M-X-94

ISSN 0704-769X

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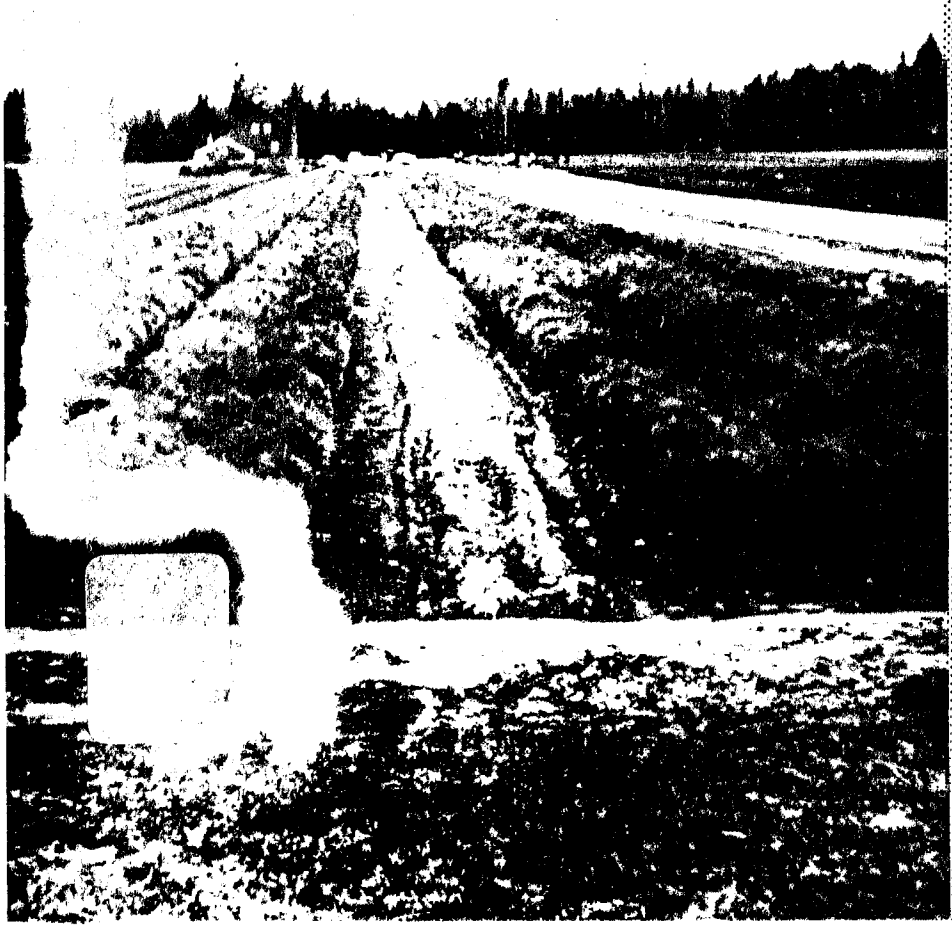
by
R.E. Wall



MARITIMES

MARITIMES FOREST RESEARCH CENTRE

The Maritimes Forest Research Centre (MFRC) is one of six regional establishments of the Canadian Forestry Service, within Environment Canada. The Centre conducts a program of work directed toward the solution of major forestry problems and the development of more effective forest management techniques for use in the Maritime Provinces.

The program consists of two major elements - research and development, and technical and information services. Most research and development work is undertaken in direct response to the needs of forest management agencies, with the aim of improving the protection, growth, and value of the region's forest resource for a variety of consumptive and non-consumptive uses; studies are often carried out jointly with provincial governments and industry. The Centre's technical and information services are designed to bring research results to the attention of potential users, to demonstrate new and improved forest managment techniques, to assist management agencies in solving day-to-day problems, and to keep the public fully informed on the work of the Maritimes Forest Research Centre.

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R. E. Wall

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Fredericton, New Brunswick

Information Report M-X-94

Canadian Forestry Service
Deaprtment of Fisheries and the Environment

1978

ABSTRACT

Most disease problems in forest nurseries can be prevented by appropriate site selection, careful choice of windbreak species, and close attention to other normal management practices. The common diseases in Maritime forest nurseries are briefly described and known factors affecting their incidence are discussed in relation to control. The major control practices are described, including some of the more promising fungicidal treatments. To minimize fungicide use, emphasis is placed on management practices.

RESUME

La plupart des problèmes de maladies dans les pépinières forestières peuvent être prévenus par le choix approprié de la station, des espèces brise-vent et par une attention particulière à d'autres pratiques habituelles d'aménagement. L'auteur décrit brièvement les maladies communes dans les pépinières forestières sises dans les Maritimes et il discute des facteurs connus qui affectent leur incidence, ce afin d'engager la lutte. Il décrit les méthodes principales de lutte, incluant les fongicides prometteurs. Mais afin de minimiser l'utilisation des fongicides, il insiste sur les pratiques d'aménagement.

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INTRODUCTION

Disease control is much more than the application of fungicides to protect a crop. It involves every aspect of nursery management: from obtaining seed to shipping out planting stock; from the selection of nursery sites to soil management. Often, the need to apply fungicides stems from a poor choice of sites, inappropriate selection of species or seed sources, or inadequate soil management.

Why does disease control especially concern forest nursery managers? Because as much as 100% of a given planting can be destroyed by a fungus disease or a physiological disturbance. Because tree seed, land, greenhouse space, and labor are expensive and losses add considerably to costs. Most important, seedlings used for reforestation must be disease free, vigorous, and superior to natural regeneration if the reforestation program is to be worthwhile. Unfortunately, many disease problems go unrecognized in the nursery and later affect the success of the plantation.

Diseases which cause seedling losses or reduce out-planting quality can only occur under certain sets of conditions – incompatibility of species to site, adverse weather, supply of disease inoculum, and a breakdown of natural controls. An understanding of the conditions required for disease development will do much to ensure appropriate management procedures and eliminate unnecessary use of chemicals.

This manual emphasizes disease problems in conifer seedlings since they are the major stock produced in Maritime forest nurseries. It is not yet known what the major problems in producing hardwood stock will be but some potential fungus diseases are listed in Appendix II.

RECOGNITION OF DISEASES

Recognition of the disease is the first step in applying appropriate controls, so it is important to appreciate some of the distinctions between different symptoms. It must be remembered, however, that many of the distinguishing symptoms are of short duration and may soon be replaced by a common symptom – dead seedlings. Specialists may be required to identify microscopic organisms associated with the disease, but the presence of a disease-causing organism (pathogen) does not necessarily mean that it was the cause of the problem in question.

A fundamental consideration in determining the cause of a disease is the history of the crop – time of planting, weather, previous treatments, temperature control if in a greenhouse, and previous symptoms. Another essential consideration is the local environment – composition of windbreaks, soil fertility and physical properties, urbanization and industrial development, and local vegetation. These factors will be considered in a discussion of various diseases – their symptoms, causes, and controls.

A key to common disease symptoms is provided on pages 2 and 3 and some of the causal fungi are described in Appendix I.

EMERGENCE PROBLEMS

Poor emergence in seedbeds and post-emergence mortality are often termed "damping-off", regardless of cause. Others prefer to restrict this term to mortality caused by fungi. Whatever the terminology, it is important to know whether the cause is abiotic or fungal. If it is the latter, treatment with a fungicide may save remaining seedlings. If the cause is abiotic (e.g. heat, low light, chemical pollution, herbicides) a fungicide may only accentuate the problem.

Damping-off

Post-emergence damping-off due to fungi may be recognized by a soft watery rot of affected seedling tissues – that is, if the symptoms are observed early enough. Any part of the seedling may be affected. If the root is rotted, resulting in wilting of cotyledons, the disease may be called root rot. If there is a moldy growth on the cotyledons, primary needles, and upper stem, it may be called top-mold. Most commonly, the soft tissues of the lower stem or hypocotyl are affected, causing seedlings to topple over at the soil line. The rot is usually

KEY TO COMMON DISORDERS OF CONIFER SEEDLINGS

A. Poor emergence
  B. Germination tests indicating poor germination
    C. Germination improved after stratification ..... Dormancy
    C. Molds growing from moist seeds in germination-test dish. ..... Low viability (poor pollination, poor storage conditions, or fungus infection).

  B. Germination tests indicating good germination ..... Pre-emergence damping-off (***Pythium, Fusarium Rhizoctonia,*** and other soil fungi)

A. Diseases occurring after emergence
  B. Mortality within three weeks after emergence
    C. Seedling tissues rotted ..... Post-emergence damping-off (***Pythium, Fusarium Rhizoctonia,*** etc)

    C. Affected tissues discolored or distorted but not decaying immediately
      D. Roots intact, full length, white
        E. Cotyledons yellow or brown ..... Heat injury or soil toxins
        E. Constriction above the soil line. ..... Excessive salts or heat injury

      D. Roots shrivelled or discolored, stems and cotyledons distorted. ..... Chemical injury

    C. No discoloration or mortality; buds form in place of primary needles ..... Induced dormancy (short day length)

  B. Symptoms occurring during primary needle and later stages.
    C. Roots intact; considerable soil adhering to root system when pulled
      D. Yellow or purple discoloration of foliage, die-back of needle tips ..... Nutrient deficiencies or chemical injuries

      D. Death of whole shoots or needles, often with growth of molds or fungus fruiting bodies on the affected parts.
        E. Death of entire seedlings or patches of seedlings, with brown or grayish fungus growth over the affected parts; usually in densely planted seed beds.
          F. Occurring during the growing season ..... Gray mold (***Botrytis***, etc)
          F. Occurring during winter months and appearing after snow melt. ..... Snow blight (***Phacidium*** and related fungi

E. Death of individual needles or shoots
F. Death of individual needles or parts of needles
G. Premature needle fall; black, often elongate fruiting bodies on affected needles . . . . . Needle casts (***Lophodermium*** and related fungi)

G. Blighting of entire needles, usually beginning at the base
H. Blighting of older needles . . . . . Needle blight (***Pestalotia*** spp, etc)

H. Yellow-red discoloration of newer needle bases, accompanied by death of buds. . . . . ***Scleroderris*** canker (***Gremmeniella abietina***)

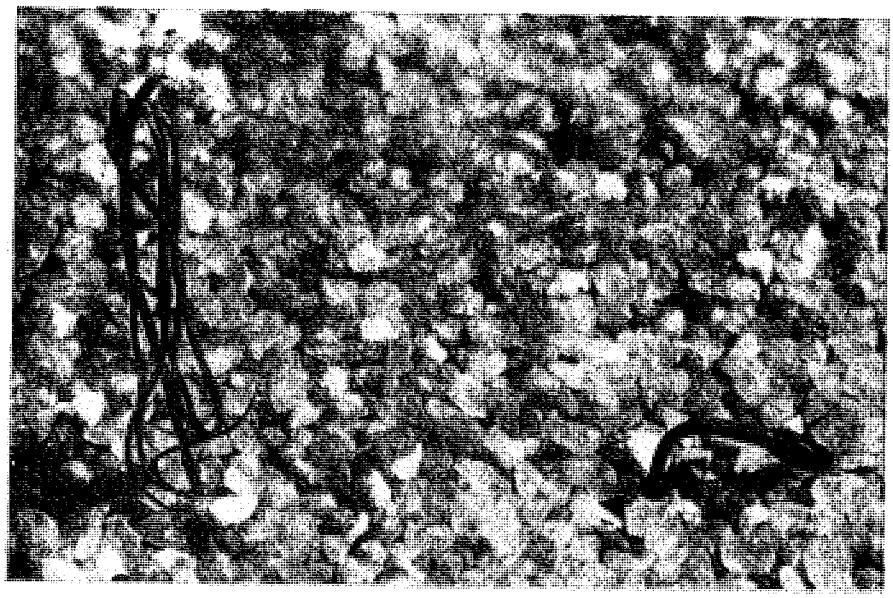
F. Death of whole shoots, usually accompanied by a stem canker
G. Tiny canker on current-year's shoot; shoots bend over to form a crook; black pycnidia on affected shoots . . . . . Shoot blight (***Sirococcus strobilinus***)

G. Shoots and buds die, turning reddish brown; Canker forms on main stem; greenish discoloration of cambium . . . . . ***Scleroderris*** canker (***Gremmeniella abietina***)

D. Little mortality; tiny outgrowths on needles or swellings on stems and branches . . . . . Rusts (***Coleosporium, Chrysomyxa, Cronartium,*** etc.)

C. Roots decayed; rootlets and cortical tissues remaining in soil when seedling pulled; above-ground symptoms variable
D. Little mortality; affected seedlings stunted and discolored. . . . . Common root rot (***Fusarium oxysporum, Cylindrocarpon*** spp. ***Pythium*** spp.)

D. Considerable mortality; flagging of needles followed by reddish discoloration of foliage; often accompanied by stem cankers. . . . . ***Cylindrocladium*** or ***Phytophthora*** root rots, heat canker (***C. scoparium, P. cinnamomi,*** excessive soil surface temperatures).



