Diseases and Insect Pests
In British Columbia Forest Nurseries

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British Columbia Ministry of Forests / Canadian Forestry Service,
Joint Report No. 12

July, 1980

The printing of this publication is funded under the Canada-British Columbia Forest Resource Development Agreement — a five year (1985-1990) $300 million program. The subject matter of this publication directly supports the primary objective of this federal/provincial agreement — to secure and expand the supply of wood in British Columbia by funding programs aimed at backlog reforestation and intensive forest management.

Canadian Cataloguing in Publication Data

Sutherland, Jack R.
Diseases and insect pests in British Columbia forest nurseries.

(Joint report — British Columbia Ministry of Forests, Canadian Forestry Service; no. 12)

Includes bibliographical references.
ISBN 0-7719-8134-X

1. Trees — Diseases and pests — British Columbia. 2. Forest nurseries — British Columbia. I. Van Eerden, Evert. II. Title. III. Series: British Columbia. Ministry of Forests. Joint report — British Columbia Ministry of Forests, Canadian Forestry Service; no. 12.

SB764.C3S97 634.9'6'09711 C80-092051-1

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Acknowledgments

We thank the following for their technical and editorial comments on specific sections or, in certain cases, all of the bulletin: W.J. Bloomberg, D. Evans, A. Funk, J.W.E. Harris, J.C. Hopkins, R.S. Hunt, W. Lock, and G.A. Van Sickle of the Canadian Forestry Service; N.V. Tonks and A.T.S. Wilkinson of Agriculture Canada; and J.C. Arrand of the B.C. Ministry of Agriculture. Nursery staff of the British Columbia Ministry of Forests reviewed the manuscript and made helpful suggestions. D.P. Lowe and J.M. Burgess helped with proof reading and the latter prepared the indexes; C.M. Lawko prepared the résumé. A.R. Craigmyle and E. Chatelle did most of the photography; A. MacEwan edited the text. Special thanks are due to J.C. Wiens, graphics specialist, for his work and advice.

Foreword

Sustained and improved production of forest seedling crops largely depends upon effective control of nursery pests. Early and correct identification of pests is the first vital step in a nursery pest management program. This booklet on forest nursery pests in British Columbia provides nursery managers with the basic information required for pest identification. It contains flow-chart keys, host and damage information, descriptions of critical life cycle stages and, where applicable, preventive cultural control practices. Recommendations for chemical controls are not included because prescriptions for these change rapidly. This booklet is not intended to supplant the accepted identification procedures of nursery pests in British Columbia, but it should provide nursery managers with improved capability for initial identification of some common and regularly recurring pests.

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Abstract

This bulletin was prepared to assist nursery personnel in identifying and controlling diseases and insect problems in British Columbia forest nurseries. The bulletin contains four main sections, i.e., a beginning one containing information such as pest prevention, chemical control and diagnosis. Then follow sections on diseases affecting seeds and roots, shoot diseases, and insects and allied pests. Each of the latter three sections contains several chapters on specific pests.

Résumé

Ce bulletin a été preparé pour aider le personnel de pépinières forestières à identifier et à contrôler les problèmes des insectes et des maladies en Colombie - Britannique. Le bulletin est divisé en quatre parties principales. La première fournit des renseignements sur la prevéntion des organismes nuisibles, leur diagnostic et le contrôle chimique. Les sections qui suivent concernent les maladies qui affectent les graines et les racines, les maladies des pousses et finalement, les insectes et les organismes nuisibles qui y sont associés. Chacune des trois dernières sections contient plusieurs chapitres sur des organismes spécifiques.

