floor. Mark off that area so that anyone who enters will know that a dangerous pesticide is present. The area should be used only for pesticides and application equipment. Never store or use food, drinks, etc. in the storage or loading area. Livestock feed, living plants, and seeds should not be stored with or below pesticides.

Never use unlabeled pesticides. If the pesticide container is damaged, use the pesticide immediately where possible. Never store pesticides in anything that will be used as a food or drink container, even for a short period of time. Pesticides stored in a soft-drink bottle, fruit jar, or similar food container, are common causes of accidental pesticide poisoning. Never dump a little of your tank mixture in a jar and hand it to your customers or friends. You will not be doing them a favor. Always wash your equipment carefully before you store it. Thoroughly rinse off the outside of any equipment while it is parked in the special wash area. Do not allow rinse water to get on the ground or into the streams, ponds, or other sensitive areas. Collect it and hold for proper disposal.

In spite of your precautions, accidents will happen. If an individual comes in contact with a spill, have him wash it off immediately, change clothes, get out of the area, and see a doctor if necessary. Clear the storage area except for a small clean-up crew. If the spill is liquid, throw activated charcoal, absorbative clay, vermiculite, pet litter, or sawdust over the entire spill. Use enough to soak up most

of the liquid; then sweep or shovel the debris into a large drum. If the spill is a dust, granular, or powder, sweep or shovel it directly into a large drum. Next, cover the area with hydrated lime or bleach to neutralize the pesticide. Rinse the whole area with plenty of water to wash away any remaining poison. Collect the rinse water and hold it for proper disposal.

Pesticide Persistence

The period of residual biological activity of pesticides varies greatly from one class of pesticides to another. Persistence is directly related to rate of application, soil type and texture, temperature, moisture conditions, rainfall, and other factors. Commercial applicators must be familiar with the persistence of each pesticide which may be applied to ornamentals or turf. This is especially true where adjacent areas may be effected, or where treated soil is used to grow other plants, or where humans and pets habitually frequent the area. Successful pest control requires a knowledge of the persistence period in order that subsequent applications may be made in order to maintain the desired degree of control. At the same time, unduly long persistence periods could be hazardous to desirable ornamental plants or turf if the pesticide is inclined to penetrate deeply into the root system of the plant.

For example, generally, herbicides which are used for preemergence weed control in turf persist for 60 to 90 days and post-emergence herbicides persist from 1 to 2 days to 3 to 4 weeks, depending upon the specific herbicide involved. Know the persistence of the material to be used.

All pesticides break down eventually. Some pesticides, such as chlordane, may take as many as 12 years. All environmental factors affect this breakdown. The persistent pesticides

are the most problem since they may end up being concentrated in a non-target plant or animal. Because of this, pest control practices should be approached with thought.

Ultimate Fate of Pesticides

When considering the ultimate fate of pesticides in our environment, it becomes a very complex problem. Pesticides are useful because they are poisonous to some plants or pests. We are trying to eliminate a specific element of nature and not effect the rest of nature. If pesticides could be confined directly to the target, then we would have few environmental problems. There may be a fine-line difference between the toxicity of pesticides to the target and non-target species. The rate of application may be the one determining factor. Non-target species may be poisoned by:

- 1) Being directly exposed; for example, clover in Kentucky Bluegrass;
- 2) Pesticides being carried by wind, water, etc.; for example, drift (fairways and tobacco close by);
- 3) Secondary poisoning, non-target specie eats target; and
- 4) Biological concentration non-target eats target or contaminated non-target containing small amount of poison and it accumulates to point of kill.

There are many familiar examples that are often discussed. In one example, when agricultural sprays were used, supposedly, the material contaminated the streams. The pesticide was concentrated by algae, then by minnows feeding upon the algae, and then death was caused to birds and fish eating these minnows. Another example during one season, DDT was sprayed to the top two inches of soil which had a concentration of 5 to 10 parts per million DDT and DDE, which is a conversion product. This was then accumulated to 120 parts per million in earthworms and in robins to 100 parts per million which was a lethal dose.

The environmental difficulty with persistent pesticides is that they remain in their original chemical form and can

in time, move throughout the environment. This means that the pesticide may end up being concentrated in a non-target plant or animal before removed from its point of application. In summary, the fate of a pesticide in an environment may be as follows: 1) May spread as drift; 2) May volatilize; 3) May undergo photodecomposition; 4) May spread with surface run-off; 5) May leach out of the soil; 6) May be degraded by microorganisms; 7) May be diluted by soil water; 8) May be attached to soil particles; 9) May be absorbed by plants which are killed; and 10) May be broken down by plants into harmless chemicals.

When making a decision regarding the use of a pesticide, keep in mind what the total effect of the pesticide could be. Consider what, if any, non-target plants or animals might also be effected. Consider the possible danger from spray drift or volatilization. Only after careful consideration and planning, should you apply pesticides.

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