Damping-off

extensive, rather than a narrow constriction at the soil line, and affected tissues are discolored – yellow green turning to dark brown or black.

Many fungi cause damping-off, so it is difficult to generalize about controls. Most damping-off fungi are soil-borne although some pre-emergence damping-off may be caused by seed-borne fungi. The three major damping-off fungi, ***Pythium*** spp., ***Fusarium oxysporum***, and ***Rhizoctonia solani*** have differing requirements so control measures for one may fail to prevent, or may even accentuate, others. Damping-off is usually less when seedlings are germinated under their optimum conditions – adequate light (10,000 lux or more), acid soils (pH 4-5), and moderate temperatures (15-25°C). Nitrogenous fertilizers and recently incorporated organic soil amendments may increase damping-off. Damping-off is more likely on older nurseries or on nurseries developed from old farmland than on recently cleared forest sites. Fungal damping-off is unlikely to occur in fresh unamended sphagnum peat used in greenhouse and container plantings.

If a damping-off problem is anticipated it is advisable to apply a fungicide at the time of seeding, either as a drench or as a seed treatment. If the likelihood of damping-off is low, it may be wise to withhold treatment until after emergence and to apply chemicals only if the disease appears. Avoid applying chemicals shortly before or during the early stages of emergence since the germinating seedling is very sensitive to chemical injury.

Disorders resembling damping-off

As mentioned previously, there are many causes of seedling mortality other than fungi. The germinating seedling is very sensitive to moisture stress, heat, and chemicals. In greenhouses, problems with early mortality are especially frequent since it is often difficult to regulate moisture in the organic media used, temperatures often rise to critical levels, and low light during winter months causes etiolation, induced dormancy and increased sensitivity to chemicals. Poorly rooted and distorted seedlings frequently occur in greenhouses where the fungicide, captan, has been applied. Temperatures above 30° C, even for a few hours can kill seedlings in the cotyledonary stage. Excessive fertilizer salts in the growing medium can kill newly emerged seedlings, usually by causing a constriction at the base of the stem – a symptom resembling damping-off.

Pre-emergence treatments with herbicides can cause considerable seedling losses, especially if the chemicals leach downward into the region of root absorption. Young seedlings affected by the triazine herbicides first show a straw-yellow discoloration of the cotyledons. This discoloration moves down the stem and kills the primary needle primordia but the roots, where the chemical is absorbed, usually remain white and turgid.

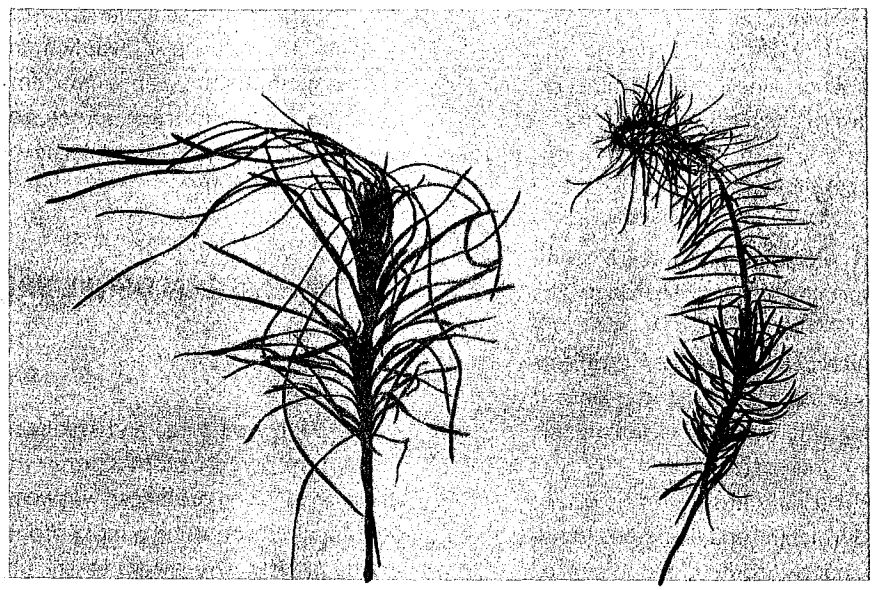
Prevention of seedling injury requires considerable judgment. Provision of adequate light and moisture to ensure speedy establishment is paramount. Use of heavy shades or burlap during the emergence period is a questionable practice although some species may need some shading later. Until seedlings are established, frequent watering is needed to keep the soil surface moist. A mulch of coarse sand, especially on dark soils, is often used to slow down surface evaporation and reduce surface temperatures. Herbicide injury should not occur if seedling establishment is rapid, i.e. before appreciable downward movement of the herbicide. Instances of fungicide injury can be reduced by restricting their use to situations where damping-off is likely to occur and avoiding their application during germination. Since the emerging seedling needs no outside nutrient source, soluble fertilizers should not be applied until the primary needles begin development.

DISEASES IN DENSE SEEDBEDS

Molds

With branching and secondary needle development, a dense canopy forms which restricts air drainage. During prolonged wet weather or in poorly ventilated greenhouses, a mold problem will develop unless preventative measures are undertaken. Most of the molds are weak parasites, that is, they become established on dead or senescent tissues and spread onto healthy seedlings if moist conditions prevail.

Gray mold on red pine seedling



Sirococcus shoot blight on red pine (left) and black spruce (right)

The gray mold fungus, ***Botrytis cinerea***, first becomes established on dead lower needles or on suppressed seedlings. Other common mold fungi — ***Fusarium***, ***Alternaria***, ***Pestalotia***, etc. — can similarly become established in seedbeds.

Shoot blight

Somewhat different from gray mold, in that it attacks succulent shoots rather than senescent tissue is the fungus ***Sirococcus strobilinus***, the cause of shoot blight. It invades juvenile needles and moves into the stem where it causes a small canker. The distal portion of the shoot then collapses, forming a characteristic crook. Tiny black pycnidia form on the affected tissues, and spores from these pycnidia are spread to new shoots by splashing raindrops. Symptom expression occurs within 10-20 days after infection so that during a wet summer, several generations of the fungus can wreck havoc in seedbeds. In the autumn, the later maturing summer shoots of pines can be infected. The fungus has been found on cones of trees surrounding nurseries and this is thought to be one means of overwintering and a source of inoculum in the spring. It has been detected also in recently emerged seedlings and therefore may be seed transmitted.

During warm, dry summers shoot blight is not likely to cause appreciable damage.

Snow blight

In regions of heavy snowfall, snow mold or snow blight often kills or disfigures patches of seedlings. The fungi causing snow blight (***Phacidium*** and related genera) are usually found on the lower branches of spruce and fir in surrounding forests. These produce spores in the autumn which may spread to nurseries, where they germinate and invade the needles after snowfall. The fungus spreads under the snow cover and causes considerable damage especially in parts of the nursery where snowmelt is delayed. In the spring, affected patches of seedlings turn brown and a white mold may be seen on the surface of the foliage.

Control of gray mold, shoot blight, and snow blight

Obviously, reducing seedbed density will minimize most of the above problems. Excessively dense seedbeds should be thinned by removing suppressed seedlings. Containers should be spread out if space permits. If density still presents a hazard and if wet weather prevails, protective sprays of captan, captofol, or chlorothalonil will slow the spread of mold and shoot blight fungi. These may be combined with benomyl or thiabendazole for additional protection.

Snow blight and shoot blight fungi usually spread to the nursery from conifers in nearby windbreaks or forests. Windbreaks of pine or spruce around a nursery engaged in the production of these species are a definite hazard and should be replaced by species not likely to harbor conifer diseases. Plantings of these species can also serve as a protective screen from surrounding forests of spruce, fir, or pine. These precautions will minimize considerably the need to apply fungicides.

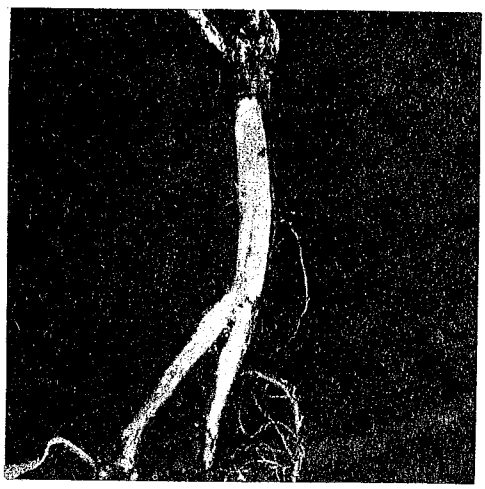
PROBLEMS IN SEEDBED AND TRANSPLANT STOCK

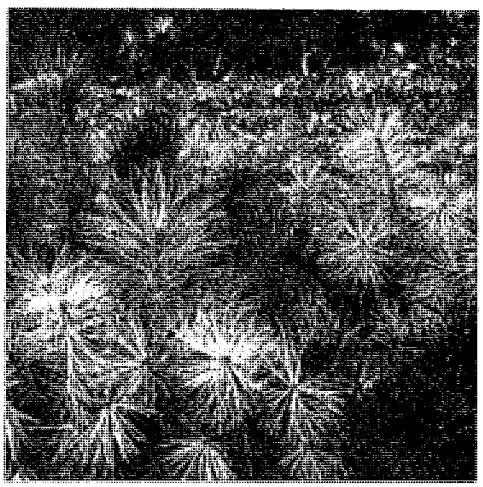
With increasing seedling size, diseases are not so likely to cause mortality as a decline in vigor, loss of root surface, and reduced value for outplanting. As with emerging seedlings, physiological disturbances may be confused with fungus diseases. Nutrient deficiency and toxicity symptoms are especially prevalent among older seedlings and these vary from slight yellowing of foliage (nitrogen deficiency, lime-induced chlorosis, iron deficiency) to reddish and purple foliage discoloration with dieback of needle tips (phosphorus, magnesium or potassium deficiencies, injury by heat or chemicals). Flagging of foliage followed by mortality is often indicative of moisture deficiency or salt injury. Any or all of the above symptoms can be caused by root rots.

Root rots

Root rots are caused by a variety of soil fungi, the most common of which are species

Effects of root rot in a transplant bed





Some symptoms of root rot

of ***Fusarium, Cylindrocarpon, Cylindrocladium, Phythium*** and ***Phytophtora. Fusarium*** and ***Cylindrocarpon*** are prevalent in most cultivated soils but their presence does not necessarily present a root rot hazard. Pathogenic strains are more likely to invade roots of stunted or suppressed seedlings than roots of vigorous, actively growing stock. ***Pythium*** and ***Phytophthora*** invade succulent root tips, especially in wet, poorly aerated soils, and either decay the roots or live inside them parasitically. Often all of these fungi can be found within a single root system but if growth remains vigorous, ensuring continuous root replacement, there is little apparent damage. ***Cylindrocladium scoparium*** and ***Phytophthora cinnamomi*** appear to be more dangerous pathogens, killing large patches of seedlings regardless of vigor. Fortunately these latter fungi have not yet been discovered in the Maritimes.

Parasitic nematodes of the genera ***Pratylenchus, Paratylenchus, Xiphinena*** and ***Tylenchus,*** as well as many soil insects may contribute to root rot problems.

Suberized roots and mycorrhizal short roots are more resistant to infection than long succulent white roots. Inoculation of nursery seedbeds with mycorrhizal fungi may improve seedling growth, in part, by increasing root rot resistance. Root rot problems often begin early in the life of the seedbed when most of the roots are succulent. Since the same fungi that cause damping-off also cause root rots, control of damping-off can do much to lessen later problems.

The standard recommendation for root rot control is that of soil fumigation prior to seeding. This is expensive, and with complete sterilization of the seedbed, the soils may soon be reinvaded by pathogens. Use of a partial sterilant such as dazomet can largely eliminate the reinvasion problem. The selection of well-drained sandy soils for conifer seedlings will do much to minimize root rots and if poor drainage and poor soil aeration is anticipated, tiling and organic matter amendments may partially alleviate the problem.

There are no well developed methods of eliminating root rots in an established crop. Massive dosages of fungicides drenched into the upper 20-30 cm of soil might lower fungus populations but would not eliminate the dormant spores and sclerotia. There are few alternatives other than rigorous culling of seedlings after lifting. After outplanting, the root rots acquired in the nursery may disappear, but the use of such seedlings slows plantation development and increases the rotation age.

