Controlling SOIL-BORNE DISEASES in Ohio Nurseries

Figure 1—Post-emergency damping-off of Scotch pine seedlings. Collapse of cells at the soil surface causes plants to fall over.

The production of vigorous, disease-free plants is necessary if the nurseryman is going to continue to satisfy the consumer. Diseased plants are not appealing and will not command a premium price on the market. Such plants, when sold, often do not survive, or if they live, do not grow well. The nurseryman should strive to produce healthy plants in a minimum amount of time, which would result in a higher profit.

Nurseries are located in almost every county of Ohio. Consequently, there is a wide range of soil types and climatic conditions which may give rise to a variety of diseases. Some of these diseases may be more severe in certain areas than others. Often when a plant dies or appears unthrifty, many explanations are suggested, such as unfavorable weather or soil conditions, over or under watering or fertilizing, cultivation injury, planting too deeply or numerous other causes. These factors may favor the entrance of pathogenic microorganisms into plant tissue where they kill or weaken the plant. If practices are followed to reduce the chances of these organisms entering plant tissues, the possibility of producing a vigorous disease-free plant increases.

Nurserymen are engaged in a highly specialized form of agriculture on land which is constantly increasing in value. The cost of a disease control program is highly important, also. One way to control plant diseases, particularly root diseases, is to practice crop rotation. Rotation of nursery crops with non-nursery crops may not be feasible or economical; therefore, other methods have to be used that may appear costly. However, when disease control recommendations are integrated in the overall cultural program, the result should be higher yields of healthier plants in a shorter period of time than would be obtained from a haphazard or no disease-control program.

Cause of Disease

Growers should understand that although some diseases may be serious under certain weather conditions, these conditions themselves are not the cause. Diseases are caused by pathogenic microorganisms, such as bacteria, fungi, viruses, and nematodes. These microorganisms thrive and reproduce at a rate governed by the environment, and they may attack either weak or healthy plants. It is not true that healthy, vigorous plants are less susceptible to disease. Some types of microorganisms are most destructive on the healthiest of plants, and other disease organisms are most damaging on the weak, unthrifty plants.

Types of Diseases

There are four major types of diseases that cause losses in the nursery. These diseases may affect both woody and herbaceous ornamentals.

Damping-off of seedlings is a disease caused by soil-inhabiting fungi, such as *Pythium, Phytophthora,* and *Rhizoctonia.* These organisms may attack the seed before it germinates (pre-emergence damping-off). Infected seed rots, resulting in low germination percentages which are often blamed on poor seed quality. Damping-off may also occur in the seedling state (post-emergence damping-off) as shown in Figure 1.

Stem rot of cuttings appears after cuttings have been "stuck." Rot-organisms (fungi and bacteria) in the rooting medium may enter the basal portion of the stem and cause a rot that progresses up the stem. Leaves turn yellow and fall. Wilting of new growth is evident, as shown in Figure 2.

Foliage rots of cuttings and seedlings are the same fungi that cause basal rots and damping-off of cuttings and seed-

Figure 2—Stem rot of yew cuttings. Note wilting branches, loss of leaves, and black basal portion of stem.

lings. They may also attack the leaves if conditions are favorable. Infected leaves turn black and fall.

Root rot and wilt occur in established plants growing in cans, flats, or nursery plots. The plants may show signs of low vigor, discoloration, or loss of foliage. Examination of the root systems usually reveals a decay of the small rootlets due to rot organisms. A more sudden and drastic wilt may occur on some plants which are susceptible to *Verticillium* and *Fusarium* wilts. Wilt diseases are also caused by soil-inhabiting fungi. These wilt fungi invade the roots and eventually grow internally throughout the plant. Death results when the water vessels become plugged with gums, thus causing the leaves to wilt. This type of disease will be referred to again in the following pages.

Other causes of trouble in roots may be due to parasitic nematodes. These are eel-like worms that inhabit the soil and, together with rot organisms, may under certain conditions reduce vigor of nursery stock.