Introduction

Pests directly affect the quantity and quality of forest nursery seedlings and they can cause indirect losses by disrupting reforestation plans or reducing survival of outplanted stock. Infested stock can also disseminate pests to new areas. Furthermore, since control is often based on pesticide usage, pest outbreaks may lead to environmental contamination. Recent increases in forest nursery seedling production have made nursery managers more aware of pest losses in British Columbia forest nurseries. Consequently, this bulletin was prepared to help in the identification and control of important disease and insect pests in local nurseries. It is formatted so that the user can tentatively identify insect or disease problems by referring to the flow-chart keys and then consulting the specific chapters on each pest for more information on hosts, damage, life history and control. We have attempted to provide sufficient information, with minimal technical jargon, to allow the user to identify specific pests, and follow the logic of the control recommendations. Emphasis has been placed on preventive control, e.g., via manipulation of cultural practices, rather than on remedial procedures such as eradication by pesticides. Some preventive practices emphasized include:

Nursery Site Factors

1. Select a sandy, well-drained, moderately acid soil for a bareroot nursery. Such soils generally favor seed germination and seedling emergence and growth while hindering pest survival and growth; they are also easier to rid of pests.
2. Select a site that has an adequate supply of water that is free of toxic chemicals, pH problems and pests.
3. Select a site that is unaffected by adverse weather factors such as flooding, frost pockets or heaving and severe winds.
4. Avoid areas with high levels of pests in the surrounding stand.

Cultural Practices

1. Prevent exposure to factors such as frost damage, nutrient deficiencies and toxic chemicals that pre-dispose seedlings to pests. Keeping seedlings healthy deters pest attack and losses.
2. Regulate environmental factors such as watering, aeration and lighting, so that they hinder pest development or survival while not adversely affecting seedlings.
3. Use sanitation and pest exclusion practices such as: (i) restricting or preventing movement of pest-infested stock or equipment among nurseries, (ii) removing infested seedlings or those that are potential sources for pest build-up, (iii) periodically checking water supplies for pests, (iv) regularly checking soil amendments or container mix components for pests, (v) ridding the nursery environment of alternate hosts, e.g., rusts, and (vi) where practical, producing stock in insect-proof container nurseries.
4. Survey to detect potential or incipient pest problems.
5. Bare fallow soils or use crop rotation schemes unfavorable to pests.
6. Grow susceptible hosts outside pest-infected areas, e.g., *Abies* species outside the woolly aphid quarantine area.
7. Plant resistant species, provenances or age classes in infested areas, e.g., put transplants in damping-off prone areas.
8. Use pesticides to prevent rather than to eradicate pests.

Note: See chapters on each pest for specific preventives.

Noninfectious and Infectious Diseases

Plant diseases can be classified according to the plant part affected, the type of symptom, or as infectious or noninfectious. Although only infectious diseases are covered here, the nursery manager must also have an appreciation of noninfectious problems or, as they are often called, physiological disorders. Included in the latter are problems caused by inclement weather, unfavorable soil conditions, and injuries from toxic chemicals, such as herbicides (Figs. 1 to 4). Pathogens are not involved, and noninfectious problems are not contagious. Noninfectious diseases directly affect seedling quantities and qualities but, more often, their indirect effect of predisposing seedlings to infectious diseases is more important. For example, frost or fertilizer-damaged seedlings are more prone to storage moulds and often suffer gray mould losses because the pathogen, *Botrytis cinerea*, builds up on the killed foliage and spreads to healthy seedlings. Pre-emergence damping-off losses are often higher in compact soil, because of hindered germinant emergence, and soil pH may be selectively favorable or unfavorable for pathogens.

Infectious diseases are caused by pathogens, mainly fungi, and can spread among plants. Prerequisites for development of an infectious disease are: (i) a susceptible host, (ii) a pathogen, and (iii) a suitable environment. Reforestation needs and climatic restrictions dictate which seedlings species must be grown where; therefore, diseases generally cannot be avoided by changing the host species. Sometimes successful control is possible by pathogen exclusion procedures, such as eliminating a rust's alternate host from within or around the nursery, but the ubiquitous nature of many pathogens normally makes pathogen exclusion impractical. However, it is frequently possible and practical to manipulate cultural practices, e.g., by reducing humidity during periods of damping-off or gray mould outbreaks, so that the environment is unfavorable for disease development.

Figure 1. Fertilizer burn on foliage of western hemlock container seedlings. Note the fertilizer pellets (arrow).