Stem cankers

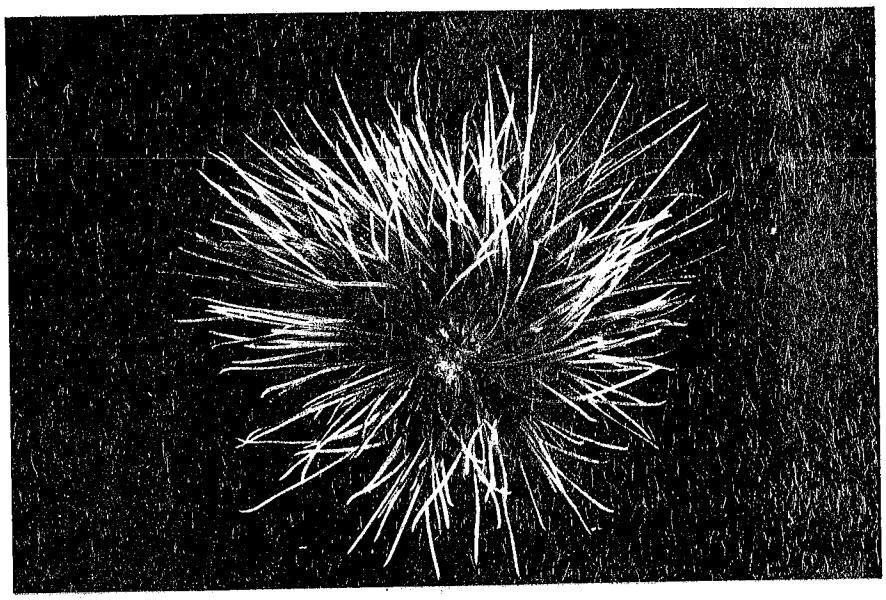
Excessive heat at the soil surface can cause sunscald or heat canker of the lower stem which weakens the root system and provides an entry point for root-and stem-infecting fungi (***Cytospora, Pestalotia, Fusarium***). Roots usually decay quickly after heat canker and the tops soon die, creating a situation closely resembling ***Cylindrocladium*** and ***Phytophthora*** root rots.

Stem-infecting fungi also may invade through needle bases. Previous mention was made of ***Sirococcus strobilinus*** but other fungi in this category are ***Pestalotia*** spp. and ***Gremmeniella abietina*** (***Scleroderris lagerbergii***). ***Scleroderris*** canker is especially dangerous to pines since it may be carried to the plantation and cause considerable destruction there and in surrounding natural regeneration.

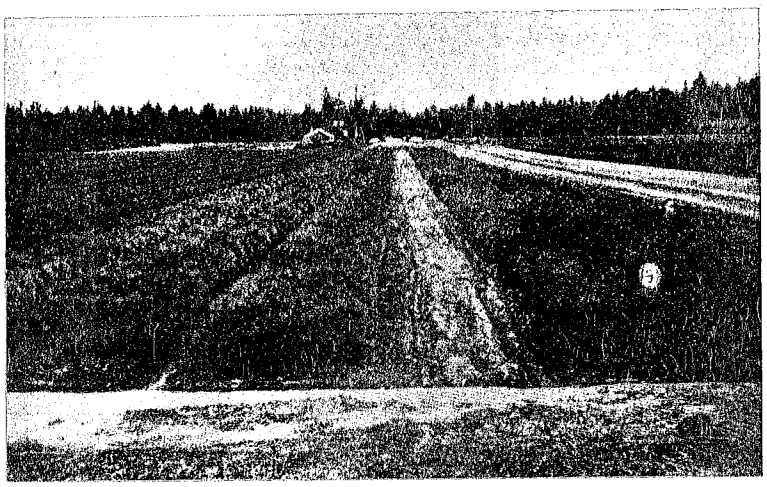
Gremmeniella invades needles or buds and spreads down the twigs and branches into the main stem. Early symptoms are death of buds accompanied by reddish discoloration of needle bases. Cankers on the branches and main stem are surrounded by greenish discoloration in the cambium. As with ***Sirococcus*** and snow-mold fungi, a most likely source of primary infection is from diseased trees around the nursery. This is another reason for sanitation and careful selection of windbreak species. Spores of the fungus are disseminated throughout the spring, summer, and fall, especially during wet weather and infection of nursery stock can be limited by periodic applications of chlorathalonil during the growing season.

Needle casts

Needle casts are another potential threat to nurseries. A particularly virulent strain of ***Lophodermium pinastri***, the pine needle cast fungus, has appeared in the United States and is being spread



Scleroderris canker of pine



Lophodermium needlecast of pine

through widespread movement of nursery stock and Christmas trees. Needle cast first appears as yellow to brown discoloration of older needles along with premature needle fall. Black elongated fruiting bodies later appear on affected needles. Spores are produced throughout the growing season , but the peak period for infection by ***Lophodermium*** is late July to early September. Red, Scotch, and jack pine are most susceptible and sources of primary infection are likely to be from these pines growing around the nursery. Sprays of maneb or chlorothalonil, especially when wet weather prevails, will reduce the amount of infection.

Winter browning

Often confused with needle cast is winter browning. Exposed foliage may become desiccated by winter winds and appear brown in the spring. However, a uniform rather than a scattered needle discoloration should help separate winter browning from needle casts. The seedlings usually recover but their suitability for outplanting is lessened. Frequent winter injury should raise some doubts about the suitability of affected species for the region in which it is being grown.

Rusts

The symptoms and types of damage caused by rusts vary considerably and may not appear until after outplanting. All are obligate parasites (derive their nutrition entirely from the host), and most require two unrelated hosts to complete their life cycle. Spore masses of the fungi often have a reddish color — hence the name rusts. Stem rusts (***Cronartium*** spp., ***Endocronartium harknessii***) cause galls, blisters, or cankers on stems and branches. Needle rusts (***Chrysomyxa, Coleosporium, Pucciniastrum***) are usually confined to needle surfaces.

Control of rusts through the use of fungicides has not been adequately tested to make recommendations. In nurseries, control should be relatively easy through removal of local alternate hosts. Needle rusts of spruce (***Chrysomyxa*** spp.) have labrador-tea as the main alternate host. Needle rust of hard pines (***Coleosporium solidaginis***) is spread from asters and goldenrods. White pine blister rust (***Cronartium ribicola***) completes part of its life cycle on currants and gooseberries. Sweet-fern blister rust (***Cronartium comptoniae***) on hard pines has sweet-fern and sweet gale as alternate hosts. ***Endocronartium*** (***Peridermium***) gall rust of jack and Scotch pines has no alternate host but may persist on pines surrounding the nursery. Other alternate hosts of conifer rusts are oaks, poplars, ferns, raspberries, and blueberries (see Appendix III).

STORAGE MOLDS

Many of the fungi that overrun seedlings in cold storage originate in the nursery (***Botrytis, Fusarium, Phacidium, Rhizoctonia, Pythium***), while others are common airborne contaminants.

The tendency to mold decreases with temperature so that seedlings held in frozen storage seldom mold. However, severe molding can occur during the thawing-out period. Packing seedlings in sphagnum moss is thought to suppress molds. Application of a fungicidal spray (captan, benomyl, thiophanate) prior to lifting has been found to increase outplanting survival after storage, presumably through suppression of molds. Dipping of seedlings in fungicidal suspensions prior to storage also has been recommended.

LOSSES IN OVERWINTERED CONTAINER STOCK

Much of the summer-grown container stock is now overwintered outdoors, either in the original container or in "Nissula" rolls. Considerable losses result from this practice. Although snow blight is a potential problem, most recent losses appeared to have been the result of winter drying. Unfortunately, the taller and more exposed seedlings were usually most damaged, contributing to genetic depauperization of the stock.

Container stock is usually fed liquid fertilizers which are relatively high in nitrogen. This may be appropriate for the first few weeks of growth, but the levels of nitrogen should then be reduced to increase the root-shoot ratio and facilitate hardening-off. Removal from the greenhouse well before the autumn months will expose seedlings to gradual reductions in temperature and daylength and speed up the hardening-off process.

Some protection of overwintered seedlings such as that provided by lathe houses would greatly reduce losses. Overwintered seedlings should be placed on the ground to slow down the desiccation of

the roots. In regions with heavy snowfall, periodic sprays with fungicides during the fall should limit the possibility of snow blights. Spruce or fir branches should not be placed over seedlings as these are potential sources of disease inoculum.

DISEASE CONTROL THROUGH NORMAL MANAGEMENT PRACTICES

It can be seen from the previous discussion that all of the common diseases are subject to natural controls involving weather, host resistance, other microorganisms, and soil characteristics. Various management practices can do much to prevent the breakdown of these natural controls; also, management schemes other than chemical control can do much to reduce the availability of disease inoculum. Although situations vary considerably from region to region, certain well established rules apply to most nursery sites.

Selection of the nursery site

This section may be of little value to established nurseries, but since site is so critical in disease control, some important points must be considered.

The nursery should be located in the same ecoregion as the seed sources and planting sites in order to ensure that the planting stock is adapted to the local climate and possesses a certain degree of resistance to many of the native diseases.

Somewhat contrary to the above criterion, the nursery should ***not*** be surrounded by trees of the same species as those grown in the nursery or by alternate hosts of conifer rusts. Conifers in the vicinity of the nursery must, at least, be disease-free and well adapted to the site. Hosts of rusts should, at least, be in locations where weed control can be practiced.

Conifer nurseries must be located on deep, well-drained, sandy soils free of underlying hardpans or clay seams in order to minimize root rot problems and to facilitate early access to the land in the spring.

It is advisable not to locate nurseries on former agricultural lands. These are sources of weeds and the common root rot and damping-off fungi. Because of the danger from atmospheric pollutants such as sulfur dioxide, it is likewise advisable not to locate near industrial centres.

Many of the above criteria may not apply to greenhouses producing container stock. However, ventilation systems in greenhouses do not eliminate air-borne spores and toxic gases, so the local environment also should be considered for container operations.

Sanitation practices

In a confined area such as a nursery, it should be feasible to eliminate many sources of disease inoculum within the immediate surroundings. Also, it should not be too expensive to remove suppressed and probably diseased seedlings from the seedbeds during routine thinning and weeding operations. These practices will do much to prevent serious outbreaks of disease.

Windbreak or nearby forest trees that may harbor disease have been mentioned in previous sections. Red, Scotch, and jack pines can be sources of ***Lophodermium*** and ***Scleroderris***. Scotch and jack pine may harbor ***Peridermium*** gall rust. The spruces and pines can be sources of ***Sirococcus***. The lower branches of spruce-fir thickets could harbor snow-mold fungi. If these species surround the nursery they should be inspected regularly for diseases and lower branches and suppressed trees should be removed. Those trees close to seedbeds should be cut and replaced by unrelated windbreak species. Potentially good windbreak species are pea shrub and Russian olive — unless these species are to be produced as nursery stock. Diseases reported on windbreak and ornamental species are listed in Appendix II.

Alternate hosts of rust diseases are numerous and are listed in Appendix III. Rusts that have caused problems in nurseries or plantations in eastern North America are the spruce needle rust (alternate hosts, labrador-tea), sweet-fern blister rust (alternate hosts, sweet-fern and sweet gale), white pine blister rust (alternate hosts, currants and gooseberries), and balsam fir needle rusts (alternate hosts, blueberry, fireweed, chickweeds, and ferns).

Removal of diseased seedlings or potential disease reservoirs in nursery beds is a very important sanitation practice that can be combined with weeding and thinning. Even if no specific disease symptoms are apparent, crowded and suppressed seedlings may be assumed to have root rot and are likely epicenters for gray mold. It is best to remove them before they become sources of inoculum for surrounding seedlings.

Imported seedlings are potential sources of new diseases and should not be planted in or near the nursery.

DO NOT PLANT CONIFER WINDBREAKS AROUND A CONIFER NURSERY

Soil management

Drainage, texture, organic matter, fertility, pH, and nutrient balance all affect disease incidence, often in such complex ways that it is difficult to generalize.

Adequate drainage is paramount, especially for conifer nurseries. Otherwise, poor aeration of root systems will result in root rot and nutritional problems. Underlying hardpans should be broken up and low spots either tile drained or removed from production. In fine textured soils, low permeability may be a problem and intense sunlight after rains or irrigation may bake the soil surface and restrict root aeration.

Soil texture may be improved through addition of organic matter. This is an essential practice in most nurseries but it must be remembered that decomposing organic amendments tie up nutrients, stimulate the activity of soil fungi, and may even have a direct toxic effect on roots. A fallow period of one to several months is advisable after organic amendments.

Maintainence of well-balanced nutrient levels in nursery soils is especially important in combatting diseases of senescent or low vigor stock such as root rots and stem cankers. Excessive levels of certain nutrients can be very deleterious at certain stages of production. For instance, high nitrogen can render germinating seedlings more susceptible to damping-off. It is better to apply fertilizers to the growing crop than before sowing unless slow release fertilizers are used.

Conifer damping-off is usually less prevalent in acid soils than in neutral or alkaline soils. Therefore, it is seldom necessary to lime forest nurseries and in fact, many nursery soils need to be acidified.

GOOD DRAINAGE, SLIGHTLY ACID pH, AND WELL-BALANCED SOIL FERTILITY ARE IMPORTANT IN DAMPING-OFF AND ROOT ROT CONTROL

This may be done by applying sphagnum peat or by drenching with sulfuric or phosphoric acids. The latter treatments, though drastic, will also destroy many pathogens. Soils should not be acidified to much less than pH 4.5 and acidification should not be necessary unless the pH exceeds 6.0.

Cover crops are often planted after lifting to prevent soil erosion and to augment organic matter levels. There are many conflicting reports on the effects of different cover crops on specific soil-borne diseases so that no particular crop can be recommended to suppress any of the root rot and damping-off fungi. After any cover crop, a fallow period is necessary to allow decomposition, release of nutrients, and stabilization of soil fungus populations.