What to Do

Some growers do not follow sound or recognized methods of plant-disease control and appear to obtain a degree of success in producing salable plants. Losses that occur in the cutting bench or liner stage are often attributed to the weather or numerous other causes. Also, the grower has become adjusted to a certain amount of loss with each crop and accepts this as being inevitable. Actually, such early losses could be eliminated or greatly reduced resulting in more efficient production if certain precautions are taken. It is easier to prevent disease-producing organisms from becoming established than to use trial and error methods to keep them in check once they appear. Furthermore, once some diseases are established there are no control methods known. The entire program of control of soil-borne diseases in the nursery should be based upon the use of:

—clean (disease-free) propagating stock,

—clean, propagating media and soil,

—sanitation practices to avoid recontamination with disease organisms.

The recommendations that follow are devised with the aim of preventing disease-infected soil from coming in contact with healthy propagated plants. There are three principal places in a nursery where plants may contact disease organisms:

—the propagation house,

—flats, cans, or nursery field plots,

—storage prior to sale.

Prevention of Diseases in the Propagation House

Take every possible precaution to prevent disease organisms, especially those present in the soil, from becoming established during the process of propagation. The propagation house should be in a somewhat isolated location, away from the daily activities of the nursery business. Starting a new planting of a specific crop with inferior seedlings or rooted cuttings may be a costly proposition. The following recommendations, if practiced, should result in a high percentage of healthy, well-rooted cuttings or seedlings.

Use only healthy cuttings taken from the upper parts of vigorous, disease-free stock to avoid possible contamination with soil particles. Further preparation of the cuttings prior to sticking should be done in a clean, relatively dust-free area. Clean hands will prevent contamination of cuttings with possible harmful organisms. Occasional cuttings that are accidentally dropped on the floor should be discarded.

Sterilize benches, flats, pots, etc., before filling with a rooting medium. It is a waste of time and money to place sterile media in used, unsterilized benches or containers. If disease organisms are present in soil particles adhering to the unsterile containers, a severe outbreak of diseases can occur. See section on "Danger of Recontamination."

If steam is not available for sterilizing, a formaldehyde soak is effective. Use 1 gallon of commercial formaldehyde

(37 per cent) to 18 gallons of water. Dip or spray all containers thoroughly. Treated containers should be stacked and covered while still wet to retain the gas for at least 24 hours. Benches and containers should not be used until the odor of formaldehyde is gone. Both media and containers may be sterilized in one operation with steam or chemicals. For more details, see section on "Methods of Disinfesting."

Use sterile media. Sand, gravel, and soil mixes may contain many harmful microorganisms even though they are "new." To be safe, all incoming media should be sterilized before use. Old media is safe for reuse only after sterilization. Substances like perlite and vermiculite, which have been heated to a high temperature during the manufacturing process, are sterile and can be used directly without further treatment.

Use treated seed. Disease organisms may be carried within the seed as well as on the surface of the seed. Hot-water- and mercuric-chloride-soak treatments will kill disease organisms within the seed, but often reduce germination. In such cases, disease-free seed should be purchased, if possible. Protectant fungicides, such as thiram and captan, can be used to destroy organisms on the surface of the seed and to protect it in the soil from fungus attack until it sprouts.

The proper use of water is essential to success in the propagation house. Excess water in the medium, due to inadequate drainage, may enhance the development of root-rot organisms, such as *Pythium. Rhizoctonia,* another fungus organism, may spread over the leaves from cutting to cutting.

Methods of Disinfesting Media

Disinfesting is necessary to eliminate disease-causing organisms. The medium should be free of large pieces of organic matter, well-granulated, and of proper moisture content. If soil is to be treated, it should be in good, seedbed condition for best results; if too dry, moisten with water a few days before disinfesting. This will allow heat or fumigants to penetrate the mass more readily.