Figure 2. Fertilizer burn on foliage of 2-year-old, bareroot white spruce.

Figure 3. Effects on 2-year-old bareroot Douglas-fir seedlings of solvent used to bond sections of plastic irrigation pipe.

Figure 4. Herbicide damage (two right-hand seedlings) on Douglas-fir.

Some of the main characteristics distinguishing noninfectious and infectious diseases include:

CHARACTERISTICS	**NONINFECTIOUS**	**INFECTIOUS**
Symptoms (host appearance)		
Within nursery	Usually well demarcated within a specific section or seedbeds; often corresponding to cultural practices or environmental factors.	Usually limits not defined; not corresponding to cultural practice or environmental factors.
On affected seedlings	Usually clearly delineated, e.g., specific sections of needles killed by fertilizer burn, or damage oriented from the direction of the sun or wind; most seedlings equally affected; no spreading to other seedlings.	Usually not oriented to direction of sun or wind; often spreading to other seedlings.
Type	Tissues usually desiccated, physically damaged, chlorotic, etc., but not decayed.	Tissues often decayed or swollen.
Development rate	Usually develop quickly, e.g., after fertilizer or herbicide application or inclement weather. Symptoms usually all developed to the same stage.	Usually develop slowly, uneven development rate, e.g., some seedlings dead while others are dying and others are unaffected.
Signs (evidence of pathogen)	No evidence of pathogen.	Pathogen, e.g., fungus mycelium or spore-producing structures, often present.
Hosts	Can affect numerous hosts of various ages.	Often restricted as to host and host age.

Insects and Allied Pests

There are fewer pest insects and allied pests (e.g., mites) than diseases in British Columbia forest nurseries. Except for certain aphids and the spruce spider mite, most of these pests are not host specific on conifers. They are, instead, pests with wide host ranges and do not prefer conifer seedlings; e.g., the marsh crane fly and June beetles prefer grasses. Nursery insects are also usually characterized by rapid and erratic buildup of destructive populations. Both of these factors complicate the implementation of preventive control surveys to predict insect occurrence. However, several of the procedures listed in the introduction of this bulletin can be used to prevent insect-caused losses.

The insects covered here are ones that regularly occur in forest nurseries rather than those, such as certain defoliators, that occur incidentally. Although the European pine shoot moth, *Rhyacionia buoliana* (Schiffermüller), and the balsam woolly aphid affect growing and shipping regulations of certain stock, these pests are not included because they have not damaged forest nursery seedlings[1].

Chemical Control

Implementing sound preventive and cultural control programs greatly reduces the necessity for using pesticides. Nonetheless, the applicator must be thoroughly familiar with the biology of the pest and host as well as with the application techniques, safety, and governmental regulation when pesticides are used. These latter topics are adequately covered in the most recent editions of:

Handbook for Pesticide Applicators and Pesticide Dispensers. Pesticide Control Branch, Ministry of the Environment, Province of British Columbia, Victoria, B.C.

Nursery Production Guide. Ministry of Agriculture, Province of British Columbia, Victoria, B.C.

Forest Pesticide Handbook of British Columbia. Council of Forest Industries of British Columbia, Vancouver, B.C.

Annual Pesticide Recommendation Guide. Prepared by Nursery Agrologists of the British Columbia Ministry of Forests, Victoria, B.C.

Pest Diagnosis

The use of criteria such as type of damage, plant species affected and season of symptom appearance often allows both pest-caused and noninfectious problems to be identified at the nursery. To aid in identification, we have included flow-chart keys and illustrations preceding the sections on seed, root or root collar diseases (page 10), shoot diseases (page 20), and insect and allied pests (page 34). Decide if a problem is disease- or insect-caused; use the headings for the keys on pages 10, 20 and 34. Examine the pictures on the opposite page for the symptom or stage of the pest that you have tentatively identified, then consult the text chapter for details on the pest's biology and control. If you are unable to identify the problem by using the information in the main body of the bulletin, consult the table of pests of minor importance on page 50. When in doubt about the identity of a pest, consult a plant pathologist or an entomologist.