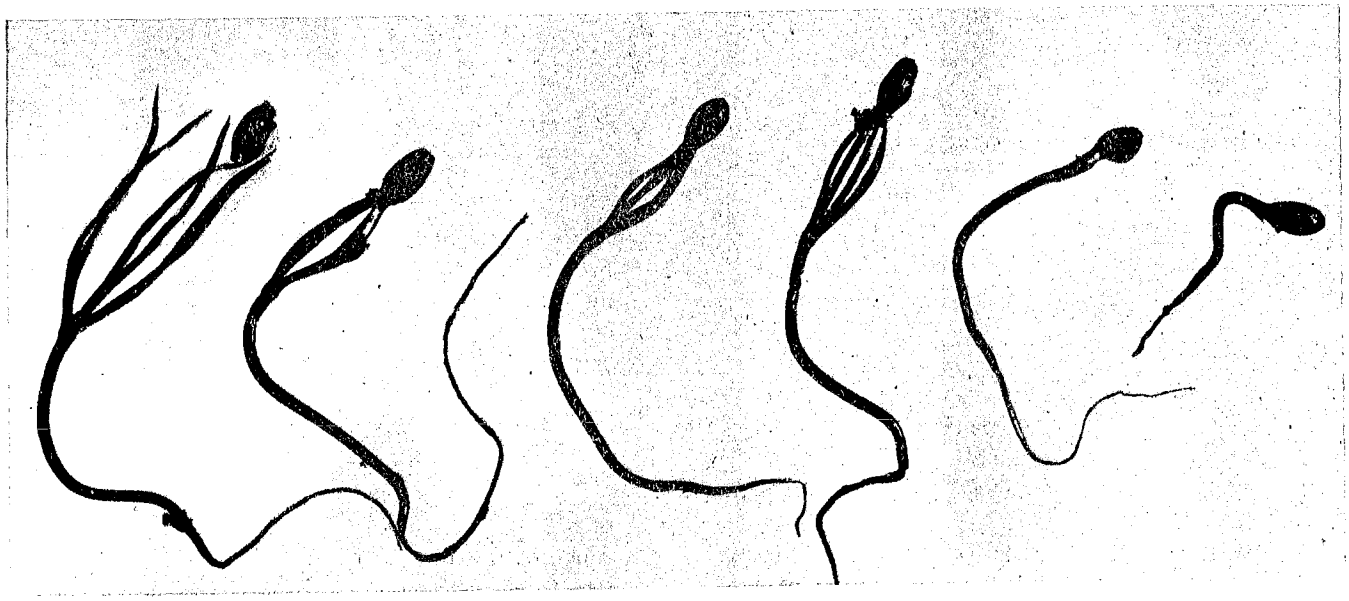
DO NOT PLANT IMMEDIATELY AFTER PLOUGHING DOWN COVER CROPS OR ORGANIC AMENDMENTS

CHEMICAL CONTROL

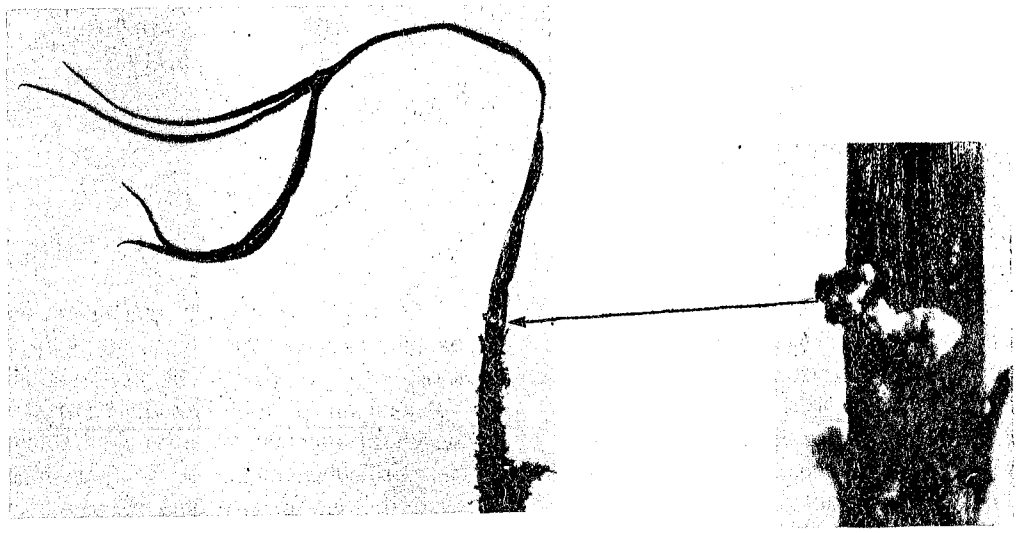
Pesticides are toxic chemicals and must be handled as such. Data on their toxicity are based on short-term responses of laboratory animals and do not take into account their long-term effects on living systems. Protective clothing, masks, and gloves should be worn when mixing or applying these materials, even if their toxicity data indicate relatively little danger. In any case, read the label and follow the recommendations in the pesticide safety handbook.

The stages of seedling development that may require fungicide treatment together with appropriate fungicides are listed in Appendix V. Trade names and chemical structures are given in Appendix IV. It is important to note that formulations containing the same active ingredients are not necessarily the same. The so-called inert ingredients of a formulation are not entirely inert since they contain adjuvants – spreaders, stickers, and agents that enhance plant penetration or mobility through the soil.

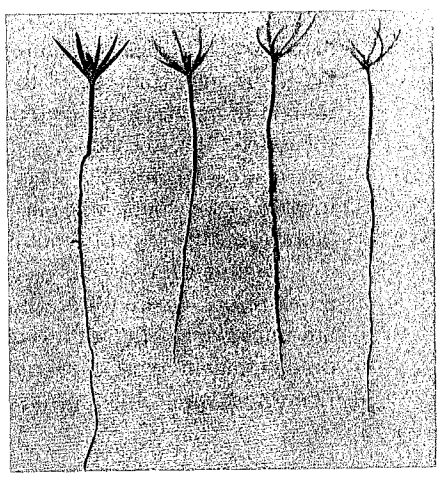
The regular use of fungicides should be considered a last resort, where other disease prevention methods are impossible. The need to use them should be fairly predictable in most nurseries. Damping-off is most likely to be a problem on soils with a long history of



Captan injury



Salt injury



Injury suspected to be due
to triazine herbicides

cultivation, especially old farms. Gray mold is a threat only in dense seedbeds during wet weather or in poorly ventilated greenhouses. ***Sircoccus*** shoot blight seems to be a problem only in damp cool summers. Snow-blights are likely to occur only in regions of heavy snowfall. The probability of needle casts, rusts, shoot blight, ***Scleroderris*** canker and snow blight increases with the frequency of host species around the nursery.

Soil fumigation

Fumigation or sterilization is necessary only where serious root rot, nematode, or weed problems hamper production. The operation is expensive, time-consuming, and hazardous to the operator. If not done properly, seedling losses can result.

Most soils contain a complex association of bacteria and fungi which tend to hold the root rot and damping-off fungi in check. If a fumigant destroys most components of this association, it is vulnerable to reinvasion by rapidly growing fungi. If these rapidly growing fungi happen to be pathogens, a serious damping-off problem can result. Damping-off due to ***Rhizoctonia solani*** has caused losses most frequently in seedbeds fumigated with methyl bromide, vapam, and vorlex in Maritime nurseries. Contamination probably occurred from wind-blown soil from other parts of the nursery, or from soil moved by splashing rain water, irrigation water, or cultivating equipment. If broad-spectrum fumigants are used, further protective measures against damping-off may be necessary.

The problem of reinvasion by pathogens may be circumvented by the use of partial or slow-release sterilants. Dazomet at 200-300 kg a.i./ha will destroy most damping-off and root rot fungi, nematodes, and weed seeds but will leave a residual population of bacteria and other antagonists as checks against re-invasion. Older materials with a similar effect are allyl alcohol and formaldehyde.

Fumigants should be applied at least three weeks prior to seeding; during cold weather a longer waiting period is necessary. To determine if residual toxicity is a threat to tree seed, soils may be tested by germinating seeds of radish or other rapidly germinating species in representative samples.

The method of application will vary with the material used. Highly volatile fumigants such as methyl bromide or chloropicrin must be injected into the soil, and the seedbeds then covered with plastic.

UNNECESSARY OR EXCESSIVE USE OF CHEMICALS CAN CAUSE AS MUCH DAMAGE AS THE TARGET DISEASES.

For vapam or vorlex, a water seal applied immediately after injection is usually adequate. Dazomet may be applied as a broadcast treatment, then worked into the soil and water-sealed.

Seed treatment

Pelleting of seed with fungicides has been a standard practice in some nurseries for protection of emerging seedlings against damping-off. Insecticides, bird repellants, and rodent repellants may be included in the treatment. Since insufficient material will adhere to seeds to give adequate protection, a sticker must be used. The common stickers are methyl cellulose (methocel) at 100-200 ml of 4% suspension per kg of seed, or latex (Dow Latex 612) at 300-400 ml of 10% suspension per kg. The seed is uniformly wetted with the sticker, the fungicide is added, and the resulting slurry is rotated in a flask or drum until the seeds are uniformly coated. The seeds should then be spread out to dry before sowing.

The quantity of fungicide to be applied usually varies between 0.1-1 kg per kg of seed. Lower rates may be ineffective and higher rates may cause seedling injury. The fungicides generally applied are thiram (Arasan) and captan.

Seed pelleting will almost always delay germination and can injure the germinating seedling. Therefore, the practice should be carried out only for seedbeds that have a history of damping-off. It is not necessary to treat seeds for dazomet-treated seedbeds or for container plantings where fresh sphagnum peat is to be used. Likewise, it is unnecessary if a pre-emergence fungicide drench is to be used.

The effects of seed treatment will last for only a short time after emergence. If a severe damping-off problem exists, postemergence drenches may be necessary in addition to seed pelleting. However, it should first be determined if postemergence mortality is damping-off (rotting of seedlings) or fungicide injury (yellowing, twisting of cotyledons, poor root growth).

Seedbed drenching

Drenching implies the application of fungicide in large volumes of water to achieve penetration of the upper 2-3 cm of soil. Since this may not be feasible in most nurseries, fungicides may be sprayed or dusted onto the soil surface and penetration achieved through normal rainfall or irrigation. A pre-emergence drench is a convenient substitute for seed treatment and will require similar quantities of material per hectare. To minimize seedling injury, pre-emergence treatments should be applied immediately after sowing rather than during the interval between sowing and emergence.

Post-emergence treatments may be applied if damping-off or root rot problems are anticipated or if a few damped-off seedlings are found in the seedbeds. Soils that have been sterilized with methyl bromide, vapam, or other broad-spectrum fumigants may require such treatments. It is unlikely that either pre- or post-emergence drenches will be required in dazomet-treated seedbeds, recently cleared forest soils, or container plantings using sphagnum peat as a medium.

As with seed treatment, captan or thiram (wettable powders) may be used for seedbed drenching. However, both of these materials can be phytotoxic and may soon be replaced by newer products. Ethazole, chloroneb, or the thiophanates are very promising in this respect but since they have much narrower fungicidal spectra than either captan or thiram they may provide protection against only one or two species of damping-off fungi. For this reason, combinations such as ethazole plus thiophanate methyl, chloroneb plus thiophanate methyl, or chloroneb + benomyl are suggested. These should each be applied at 5-20 kg a.i./ha, depending on the severity of the damping-off problem.

Foliar sprays

In the absence of adequate sanitation or in dense seedbeds, protection against foliage and stem diseases may be required. Fungicides may be sprayed onto the growing stock in 1-3 kL of water/ha throughout the growing season for prevention of gray mold, shoot blight, needle casts and *Scleroderris* canker or during the fall months for snow blights. Sufficient pressure must be used to ensure penetration of the foliage and the deposit of fungicide should have dried on the surface before rains or irrigation. Most of the surface protectants (captan, captofol, chlorothalonil, maneb) will remain effective for about two weeks while the systemics (benomyl, thiabendazole, thiophanate) may provide longer protection against some diseases. However, the systemics have not been found to be very effective against several of the conifer seedling diseases and, if applied, should be used only in combination with one of the protectants.

During prolonged hot dry weather, foliar sprays should not be necessary as conditions are not suitable for spore dispersal and infection.

SUMMARY

Disease control in the forest nursery involves all aspects of management. The first step in control is in the selection of the nursery site, ensuring that the species and seed sources to be grown are adapted to the local climate and soils and that uncontrollable sources of disease inoculum or atmospheric pollutants are not present in the vicinity. The next step is the improvement of the site through modifications of soil drainage, structure, and pH and by removing sources of disease inoculum around the nursery. These two steps should prevent most of the presently known disease problems but if fungus diseases still threaten production, chemical control will be necessary, either in the form of soil sterilization or by the direct application of fungicides to seed, seedbeds, or growing stock.