Sterilization with steam is an excellent way to control root problems caused by *Pythium, Pythophthora, and Rhizoctonia.* These three fungi are the main causes of damping-off. Soil or rooting media in benches or flats should be heated throughout the entire depth to a minimum of 180 degrees F. This may take several hours. Sterilization should then continue for one hour. Take the guess work out of sterilization by using soil thermometers. If *Verticillium* is a problem, a longer period of sterilization is desirable. When the old, pan method is used, steam penetration is satisfactory only to a depth of 6 to 8 inches. The use of plastic to cover ground beds or benches during the sterilization process is much more convenient. The plastic adheres to the sides of the bench thus preventing loss of steam. Be sure the soil reaches proper sterilizing temperature around the edges of the bench. Check soil temperature with accurate thermometers. Heat also destroys weed seeds, nematodes, and insects as well as their eggs.

Chemicals can be used to disinfest soil or rooting media instead of steam. Materials such as methyl bromide, chloropicrin, Vapam or VPM, Mylone, Vorlex, or formaldehyde may be used according to the manufacturer's recommendations. In some instances, the medium must be covered with plastic to insure good penetration of the volatile material. Before using fumigants consider the following:

—Microorganisms in plant residue or in soil clods are especially difficult to kill. Therefore, the soil should be granular or in "good planting condition." If too wet, the gas will not diffuse uniformly; if too dry, the gas may pass through the mixture too rapidly.

—Most soil fumigants do not perform satisfactorily at soil temperatures below 50 degrees F. More effective fumigation is obtained at temperatures between 65 and 75 degrees F.

—Fumigants are toxic to plants as well as humans and should be used with care. Thorough aeration of the soil after treatment is necessary. Residual toxicity even after aeration may be injurious to some plants. Therefore, small-scale treatments may be necessary on questionable crops.

—Most fumigants are specific for the control of certain types of microorganisms. Do not expect one material to eliminate all microorganisms, weeds, and nematodes. Consult the labels and follow directions carefully. A treatment that does an incomplete job of eliminating harmful soil-organisms may result in severe losses (see page 4).

Fungicide drenches may be used to control local outbreaks of diseases, such as damping-off. This type of control should be considered as a second line of defense against disease organisms, inhibiting rather than eradicating them. All diseased plants should be removed before treatment. Apply the drench liberally to an area extending at least one-foot beyond the edges of the infested spot. Do not expect complete control with a drench. It should be applied again in 10 days since most fungicides are inactivated in soil. Fungicide materials, such as captan, ferbam, thiram, nabam, Semesan, Terraclor, and Dexon or a combination of Terraclor and Dexon, have been used as drenches. Be sure to consult the label for plant toxicity before using. If such information is not given, treat a small area first before using on a large scale or consult your county Extension office.

Prevent recontamination after the above precautions have been taken. It is easy to recontaminate propagation benches, for example, by careless maintenance or examining cuttings with dirty hands. Recontamination of a clean bench with disease organisms can cause considerable damage. Here are some precautions to take that will help prevent contamination:

—Keep walk ways clean and free of debris.

—Keep equipment off the floor so it will not become contaminated, especially hose nozzles. Disinfest trans-

planting equipment before using and often during use, either with steam or a formaldehyde wash.

—Keep pets and other animals from walking on benches.

—Keep shoes and dirty equipment off benches.

—Keep grass and weeds mowed around greenhouse to reduce insect build-up. Some insects carry disease organisms from weeds to the crop.

—Avoid using outdoor equipment in the greenhouse, unless it is properly disinfested with steam or formaldehyde.

The propagation house should be labeled, "Restricted Area—Keep Out." Only the owner or propagator should be allowed into the house. This will eliminate some of the hazards of contamination.

Danger of recontamination exists. A sterile soil or rooting medium does not remain free of microorganisms very long because of contamination from the air and water. In most instances these are harmless organisms. The importance of avoiding contamination by disease-producing organisms at this time cannot be overemphasized. If parasitic organisms are introduced into a bench of cuttings when the medium has a low population of common microorganisms, the parasite will grow rapidly due to lack of competition. Under such conditions losses could be enormous —far exceeding the losses that might occur under unsterile conditions. The same danger exists when one places sterile media in unsterile containers. A similar situation exists when an incomplete job of sterilization is done. This results in eliminating most of the harmless organisms, but allows certain parasitic ones to survive.