More specific points are re-emphasized as follows:

DO NOT ESTABLISH NURSERIES ON OLD FARMS, ORCHARDS, OR NEAR MANUFACTURING PLANTS.

DO NOT ESTABLISH NURSERIES ON HEAVY, POORLY DRAINED, OR ALKALINE SOILS.

DO NOT PLANT PINE OR SPRUCE WINDBREAKS AROUND THE NURSERY.

DO NOT PLANT IMPORTED STOCK IN THE NURSERY.

DO NOT PLANT SEED OR TRANSPLANT STOCK IMMEDIATELY AFTER PLOUGHING DOWN COVER CROPS OR ORGANIC AMENDMENTS.

DO NOT TRANSPLANT CULL SEEDLINGS IN THE NURSERY.

DO NOT APPLY LIQUID OR SOLUBLE FERTILIZERS UNTIL WELL AFTER EMERGENCE.

PRACTICE GOOD WEED CONTROL IN THE VICINITY OF THE NURSERY.

THIN DENSE SEEDBEDS, REMOVING STUNTED OR DISCOLORED SEEDLINGS.

CULL OUT STUNTED, DISCOLORED, OR POORLY ROOTED SEEDLINGS BEFORE TRANSPLANTING OR SHIPPING.

KEEP GREENHOUSES WELL VENTILATED, WITH TEMPERATURES BETWEEN 15° AND 30° C, AND WITH PHOTOPERIODS OF 16-18 HOURS PER DAY.

BE SURE CONTAINER STOCK IS HARDENED-OFF BEFORE OVERWINTERING.

IF THE SEEDBED AREAS HAVE A HISTORY OF DAMPING-OFF, SEEDS SHOULD BE PELLETTED WITH A FUNGICIDE OR SEEDBEDS DRENCHED IMMEDIATELY AFTER SOWING.

IT IS USUALLY NOT NECESSARY TO APPLY FUNGICIDES TO CONTAINER PLANTINGS ON FRESH SPHAGNUM PEAT TO CONTROL DAMPING-OFF.

IF, AFTER EMERGENCE, SMALL PATCHES OF DAMPED-OFF SEEDLINGS APPEAR, A FUNGICIDE DRENCH SHOULD BE APPLIED.

IF WET WEATHER PREVAILS, SPRAYS AT 10-15-DAY INTERVALS ARE RECOMMENDED FOR THE CONTROL OF GRAY MOLD, SHOOT BLIGHT, NEEDLE CASTS, SCLERODERRIS CANKER, AND SNOW BLIGHT DURING THE SUMMER AND FALL MONTHS.

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GLOSSARY

adjuvant — an agent that enhances or modifies the action of the active ingredient in a pesticide formulation.

bacteria — microscopic, single celled organisms, generally lacking photosynthetic ability.

blister rust — a stem rust disease causing resinous or bleeding cankers, e.g. white pine blister rust caused by ***Cronartium ribicola.***

cambium — the meristematic region between the bark and the xylem (wood) of a tree.

canker — a disease symptom characterized by dead bark or cambium; a patch of dead bark; a stem disfiguration.

cortex — in roots and stems, the cylinder of primary tissue surrounding the vascular tissues.

cotyledons — the seed leaves, i.e. the first leaves appearing on a germinating seedling.

damping-off — death of germinating seedlings, usually through attack and destruction by fungi; seed (ling) rot; seedling blight.

dormancy — a state of inactivity; a rest period during which seeds or spores will not germinate or buds will not open.

ecoregion — a region characterized by a certain climate and vegetation.

epidermis — the outer layer or skin of leaves or stems, replaced by bark after secondary thickening of woody stems.

foliar — applied to or pertaining to leaves or foliage. Foliar treatments in forest nurseries generally refer to any treatment of above ground parts.

fumigant — a gas used to fumigate (disinfect, destroy) organisms in soil, etc. Some fumigants are liquids or solids which release a gas after application.

fungi — plant-like organisms lacking photosynthetic ability and relying on other organisms, living or dead, for nutrition.

fungicide — a chemical poison used to kill or inactivate fungi. Usually a combination of an active ingredient (poison) plus inert filler and adjuvants (stickers, wetting agents).

gall — a swelling on stems or leaves caused by fungi (e.g. ***Cronartium*** spp.), bacteria, viruses, insects, mites, or genetic abnormalities.

genetic — hereditary; transmitted from parents through the genes.

gram (g) — 0.036 oz; 1 g/liter = 0.16 oz/gal = 10 lb/100 gal; 1 g/m^2 = 8.9 lb/acre.

gray mold — a growth of fungi over patches of seedlings; usually caused by ***Botrytis.***

green manure — a crop ploughed down to build up levels of soil organic matter.

heat canker — damage to bark or epidermal tissues by radiation; commonly occurring immediately above the soil line, especially on seedlings growing on dark soils with poor thermal conductivity.

hectare (ha) — 2.47 acres.

hypha — a single strand of fungus mycelium; may lack cross-walls (aseptate, coenocytic) as in ***Pythium*** and ***Phytophthora*** or have cross-walls (septae) as in most other fungi.

inoculum — spores or other propagating units that cause new infections.

litre (L) — 0.845 Imp. qt. = 0.22 Imp. gal., 1L/ha = 0.089 gal/acre.

meristems — tissues capable of cell division and growth, e.g. the cambium or growing tip.

methyl cellulose — a sticker used for pelleting seed with fungicides.

microsclerotia — small sclerotia; dormant clumps of fungus hyphae resistant to drought, frost, chemicals, etc.

mold, mould — a fungus, particularly a mass of fungus hyphae and spores visible to the naked eye.

mycelium — the vegetative body of a fungus, consisting of hyphae.

mycorrhizal — having mycorrhizae or a symbiotic association of fungi and roots; usually characterized by short, dichotomously branched rootlets.

needle casts — a group of diseases characterized by needle discoloration, early casting of needles, and particular locular fungus fruiting bodies belonging to the genera ***Lophodermium, Hyodermella, Bifusella, Hypoderma,*** and ***Elytroderma.***

nematodes — tiny roundworms inhabiting soils, water or plant tissues; some are parasitic on plants causing root lesions, root knots, or other injuries; some may enhance the damage caused by root-rot fungi and others may feed on mycorrhizal fungi. Some genera parasitic to plants are ***Pratylenchus, Paratylenchus, Tylenchus, Meloidogyne,*** and ***Xiphinema.***

Nitrogenous — containing nitrogen (N). The major nitrogenous fertilizers are ammonium (NH^+) or nitrate (NO_3^-) compounds.

parasite — an organism which derives its nutrition from another organism.

partial sterilant — a chemical which eliminates only part of the microbial population of a soil.

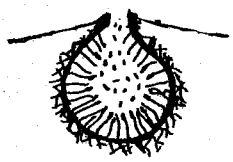
pathogen — an agent which incites disease; usually refers to a living organism or a virus.

pelleting — the formation of a thick coating of fungicide or other material onto seed, usually with the aid of a sticker.

phycomycetes — a large group of fungi characterized by aseptate hyphae (hyphae without cross-walls); includes the damping-off fungi ***Pythium*** and ***Phytophthora***.

protectant — with respect to fungicides, a formulation which prevents infection by a fungus, usually by forming a chemical barrier on the surface of the plant.

pycnidia — tiny flask shaped structures bearing spores; often partly embedded in host tissue.

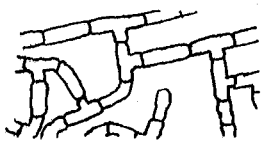


rusts — a large group of parasitic fungi, so named because spore masses of many species have a reddish color; rusts have very complex life cycles, most species requiring two hosts.

saprophyte — an organism deriving its nutrition from dead and decaying tissue.

sclerotia — dormant structures consisting of tightly woven hyphae; formed by ***Rhizoctonia, Botrytis, Cylindrocladium***, and many other fungi and found in the soil and decaying plant tissue.

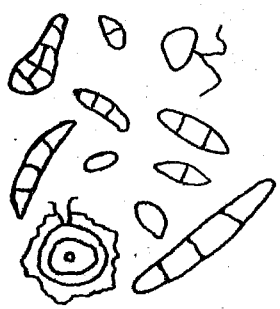
septate — having septae or cross-walls, usually with reference to fungus hyphae.



shoot blight — death of twigs, terminals, or current year's growth.

snow blight or snow mold — infection and mortality of seedlings under winter snows; caused by several different fungi, mostly in the genus ***Phacidium*** and related genera.

spores — reproductive structures of fungi consisting of one to several cells; types of fungus spores include conidia, oospores, zoospores, ascospores, basidiospores, etc. Spores germinate to produce hyphae.



stele — the central conducting tissue of a root, consisting of xylem (upward conducting vessels or tracheids) and phloem (downward conducting cells).

suberized — having a protective layer of corky cells.

succulent — with respect to tissues, soft, unsuberized, and growing; usually turgid and easily damaged.

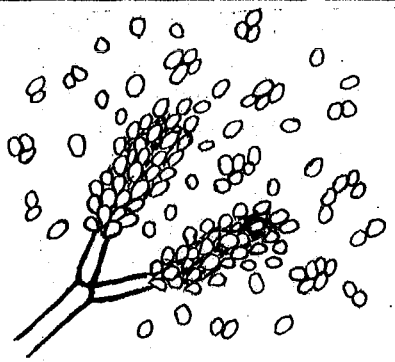
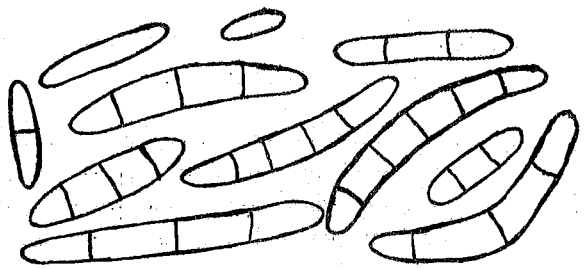
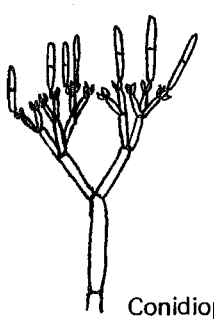
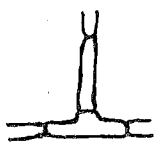
symptoms — the expression or signs of a disease; common symptoms are decays, blights, diebacks, cankers, and lesions.

systemic — translocated within the plant to tissues away from the point of application; a systemic fungicide applied to the roots may thus protect the foliage.

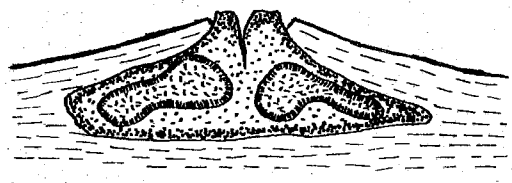
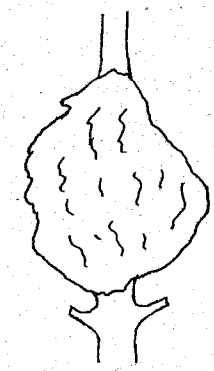
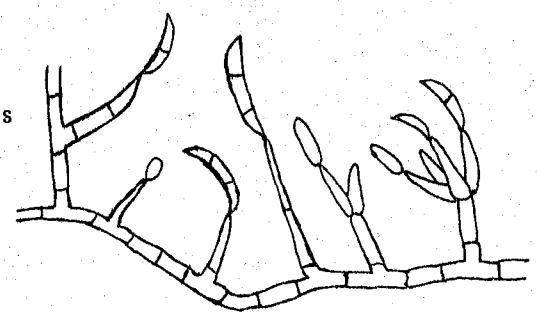
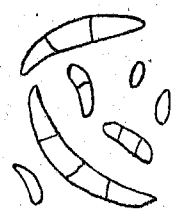
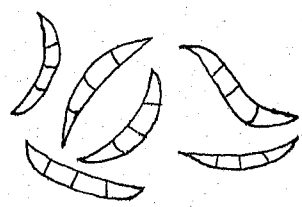
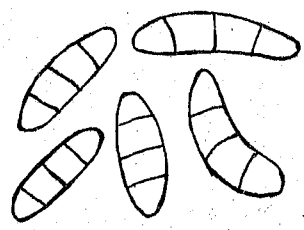
triazine — a group of herbicides including simazine, atrazine, and propazine.

APPENDIX I

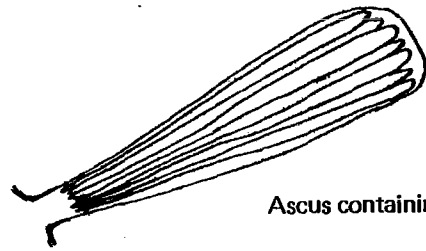
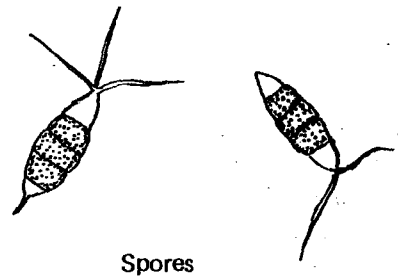
Some fungi causing diseases in conifer seedlings

Names	Diseases	Structural features
Botrytis cinerea Pers. ex Fr. (***Sclerotinia fuckeliana*** (De By) Fckl.)	Gray mold Storage molds	 Conidiophore and spores, x 200
Chrysomyxa spp.	Spruce needle rusts	
Coleosporium spp.	Pine needle rusts	
Cronartium comptoniae Arth.	Sweet-fern needle rusts	
Cronartium ribicola J.C. Fischer	White pine blister rust	
Cylindrocarpon spp.	Root rots	 Spores, x 500
Cylindrocladium scoparium Morgan	Root rot Damping-off Needle blight Stem cankers	  Mycelium Conidiophore and spores

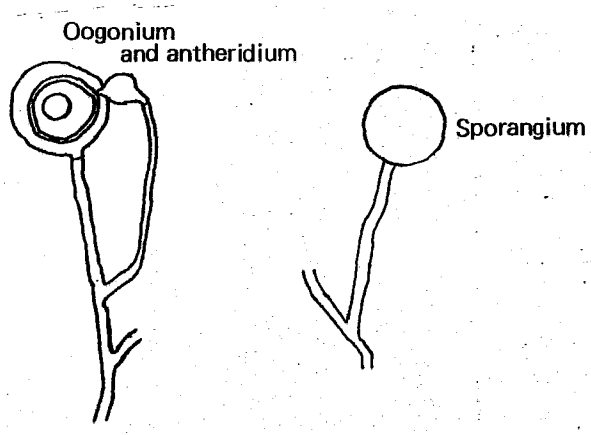
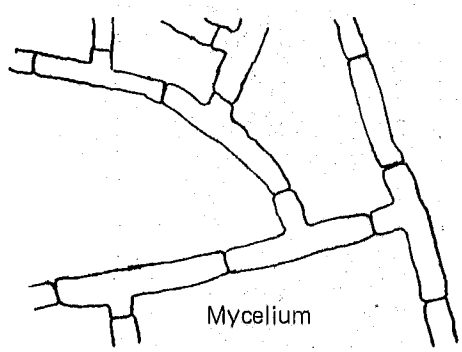
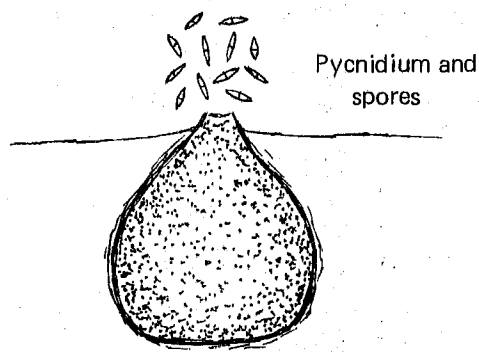
APPENDIX I (continued)

Names	Diseases	Structural features
Cytospora spp. (***Valsa*** spp.)	Stem cankers	 Pycnidium embedded in host tissue  Conidiophore and spores
Endocronartium harknessii (J.P. Moore) Y. Hiratsuka (***Peridermium harknessii*** Moore)	Pine gall rust	 Branch gall, x 1
Fusarium oxysporum Schlecht.	Damping-off Root rot Top molds Storage molds	  Mycelium and spor
Gremmeniella abietina (Lagerb.) Morlet (***Scleroderris lagerbergil*** Gremmen)	***Scleroderris*** canker of pines	 Conidia, x 700  Ascospores, x 1200

APPENDIX I (continued)

Names	Diseases	Structural features
Lophodermium pinastri (Schrad. ex Hook.) Chev.	Pine needle cast	 Ascus containing ascospores
Pestalotia funerea Desm. (***Pestalozzia funerea*** Desm.)	Needle blight	 Spores
Phacidium infestans Karst.	Snow blight	
Phytophthora spp.	Root rots Damping-off Stem canker	

APPENDIX I (continued)

Names	Diseases	Structural features
Pucciniastrum spp.	Balsam-fir needle rust	
Pythium spp.	Damping-off Root rots	
Rhizoctonia solani Kühn (***Corticium solani***, ***Pellicularia filamentosa***)	Damping-off Sore shin Storage molds	
Sirococcus strobilinus Preuss. (***Ascochyta piniperda*** Lindau)	Shoot blight of pines, spruces and hemlocks	

APPENDIX II

Potential fungus diseases of trees and shrubs which may be found in and around forest nurseries.[1]

Common and scientific names	Potential disease fungi	Major symptoms
Alder	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Alnus crispa (Ait.) Pursh	***Cenangium furfuraceum*** (Roth) Sacc.	Canker
A. rubra Bong.	***Cytospora*** spp.	Cankers, diebacks
A. rugosa (Du roi) Spreng.	***Didymosphaeria oregonensis*** Goodding	Canker
A. tenuifolia Nutt.	***Erysiphe aggregata*** (Pk.) Farl.	Powdery mildew
	Godronia cassandrae Groves	Canker
	Melanconis spp.	Canker, dieback
	Nectria cinnabarina Tode ex Fr.	Dieback
	Phyllactinia guttata (Fr.) Lev.	Powdery mildew
	Septoria spp.	Leaf spots
	Taphrina spp.	Leaf blisters
Ash	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Faxinus americana L.	***Cylindrosporium faxini*** (Ell. & Kell.) Ell. & Ev.	Leaf spot
F. nigra Marsh	***Discula quercina*** (West.) Arx.	Anthracnose
F. pennsylvanica Marsh	***Fusarium oxysporum*** Schlecht.	Damping-off
	Mycosphaerella spp.	Leaf spots
	Puccinia sparganioides Ell. & Barth.	Leaf rust
Basswood	***Cercospora microspora*** Sacc.	Leaf spot
Tilia americana L.	***Diaporthe tiliaceae*** (Ell.) Hohn.	Canker
	Discula quercina (West.) Arx.	Anthracnose
	Gnomonia tiliae Oud.	Leaf spot
	Uncinula clintonii Pk.	Powdery mildew
Beech	***Chondrostereum purpureum*** (Pers. ex Fr.) Pouzar	Silver leaf
Fagus grandifolia Ehrh	***Discula quercina*** (West.) Arx.	Anthracnose
	Gonatorrhodiella highlei A.L. Sm.	Brown mold
	Microsphaera penicillata (Wallr. ex Fr.) Lev.	Powdery mildew
	Nectria spp.	Cankers
	Phyllactinia guttata (Fr.) Lev.	Powdery mildew
Birch	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Betula alleghaniensis Britt	***Chondrostereum purpureum*** (Pers. ex Fr.) Pouzar	Silver leaf
B. papyrifera Marsh.	***Cylindrosporella*** spp.	Leaf spots
B. pendula Roth	***Dothidella betulina*** (Fr.) Sacc.	Twig blight
B. populifolia Marsh	***Gloeosporium betulicola*** Sacc. & Dearn.	Anthracnose
	Godronia spp.	Cankers, diebacks
	Melanconis spp.	Blights, cankers
	Melanconium spp.	Twig blights
	Melampsoridium betulinum (Fr.) Kleb.	Leaf rust
	Phyllactinia guttata (Fr.) Lev.	Powdery mildew
	Septoria spp.	Leaf spots
	Taphrina spp.	Leaf blisters
	Valsa spp.	Cankers, diebacks

APPENDIX II (continued)

Common and scientific names	Potential disease fungi	Major symptoms
Black locust	***Cucurbitaria elongata*** (Fr.) Grev.	Canker
Robinia pseudo-acacia L.	***Nectria cinnabarina*** (Tode ex Fr.) Fr.	Canker, dieback
Butternut	***Gnomonia leptostyla*** (Fr.) Ces. & deNot.	Leaf spot
Juglans cinerea L.	***Melanconis juglandis*** (Ell. & Ev.) Graves	Dieback
	Microstroma juglandis (Bereng.) Sacc.	White mold
	Phyllactinia guttata (Fr.) Lev.	Powdery mildew
	Sirococcus spp.	Blight
Cedar	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Thuja occidentalis L.	***Didymascella thujina*** (Durand) Maire	Needle blight
T. orientalis L.	***Lophodermium thuyae*** Davis	Needle spot
	Phacidium abietis (Dearn.) Reid & Cain	Snow blight
	Phomopsis juniperovera Hahn	Blight
Cherry	***Coccomyces hiemalis*** Higgins	Shot hole
Prunus pennsylvanica L.	***Dibotryon morbosum*** (Schw.) Th. & Syd.	Black knot
P. serotina Ehrh.	***Podosphaera clandestina*** (Wallr. ex Fr.) Lev.	Powdery mildew
P. virginiana L.	***Taphrina*** spp.	Leaf curl
Crabapple	***Coniothyrium pirinum*** (Sacc.) Sheldon	Frog-eye spot
Malus spp.	***Gymnosporangium*** spp.	Rusts
	Nectria cinnabarina (Tode ex Fr.) Fr.	Dieback
	Podosphaera spp.	Powdery mildew
	Venturia inaequalis (Cke.) Winter	Scab
Currant	***Botrytis cinerea*** Pers. ex Fr.	Gray mold
Ribes spp.	***Cronartium ribicola*** J.C. Fisch.	Rust
	Drepanopeziza ribis (Kleb.) Hohn.	Anthracnose
	Mycosphaerella ribis (Fckl.) Feltg.	Leaf spot
	Puccinia caricina DC.	Rust
	Septoria sanguinea (Dearn.)	Leaf spot
	Sphaerotheca spp.	Powdery mildew
Douglas fir	***Aleurodiscus amorphus*** (Pers. ex Fr.) Schroet.	Canker
Pseudotsuga menzeisii	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
(Mirb.) Franco	***Chondrostereum purpureum*** (Pers. ex Fr.) Pouzar	Silver leaf
	Cylindrocarpon destructans Scholten	Damping-off
	Cytospora friesii Sacc.	Canker
	Diaporthe lokoyae Funk	Canker
	Dimerosporium tsugae Dearn.	Sooty mold
	Elytroderma de formans (Weir) Darker	Needle cast
	Fomes annosus (Fr.) Karst.	Root rot
	Limacinia spp.	Sooty molds
	Melampsora spp.	Rusts
	Phacidium abietis (Dearn.) Reid & Cain	Snow blight

APPENDIX II (Continued)

Common and scientific names	Potential disease fungi	Major symptoms
Douglas fir (continued)	***Rhabdocline*** spp.	Needle casts
	Rhizina spp.	Root rot
	Rhizoctonia solani Kuhn	Damping-off
	Rosellinia herpetrichoides Hepting & Davidson	Needle blight
	Thelephora terrestris Ehrh. ex Fr.	Smothering disease
	Valsa spp.	Cankers
Elder	***Ascochyta wisconsina*** J.S. Davis	Leaf spot
Sambucus spp.	***Fusarium*** spp.	Crown rot
	Microsphaera penicillata (Wallr. ex Fr.) Lev.	Powdery mildew
	Phytophthora citricola Saw.	Crown rot
	Septoria sambucina Pk.	Leaf spot
Elms	***Ceratocystis ulmi*** (Buism.) C. Moreau	Wilt
Ulmus americana L.	***Gnomonea ulmea*** (Schw.) Thum.	Leaf spot
U. parvifolia Jacq.	***Nectria cinnabrina*** (Tode ex Fr.) Fr.	Dieback
U. procera Salisb.	***Thyrostroma compactum*** (Sacc.) Hohn	Twig blight
U. pumila L.	***Tubercularia*** spp.	Twig blight
U. rubra Mühl.	***Verticillium albo-atrum*** Reinke & Berth	Wilt
U. thomasii Sarg.		
Firs	***Aleurodiscus*** spp.	Cankers
Abies balsamea (L.) Mill.	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
A. concolor (Gord. & Glend.) Lindl.	***Bifusella linearis*** (Pk.) Hohn	Needle cast
A. grandis (Dougl.) Lindl.	***Botrytis cinerea*** Pers. ex Fr.	Gray mold
A. lasiocarpa (Hook.) Nutt.	***Cenangium*** spp.	Twig blights
	Delphinella spp.	Tip blights
	Fusarium spp.	Root rot
	Gremmeniella abietina (Lagerb.) Morelet	Canker
	Herpotrichia spp.	Brown felt blight
	Hyalopsora spp.	Needle rusts
	Isthmiella spp.	Needle blights
	Lirula spp.	Needle casts
	Lophodermium spp.	Needle casts
	Lophomerum automnale (Darker) Magasi	Needle cast
	Melampsora abieti-capraearum Tub	Needle cast
	Melampsorella caryophyllacearum Schroet	Yellow witches'-broom
	Milesia spp.	Needle rust
	Nectria spp.	Cankers, diebacks
	Peridermium spp.	Needle rust
	Placidium abietis (Dearn.) Reid & Cain	Snow blight
	Phoma abietina Hartig	Twig canker
	Potebniamyces balsamicola Smerlis	Canker
	Pucciniastrum spp.	Needle rust
	Retinecyclus abietis (Crouan) Groves & Wells	Dieback
	Sarcotrichila spp.	Snow blights