The grower should strive to develop and use sanitary measures in his daily operations in an effort to produce healthy propagating stock.

Diseases that Can Be Prevented in the Propagation House

Crown Gall

This disease is caused by bacteria that persist in the soil and enter through wounds resulting in growth enlargements (see Figure 3). Among plants most likely affected are euonymous, rose, privet, azalea, rhododendron, wisteria, flowering quince, begonia, delphinium, carnation, chrysanthemum, and dahlia.

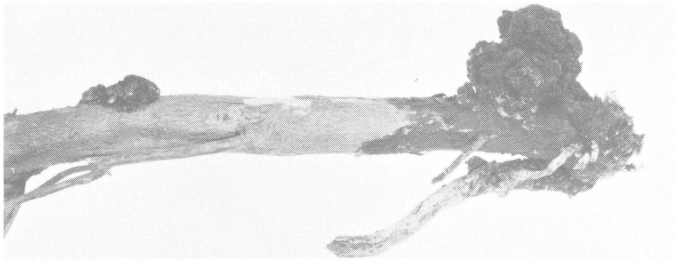

Figure 3—Crown gall caused by bacteria on basal and upper stem portion of euonymous.

Control. Sanitation in making and handling cuttings will eliminate much of this problem (see page 7). Propagation stock must be taken from healthy mother plants. Work benches, propagating knives, and hands should be free of dust and soil particles, and should be disinfested at regular intervals in 70 per cent alcohol. Using a different knife at regular intervals will allow the operator to disinfest one knife and then allow it to air dry before using. Destroy infected cuttings. Herbaceous plants or any healthy stock should not be planted in beds known to contain crown-gall bacteria. For sterilization of outdoor ground beds, see page 3. Subsequent cultivation operations must be done with care to avoid injury to the stem through which bacteria may enter.

Basal Rot of Cuttings

High losses of unrooted cuttings may result if fungus and bacterial populations of the rooting medium are high. High-moisture conditions that prevail in propagating benches are ideal for the development of certain fungi, such as Pythiums, that attack young stem tissue. *Rhizoctonia, Botrytis* and *Phytophthora* may be troublesome if temperature and moisture conditions fluctuate. Other ordinarily harmless fungi and bacteria may also enter the stem and cause further injury resulting in a dead cutting.

Control. The propagation bench must be sterilized with steam, or a formaldehyde drench prior to filling the benches with a rooting medium. If old medium is used from a previous crop of cuttings, it should be thoroughly sterilized, preferably with steam. The continued use of a rooting medium without seasonal sterilization results in a buildup of disease organisms, and decreased yields of healthy, rooted cuttings. Repeated use of a rooting medium without sterilization is definitely not recommended. Fungicide drenches may help to reduce the spread of fungus invasions if they occur after cuttings are stuck.

Leaf Molds

Probably the most common fungus causing severe damage to seedlings and cuttings is *Botrytis*. Spores of this fungus are present in the air and become established first on dead or dying leaves. It spreads rapidly—covering many plants with a gray, downy growth. The fungus thrives under cool, moist conditions.

Control. Stick only healthy cuttings. Those with leaf spots due to anthracnose, mildew, injuries, or dead leaves should be discarded. Avoid overcrowding and injury to cuttings and seedlings. If *Botrytis* threatens, decrease the moisture or increase the temperature. Occasional spraying with captan may help reduce leaf-surface fungal populations.

Viruses

Virus diseases have been recognized for quite some time on herbaceous ornamentals, but are only recently being detected in woody plants. Viruses have been reported in viburnum, lilac, rose and flowering crab, and they probably exist in other woody ornamentals as well. Infected plants may not show any severe outward symptoms of disease, however, such plants may lack vigor or be more susceptible to winter injury. Some viruses may be transmitted mechanically, that is, on tools and hands of workers. In some diseases, such as aster yellows, only a certain insect is able to transmit the virus.