APPENDIX II (Continued)

Common and scientific names	Potential disease fungi	Major symptoms
Firs (continued)	***Thyronectria balsamea*** (Cke. & Pk.) Seel.	Dieback
	Uredinepsis spp.	Needle rusts
	Valsa spp.	Cankers
Hawthorne	***Cercoseptoria crataegi*** (Ell. & Ev.) J.J. Davis	Leaf spot
Crataegus	***Fabraea maculata*** (Lev.) Atk.	Leaf spot
	Gymnosporangium spp.	Rusts
	Phyllactinia guttata (Fr.) Lev.	Powdery mildew
	Podosphoera clandestina (Wallr. ex Fr.) Lev.	Powdery mildew
Hemlock	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Tsuga canadensis (L.) Carr)	***Fabrella tsugae*** (Farl.) Kirsch.	Needle blight
	Melampsora spp.	Needle rusts
	Pucciniastrum spp.	Needle rusts
	Sirococcus strobilinus Preuss	Shoot blight
	Uraecium holwayi Arth.	Needle rust
Honey locust	***Camarosporium robinae*** (West.) Sacc.	Dieback
Gleditsia triacanthos L.	***Curcurbitaria elongata*** (Fr.) Grev.	Canker
Honeysuckle	***Ascochyta*** sp.	Blight
Lonicera spp.	***Botrytis cinerea*** Pers. ex Fr.	Gray mold
	Cercospora antipus Ell. & Holw.	Leaf spot
	Diplodina tatarica Allesch.	Twig blight
	Herpobasidium deformans Gould.	Leaf blight
	Kabatia lonicerae (Harkn.) Hohn	Leaf spot
	Leptothyrium periclymeni (Desm.) Sacc.	Leaf spot
	Microsphaera alni (Wallr.) Salm.	Powdery mildew
	Verticillium dahliae Kleb.	Canker
Juniper	***Cercospora juniperina*** Georg. & Badea	Needle blight
Juniperus virginiana L.	***Gymnosporangium*** spp.	Gall and needle rusts
	Herpotrichia juniperi (Duby) Petr.	Brown felt blight
	Lophodermium juniperi (Grev.) Darker	Needle cast
	Phomopsis juniperovora Hahn	Blight
Larch	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Larix decidua Mill.	***Botrytis cinerea*** Pers. ex Fr.	Gray mold
L. laricina (Du Roi) K. Koch.	***Hypodermella laricis*** Tub	Needle cast
L. leptolepis (Sieb. and Zucc.) Gord.	***Lophodermium laricinum*** Duby	Needle cast
	Melampsora spp.	Needle rusts
	Sclerophoma pithyophila (Cda.) Hohn.	Dieback
	Tympanis laricina (Fckl.) Sacc.	Canker
	Valsa spp.	Cankers

APPENDIX II (Continued)

Common and scientific names	Potential disease fungi	Major symptoms
Lilac	***Aschochyta syringae*** Bres.	Leaf spot
Syringa spp.	***Botrytis cinerea*** Pers. ex Fr.	Gray mold
	Macrophoma halstedii (Ell. & Ev.) Tassi	Leaf spot
	Microsphaera penicillata (Wallr. ex Fr.) Lev.	Powdery mildew
	Phyllosticta syringae West.	Leaf spot
	Phytophthora syringae Kleb.	Shoot blight
Maple	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Acer campestre L.	***Chondrostereum purpureum*** (Pers. ex Fr.) Pouzar	Silver leaf
A. macrophyllum Pursh	***Dermea acerina*** (Pk.) Rehm.	Dieback
A. negundo L.	***Kabatiella apocrypta*** (Ell. & Ev.) Arx	Arthracnose
A. pennsylvanicum L.	***Massaria inquinans*** (Tode ex Fr.) de Not.	Dieback
A. plantanoides L.	***Melanconis everhartii*** Ell.	Twig blight
A. pseudoplantanus L.	***Nectria cinnabarina*** (Tode ex Fr.) Fr.	Dieback
A. rubrum L.	***Phleospora aceris*** (Lib.) Sacc.	Leaf spot
A. saccharinum L.	***Phyllosticta*** spp.	Leaf spots
A. saccharum Marsh.	***Rhytisma*** spp.	Tar spots
A. spicatum Lam.	***Taphrina*** spp.	Leaf blisters
	Uncinula circinata Cke. & Pk.	Powdery mildew
	Verticillium spp.	Wilts
Mountain ash	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Sorbus americana Marsh.	***Fabraea maculata*** (Lev.) Atk.	Leaf spot
S. aucuparia L.	***Gymnosporangium*** spp.	Leaf rusts
S. decora (Sarg.) Schneid.	***Valsa sordida*** Nits.	Canker
Oak	***Amillaria mellea*** (Vahl ex Fr.) Kumm.	Root rot
Quercus alba L.	***Coryneum kunzei*** Cda.	Shoot blight
Q. macrocarpa Michx.	***Cronartium quercuum*** (Berk.) Miyabe ex Shirae	Leaf rust
Q. palustris Muenchh.	***Discula quercina*** (West.) Arx.	Leaf spot
Q. rubra L.	***Dothiorella*** spp.	Canker, dieback
Q. velutina Lam.	***Gnomonia*** spp.	Leaf spots
	Microsphaera penicillata (Wallr. ex Fr.) Lev.	Powdery mildew
	Taphrina caerulescens (Mont. & Desm.) Tul.	Leaf blister
Peashrub	***Fusarium solani*** (Mort.) Appelet Wr.	Crown rot
Caragana spp.	***Phyllostieta gallarum*** Thum.	Leaf spot
	Pythium spp.	Damping-off
	Rhizoctonia solani Kuhn	Damping-off
	Septoria caraganae (Jacz.) Died.	Leaf spot
	Turercularia vulgaris Tode	Dieback
Pine	***Armillari mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Pinus banksiana Lamb	***Cenangium*** spp.	Twig blights
P. contorta Dougl.	***Coleosporium*** spp.	Needle rusts
P. mugo Turra	***Cronartium*** spp.	Stem rusts

APPENDIX II (Continued)

Common and scientific names	Potential disease fungi	Major symptoms
Pine (continued)	***Endocronartium harknessii*** (J.P. Moore) Y. Hiratsuka	Gall rust
P. nigra Arnold	***Fomes annosus*** (Fr.) Karst.	Root rot
P. resinosa Ait.	***Fusarium oxysporum*** Schlecht.	Damping-off, root rot
P. strobus L.	***Gremmeniella abietina*** (Largerb.) Morelet	Canker
P. sylvestris L.	***Leucostoma kunzei*** (Fr.) Murk ex Kerm	Canker
	Lophodermella spp.	Needle casts
	Lophodermium pinastri (Schrad. ex Fr.) Chev.	Needle cast
	Macrophoma sapinea Petr.	Twig blight
	Meloderma dezmazierii (Duby) Darker	Needle cast
	Pestalotiopsis funerea (Desm.) Stey.	Needle blight
	Pythium spp.	Damping-off
	Rhizina undulata Fr.	Root rot
	Rhizoctonia solani Kuhn	Damping-off
	Scirrhia spp.	Needle blights
	Sclerophoma pithyophila (Cda.) Hohn	Needle cast
	Scoleconectria cucurbitula (Tode ex Fr.) Booth	Canker
	Sirococcus strobilinus Preuss	Shoot blight
	Valsa spp.	Cankers
Poplar	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
Populus alba L.	***Chondrostereum purpureum*** (Pers. ex Fr.) Pouzar	Silver leaf
P. balsamifera L.	***Ciborina whetzelii*** Seaver	Ink spot
P. canadensis Moench	***Cladosporium subsessile*** Ell. & Barth.	Leaf spot
P. deltoides Marsh.	***Cucurbitaria staphula*** Dearn.	Branch gall
P. grandidentata Michx.	***Cryptodiaporthe populea*** (Sacc.) Butin	Canker
P. nigra L.	***Cytospora*** spp.	Cankers
P. tremula L.	***Diplodia tumefaciens*** (Shear) Zalasky	Branch gall
P. tremuloides Michx.	***Marssonina*** spp.	Leaf spots
	Melampsora spp.	Leaf rusts
	Mycosphaerella populorum G.E. Thomp.	Leaf spot
	Pollaccia spp.	Shoot blights
	Septoria spp.	Leaf spots
	Uncinula spp.	Powdery mildews
Rose	***Botrytis cinerea*** Pers. ex Fr.	Gray mold
Rosa spp.	***Cytospora ambiens*** Sacc.	Dieback
	Diplocarpon rosae Wolf	Black spot
	Leptosphaeria coniothyrium (Fek.) Sacc.	Canker
	Mycosphaerella rosicola B.H. Davis	Leaf spot
	Peronospora sparsa Berk.	Downy mildew
	Phragmidium spp.	Rusts
	Sphaceloma rosarum (Pass.) Jenkins	Arthracnose
	Sphaerotheca spp.	Rusts
	Verticillium dahliae (Kleb.)	Wilt

APPENDIX II (Continued)

Common and scientific names	Potential disease fungi	Major symptoms
Russian olive	***Phyllosticta argyrea*** Speg.	Leaf spot
Eleagnus angustifolia L.	***Puccinia caricis-shepherdiae*** J.J. Davis	Rust
	Septoria elaeagni (Chev.) Desm.	Leaf spot
Serviceberry	***Apiosporina collinsii*** (Schw.) Hohn	Leaf curl
Amelanchier spp.	***Diaporthe tuberculosa*** (Ell.) Sacc.	Twig blight
	Entomosporium maculatum Lev.	Leaf spot
	Gymnosporangium spp.	Rusts
	Phyllosticta innumerabilis Pk.	Leaf spot
	Physalospora obtusa (Schw.) Cke.	Leaf spot
	Podesphaera clandestina (Wallr. ex Fr.) Lev.	Powdery mildew
	Valsa ambiens (Pers. ex Fr.) Fr.	Canker
Spruce	***Aleurodiscus*** spp.	Twig blight
Picea abies (L.) Karst.	***Armillaria mellea*** (Vahl. ex Fr.) Kumm.	Root rot
P. glauca (Moench) Voss	***Botrytis cinerea*** Pers. ex Fr.	Gray mold
P. mariana (Mill.) B.S.P.	***Chrysomyxa*** spp.	Needle rusts
P. pungens Engelm.	***Cladosporium variabile*** (Cke.) de Vries	Needle blight
P. rubens Sarg.	***Cylindrocladium scaparium*** Morg.	Root rot
P. sitchensis (Bong.) Carr.	***Cytospora*** spp.	Canker
	Fusarium oxysporum Schlecht	Damping-off, root rot
	Gremmeniella abietina (Lagerb.) Morelet	Canker
	Isthmiella crepidiformis Darker	Needle cast
	Lirula macrospora (Hartig) Darker	Needle cast
	Lophodermium filiforme Darker	Needle cast
	Lophomerum spp.	Needle cast
	Lophophacidium hyperboreum Lagerb.	Snow blight
	Peridermium coloradense (Diet.) Arth. & Kern.	Withches'-broom
	Phacidium abietis (Dearn.) Reid & Cain	Snow blight
	Pucciniastrum spp.	Needle rusts
	Pythium spp.	Damping-off
	Rhizoctonia solani Kuhn	Damping-off
	Sarcotrichila piniperda (Rehm.) Korf	Snow blight
	Sirococcus strobilinus Preuss.	Shoot blight
Viburnum	***Aschochyta viburni*** Sacc.	Leaf spot
Viburnum spp.	***Botrytis cinerea*** Pers. ex Fr.	Gray mold
	Cercospora spp.	Leaf spots
	Coleosporium viburni Arth.	Rust
	Microsphaera penicillata (Wallr. ex Fr.) Lev.	Powdery mildew
	Phyllosticta lentaginis Sacc. & Syd.	Leaf spot
	Plasmopara viburni Pk.	Downy mildew
	Puccinia linkii Klotzsch	Rust
	Ramularia viburni Ell. & Ev.	Leaf spot
	Verticillium spp.	Wilt

APPENDIX II (Continued)

Common and scientific names	Potential disease fungi	Major symptoms
Willow	***Cryptodiaporthe*** spp.	Canker
Salix alba L.	***Cytospora*** spp.	Canker
S. babylonica L.	***Marssonina*** spp.	Leaf spots
S. bebbiana Sarg.	***Melampsora*** spp.	Leaf rusts
S. discolor Muehl.	***Physalospora miyabeana*** Fukushi	Canker
S. fragilis L.	***Pollaccia saliciperda*** (All. & Tub.) Arx	Scab
S. laurifolia Wesm.	***Ramularia rosea*** (Fckl.) Sacc.	Leaf spot
S. lucida Muehl.	***Uncinula salicis*** (DC. ex Merat) Wint.	Powdery mildew
S. purpurea L.		
S. rubra Huds.		

[1] Based on ***Names of Plant Diseases in Canada***, Publ. QA38-R4-1 by Agriculture Quebec, 2nd Ed. (1975) and ***Index of Plant Diseases in the United States***, U.S.D.A. Agr. Handb. No. 165 (1960).

APPENDIX III

Alternate hosts of conifer rusts in eastern North America.[1]

Rust fungus	Conifer hosts	Alternate hosts
Chrysomyxa arctostaphyli Diet.	Black spruce Red spruce White spruce	*Arctostaphylos uva-ursi* (L.) Spreng. - Bearberry *Rhamnus purshiana* DC. - Cascara buckthorn
C. empetri Schroet. ex Cumm.	Black spruce White spruce	*Empetrum nigrum* L. - Crowberry
C. ledi d By	Black spruce Blue spruce Red spruce White spruce	*Ledum groenlandicum* Oeder. - Labrador-tea *Rhododendron* sp. - Azalea, Rhodora
C. ledicola Lagh.	Black spruce Blue spruce Red spruce White spruce	*Ledum groenlandicum* Oeder. - Labrador-tea
C. pyrolata Wint.	Black spruce Red spruce White spruce	*Monese uniflora* (L.) Gray. - Woodnymph *Pyrola* spp. - Wintergreens
C. woroninii Tranz.	Black spruce White spruce	*Ledum* spp. - Labrador-tea
Coleosporium asterum (Diet.) Syd.	Austrian pine Jack pine Lodgepole pine Red pine Scots pine	*Aster* spp. - Asters *Solidago* spp. - Goldenrods
C. viburni Arth.	Jack pine	*Viburnum cassinioides* L. - Witherod *V. lentago* L. - Nannyberry
Cronartium coleosporioides Arth.	Jack pine Lodgepole pine Shore pine	*Castilleja* spp. - Indian paint brush *Melampyrum lineare* Desr. - Cow wheat
C. comandrae Peck	Jack pine	*Comandra* spp. - Bastard toadflax *Geocaulon lividum* (Richards) Fern. - Northern comandra

APPENDIX III (continued)

Rust fungus	Conifer hosts	Alternate hosts
C. comptoniae Arth.	Jack pine Lodgepole pine Mugo pine Scots pine Shortleaf pine	***Comptonia peregrina*** (L.) Coult. - Sweet-fern ***Myrica gale*** L. - Sweet gale
C. ribicola J.C. Fischer	White pine	***Ribes*** spp. - Currant and gooseberry
Endocronartium harknessii (J.P. Moore) Y. Hiratsuka	Jack pine Lodgepole pine Scots pine Shore pine Shortleaf pine	Endocyclic rust with no known alternate hosts
Gymnosporangium clavariiforme (Pers.) DC.	Juniper	***Amelanchier*** spp. - Serviceberry ***Crataegus*** spp. - Hawthorne
G. clavipes (Cke. & Pk.) Cke. & Pk.	Junipers	***Amelanchier*** spp. - Serviceberry ***Crataegus*** spp. - Hawthorne ***Malus*** spp. - Apple ***Pyrus*** spp. - Pear ***Sorbus*** spp. - Mountain-ash
G. cornutum Arth. ex Kern	Juniper	***Sorbus*** spp. - Mountain-ash
G. inconspicuum Kern	Juniper	***Amelanchier*** spp. - Serviceberry
G. juniperi-virginianae Schw.	Juniper	***Malus*** spp. - apple
G. nelsonii Arth.	Juniper	***Amelanchier*** spp. - Serviceberry
Hyalopsora aspidiotus (Pk.) Magn.	Balsam fir	***Dryopteris disjuncta*** (Ledeb.) C.V. Mort. - Wood fern
Melampsora abietis-canadensis C.A. Ludwig ex Arth.	Hemlock	***Populus*** spp. - Aspen
M. epitea Thuem.	Balsam fir Larch	***Salix*** spp. - Willow
M. medusae Thuem.	Larch	***Populus*** spp. - Aspen
M. paradoxa Diet. & Holw.	Larch	***Salix*** spp. - Willow
Melampsorella caryophyllacearum Schroet.	Balsam fir	***Cerastium*** spp. - Mouse-eared chickweed ***Stellaria*** spp. - Chickweed

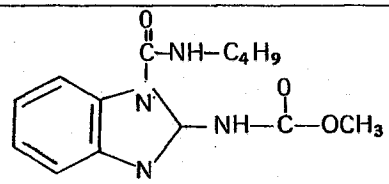
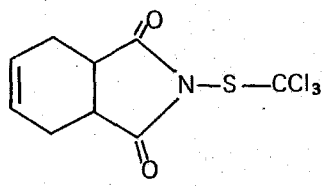
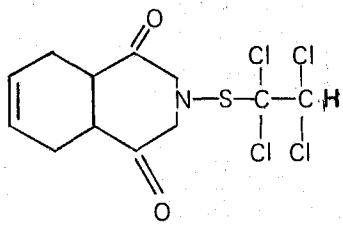
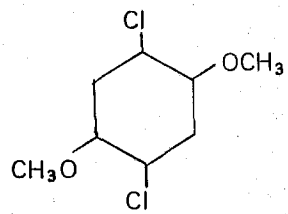
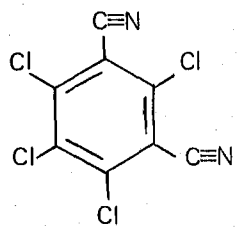
APPENDIX III (continued)

Rust fungus	Conifer hosts	Alternate hosts
Melampsoridium betulinum (Fr.) Kleb.	Larch	***Betula alleghaniensis*** Britt. - Yellow birch ***B. populifolia*** Marsh. - Gray birch
Milesia spp.	Balsam fir	***Dryopteris*** spp. - Wood fern ***Polypodium*** spp. - Polypody fern
Pucciniastrum americanum (Farl.) Arth.	White spruce	***Rubus*** spp. - Raspberry
P. epilobii Otth.	Balsam fir	***Clarkia*** spp. - Clarkia ***Epilobium*** spp. - Willowherb, fireweed
P. goeppertianum (Kuehn.) Kleb.	Balsam fir	***Vaccinium*** spp. - Blueberry
P. vaccinii (Wint.) Jorst.	Hemlock	***Rhododendron*** spp. - Rhododendron ***Vaccinium macrocarpon*** Ait. - Cranberry
Uredinopsis mirabilis (Peck) Magn.	Balsam fir	***Onoclea sensibilis*** L. - Sensitive fern
U. osmundae Magn.	Balsam fir	***Osmunda*** spp. - Flowering fern
U. struthiopteris Stoerm. ex Diet.	Balsam fir	***Pteretis pensylvanica*** (Willd.) Fern. - Ostrich fern

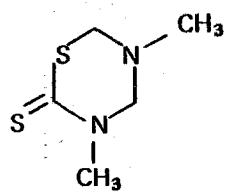
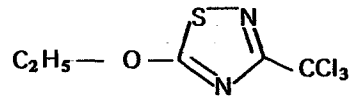
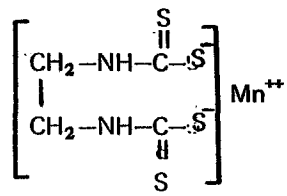
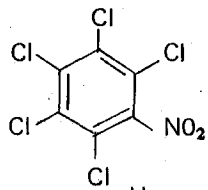
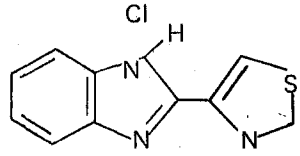
[1] Compiled from ***Forest Fungi of the Mairitime Provinces***, Dep. Environ. Inf. Rep. M-X-51 by L.P. Magasi and J.M. Manley (1975) and from ***Index of Plant Diseases in the United States***, U.S.D.A. Agr. Handb. No. 165 (1960).

APPENDIX IV

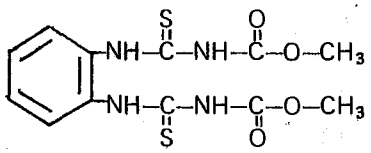
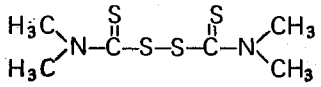
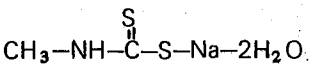
Fungicides which have been used or tested for nursery disease control.

Common names	Trade names	Structural formula	Potential uses and precautions
Benomyl	Benlate		Systemic fungicide which controls gray mold.
Captan	Captan Orthocide		Foliage and seed protectant which may be used for damping-off, gray mold, shoot blight, and storage molds. May be phytotoxic to seedlings.
Captofol	Difolatan		Foliar protectant.
Chloroneb	Demosan Tersan SP		Soil fungicide which may be used to control damping-off.
Chlorothalonil	Bravo Daconil		Foliar fungicide for control of *Sirococcus* shoot blight, *Lophodermium* needle cast, and *Scleroderris* canker.

APPENDIX IV (continued)

Common names	Trade names	Structural formula	Potential uses and precautions
Dazomet	Mylone		Soil sterilant for control of weeds, nematodes, and root-rot fungi.
Ethazole Truban	Truban		Soil fungicide for control of ***Pythium*** and ***Phytophthora***. May be combined with quintozene or thiophanate methyl for increased effectiveness.
Mancozeb	Manzate 200 Dithane M-45	Maneb + Zn^{++}	Foliar fungicide.
Maneb	Dithane M-22 Manzate		Foliar fungicide for control of needle casts, shoot blights.
Methyl bromide	Dowfume MC Brom-o-gas Meth-o-gas Terr-o-gas Trizone	CH_3Br	Soil fumigant for nematodes, weeds, and fungi. Recommended for ***Cylindroladium*** root rot.
Quintozene (PCNB)	Terrachlor		Soil fungicide for control of ***Rhizoctonia***. May be injurious to germinating seedlings.
Thiabendazole (TBZ)	Mertect		Systemic fungicide with potential uses similar to benomyl and the thiophanates.

APPENDIX IV (continued)

Common names	Trade names	Structural formula	Potential uses and precautions
Thiophanate methyl	Easout Topsin M		Systemic fungicide with potential usefulness against damping-off and gray mold. Should be combined with ethazole for damping-off control.
Thiram	Arasan Tersan 75		Seed treatment, soil fungicide and animal repellant. Has been used extensively for control of damping-off.
Vapam	Vapam VPM		Soil fumigant for weeds, nematodes, and fungi.
Vorlex	Vorlex	$CH_3-N=C=S$ + Chlorinated hydrocarbons	Soil fumigant for weeds, nematodes, and fungi.
		Other chemicals with fungicidal properties.	
Allyl alcohol	AA Soil Drench AA	$CH_2=CH-CH_2OH$	Soil fumigant for weed control.
Anhydrous ammonia		NH_3	Fertilizer and fumigant. May injure conifer seedlings.
Azides	Smite	KN_3 or NaN_3	Soil fumigant for weeds, nematodes, and fungi. May injure conifer seedlings if applied too soon prior to sowing.
Chloropicrin	Picfume Larvacide	CCl_3-NO_2	Soil fumigant for nematodes, insects, and weeds.
Sulfuric acid		H_2SO_4	For soil acidification and weed control.

APPENDIX V

Stages in seedling production at which fungicide treatments may be necessary.

Stage	Diseases	Materials,[1] rates,[2] and methods of application
1. Pre-planting	Root rots, nematodes, weeds	(a) Dazomet at 200-300 kg/ha [3] (b) Methyl bromide[4] under plastic (c) Vapam or vorlex[4] with water seal
2. Seed treatment	Pre- and post-emergence damping-off	Thiram or captan at 0.2-0.5 g/g seed pelleted onto seed with latex or methyl cellulose sticker. Not necessary after 1(a).
3. Pre-emergence	Pre- and post-emergence damping- off	Chloroneb, ethazole, or thiram at 5-10 kg/ha alone or in combination with benomyl or thiophanate methyl at 3-5 kg/ha. Apply as a spray or drench. Not necessary after 1(a) or 2.
4. Post-emergence	Post-emergence damping-off, root rots, gray mold	Same as in 3 or captan, quintozene or chloroneb at 10-20 kg/ha.
5. Primary needle growth	Late damping-off, root rots, gray mold, ***Sirococcus*** shoot blight	Captan, chlorothalonil, or quintozene at 2-10 kg/ha. Benomyl at 0.5-2 kg/ha may be applied in combination.
6. Secondary branching	Gray mold, shoot blights, ***Scleroderris*** canker, needle cast	Foliar sprays of captan, captofol, chlorothalonil, maneb, or mancozeb at 2 kg/ha at 10-15 day intervals if wet weather prevails.
7. Autumn	Snow blights	Captan or captofol at 2 kg/ha alone or in combination with benomyl at 0.5 kg/ha until snowfall.
8. Pre-storage	Storage molds	Captan at 2 kg/ha or benomyl or thiophanate methyl at 0.5 kg/ha 1-2 days prior to lifting.

[1] All materials mentioned are common names; for trade names see Appendix IV.

[2] Rates refer to active ingredients, for rates of formulated product, multiply by $\frac{100 + \%\text{ active ingredient}}{100}$.

[3] One kg/ha = 0.9 lb/acre.

[4] Use manufacturers' recommended rates.