Control. Weeds are known to harbor viruses. Sometimes weed hosts do not show visible symptoms of infection. However, insects, such as aphids and leaf hoppers, that feed upon infected weeds, may then go to ornamental plants to feed, and thus transmit the virus. Therefore, it is important to eradicate weed hosts and spray with appropriate insecticides to control insect infestations. Plants with abnormal color or leaf shape should be rogued out. Plants appearing abnormal in any respect should not be used for propagation.

Prevention of Diseases in Nursery Plots

Certain diseases, such as those occurring on foliage, can be prevented or stopped in the field with the proper use of fungicides. Root diseases, however, cannot be controlled readily once they appear. These are troubles that are most costly, because they result in reducing the growth-rate potential of plants. Consider the following factors before planting in the field. They may help to avoid unfavorable growing conditions that are conducive to root-disease problems.

Field Site

Some plants are more tolerant than others to "wet feet." Such plants as rhododendrons, azaleas, and taxus are sensitive to reduced oxygen supply which usually prevails in a wet soil. Roots injured by suffocation may be much more susceptible to attack by soil organisms. Also, cold, wet spots are known to favor the growth of certain root-rotting organisms that could invade young roots resulting in a stunted plant. Stunted plants shown in Figure 4, however, may be found where drainage is not particularly a problem, except during periods of excessive rainfall. To avoid these situations, it may be necessary to tile a field to remove excess water. If the water is moving across the field from another area, consider contour plantings in the watershed area to minimize surface flow and thus reduce the spread of disease organisms. Your County Extension Agent or nursery inspector may help you solve such problems.

Certain areas in a nursery may remain excessively wet for a longer time than surrounding areas due to an impervious layer in the subsoil called a hardpan. Such an area is not as productive as it could be and, as explained above, root rot organisms thrive under extreme moist conditions. This area could serve as a source of contamination for the whole nursery. Shallow hardpans are usually corrected by using a subsoiler which breaks up the impervious layer, allowing excess water to drain.

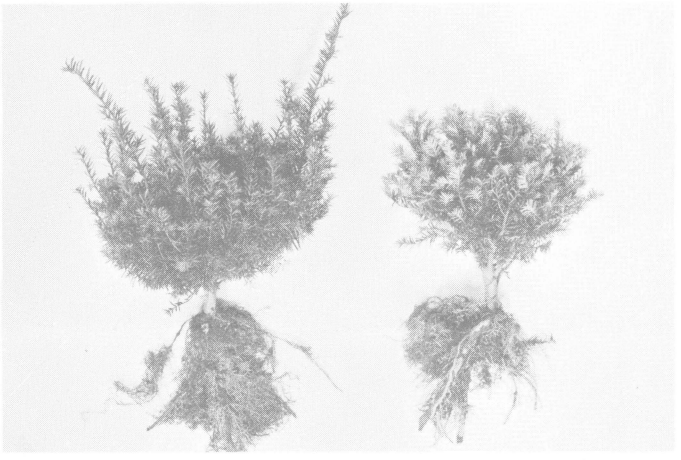

Figure 4—Two *Taxus* plants of the same age. Left, healthy plant with abundance of new growth; right, diseased plant with approximately one-third of root system rotted due to soil microorganisms.

Nematodes in the Soil

Nematodes are probably present in all Ohio soils. There are two types—a saprophytic nematode that lives on dead organic matter, and a parasitic type that must have living plants on which to feed in order to survive. The latter are the important ones in nursery production. High populations of parasitic root knot, lesion, dagger, and other nematodes have been found in many Ohio nurseries. The continued cropping of nursery soils to certain plants has favored a build-up in some areas to a point where plants are stunted. Since nematodes do not move very fast in soils, tremendous benefits may be obtained from side-dressing applications of nematocides as shown in Figure 5. Another method of treatment is shown in Figure 6, where a granular nematocide is applied simultaneously with soil preparation. In addition to reduced plant vigor, there is evidence that nematode-infested plants are more susceptible to winter injury as demonstrated in Figure 7. This may

Figure 5—Sidedress application of liquid nematocide into root zone of euonymous.

Figure 6—Application of a granular nematocide at time of soil preparation. This method is especially suitable for preparing ground beds for cuttings to be grown for a year prior to transplanting to the field.

be not only due to the direct damage done by the nematodes, but also to that caused by root disease organisms that enter nematode-wounded roots. In some instances, it may be possible to reduce the growing time of a crop by one or two years by planting in fumigated soil. In addition to the benefits derived by planting in fumigated soil, the grower runs less risk in having stock rejected by plant inspectors.

Control. Parasitic nematode populations can be reduced by removing their food source by rotation with non-host crops. This is not entirely satisfactory because of the following reasons:

—the host range of some nematodes is not well known,

—crop rotation removes valuable land from production,

—the whole operation is time consuming, requiring two or three years.

Severely infested plots may be kept fallow for one year with frequent disking or spraying with herbicides to control weed growth. There is evidence that such treatment drastically reduces parasitic nematode populations apparently by starvation.

Various kinds of soil fumigants are available as mentioned on page 3. Some kill nematodes only, while others are effective against nematodes, weeds, and disease-producing microorganisms. The most effective fumigants are those applied as a gas. Equipment for general application as well as side-dressing for nematode control vary from simple gravity flow to pressure equipment (Figures 5 and 6) depending upon the material to be applied.

Frost Pocket and Winter Injury

Extremely low temperatures during the winter or late frosts in the spring after plants have broken dormancy may injure stem tissues and leave the plants open to invasion by disease-causing organisms. Some hybrid rhododendron varieties are especially susceptible to this type of injury.

Avoid fields with low pockets where winter injury and late spring frosts are more likely to occur. Plant only strains or varieties that are of known hardiness in such areas.

Winter survival of *Caryopteris* has been shown to be directly proportional to the degree of infestation of the roots with root-knot nematodes (see Figure 5).

Winter survival of other nursery crops may also be directly related to the extent of root damage from nematodes, microorganisms, and poor soil drainage.

Hardening-Off Plants

Winter injury and subsequent infection by disease organisms may also occur where plants are not properly hardened-off. The latter is a complex physiological process that occurs in the fall and is associated with increased carbohydrate content of the tissues.

Cultural practices that encourage vegetative growth late in the season should be avoided. Plants with a good, vigorous root system are less likely to suffer winter injury.

Figure 7—Comparative overwinter survival of Caryopteris in a plot that received 4 gallons of Nemagon EC-2 (right) and in an untreated check plot (left).

Sanitation

This is as important in the field as it is in the propagation house. If lining out plants have been produced under sanitary conditions as described above and planted in a good location in the field—preferably in fumigated soil—the growth response should greatly exceed that of plants where no precautions were taken. If the cuttings are to be planted in narrow beds under shade for a year or two before being placed in the field, the soil should be treated with a fumigant (see soil fumigants, page 3) prior to planting.

The grower should constantly be aware of abnormal plants in the beds. Abnormal plants should be removed and burned. This is necessary to keep diseases from building up. Pruning equipment should be disinfested regularly, and especially after using on plants suspected of being diseased. Clean pruning cuts that heal quickly (avoid stubs) should be made to minimize the chance of canker-type diseases from becoming established. Since foliage diseases are spread rapidly by pruning or otherwise handling plants when wet, such activities should be undertaken only when the foliage is dry.

Mechanical Injury

Any injury to the stem at ground level by insects or machinery will cause a setback of growth as well as provide a site of entry for soil organisms. *Verticillium* and *Fusarium* species may invade through such wounds. Many kinds of organisms can be found within wounded plants. Just how much damage they do is often difficult to determine. Injured plants never seem to "catch-up." Broken branches are also susceptible to invasion by canker-producing organisms, which may eventually cause death of a major portion of a specimen, reducing its value.

To avoid mechanical injury to plants, be sure equipment is properly adjusted when cultivating for weed control. Carelessness in the operation of all types of equipment, including the hoe, accounts for most losses arising from injuries.

Prevention of Diseases in Storage

After much effort has been made to produce disease-free plants in the propagation house and the field, they may still become diseased during the period of storage. Unfortunately, there are disease-producing organisms that thrive at temperatures and humidities considered optimum for storing plants.

Probably the most damaging disease to plants in storage, especially roses, is gray-mold rot (Figure 8) due to a fungus called *Botrytis*. *Botrytis* is commonly found on dead or dying plant parts. It produces spores profusely and once established on dead tissue, the fungus may invade healthy plant parts. This fungus can grow at 32 degrees F., and flourishes when the humidity is high and air circulation is low.

Fusarium, Alternaria, Mucor, Rhizopus, and *Penicillium* species have also been isolated from rotted nursery plants in storage. Losses due to these organisms often occur only when wounded stock is stored or when plant roots are injured by sub-freezing temperatures after being lifted from the soil.

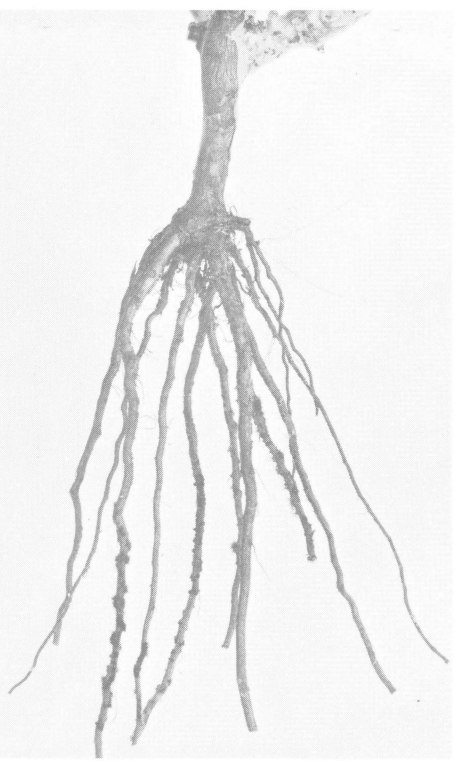

Figure 8—Botrytis spore bodies (blackish fuzz) on rose roots in storage at 34 degrees F.

Control. The following precautions will help to reduce storage losses:

(1) Digging of nursery stock should be done when the temperature is above freezing. Dig only enough stock that can be stored in a day. Stock exposed to overnight frosts may be injured sufficiently to allow rot organisms to invade during the storage period.

(2) Cull plant material in the field. Occasional diseased plants should not be brought into storage with healthy plants. They occupy space and may be a source of contamination to other plants. Such items as bulbs and corms,

or fleshy roots, may be treated with a fungicide before placing in storage to reduce secondary rots.

(3) Do not store deciduous plants with leaves. Plants should be stored free of leaves and other dead organs, such as flowers or fruits. Dead plant parts may harbor disease organisms like *Botrytis* and other fungi that can become injurious under storage conditions.

(4) Spray bins and plants with Botran (75%), 1⅓ pounds per 100 gallons of water, prior to storage. This should help to control *Botrytis*. A 20 per cent Terraclor dust may be used to control other fungi on stored stock.

(5) Proper regulation of both temperature and humidity to avoid condensation of moisture will help to prevent growth of microorganisms. An increase in temperature for a short time may allow spore germination to occur. Growth of the fungus may then proceed even at a lower optimum storage temperature.

(6) Keep a record of storage operations. A small investment in a hydrothermograph, for example, which records moisture and temperature continuously will reveal fluctuations in these two critical environmental factors. Such data, along with notes on the date and condition of plants entering storage, the rates and frequency of fungicide applications, etc., may help to explain the cause of losses should they occur. Contact your plant inspector, area Extension agent, or the Plant Disease Clinic to solve disease problems in the storage, propagation house, or elsewhere in the nursery. The Plant Disease Clinic is located in the Department of Botany and Plant Pathology, The Ohio State University, 1735 Neil Avenue, Columbus, Ohio 43210. Forms are available from county Extension offices or by writing to the Plant Disease Clinic.

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