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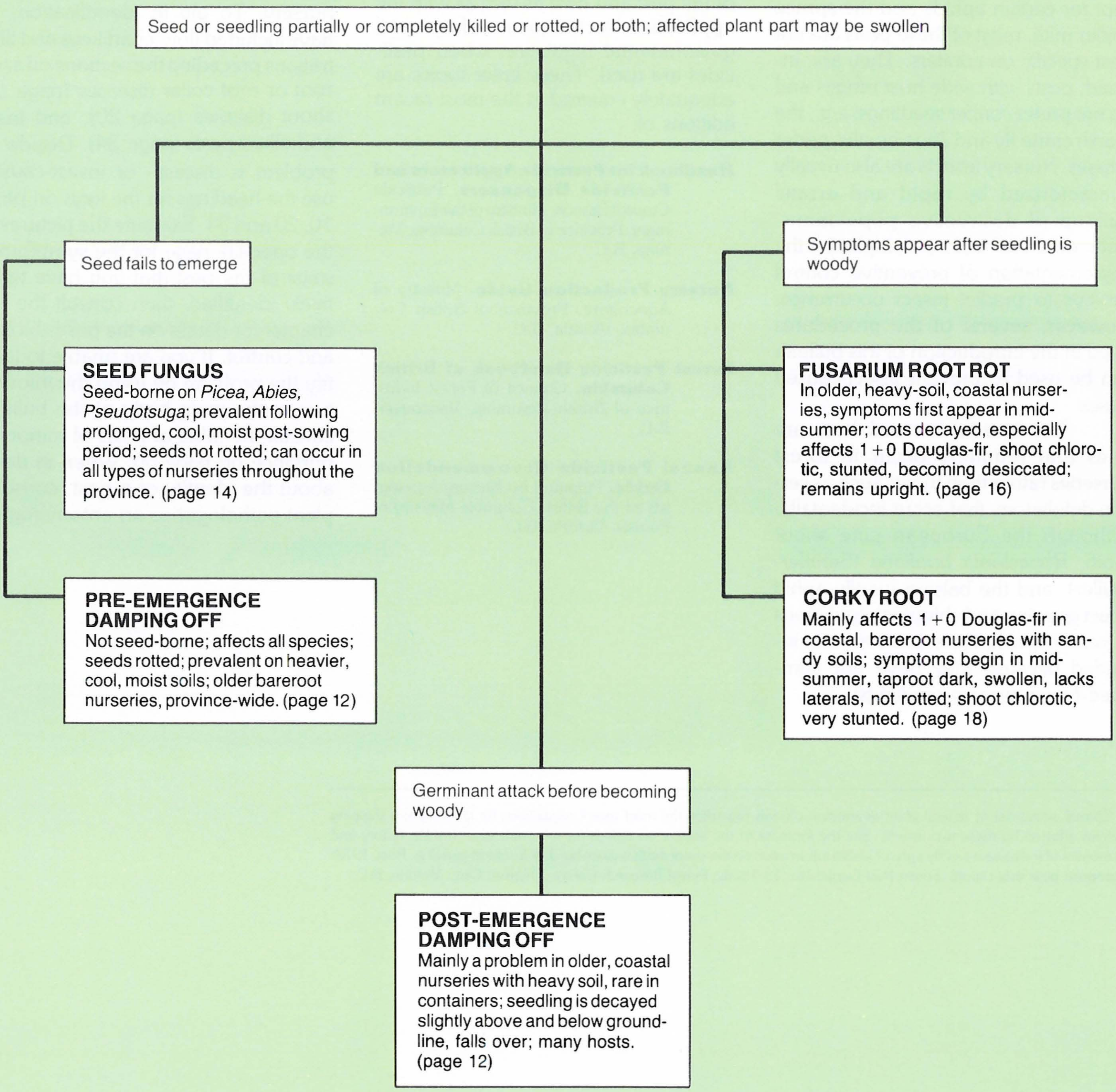
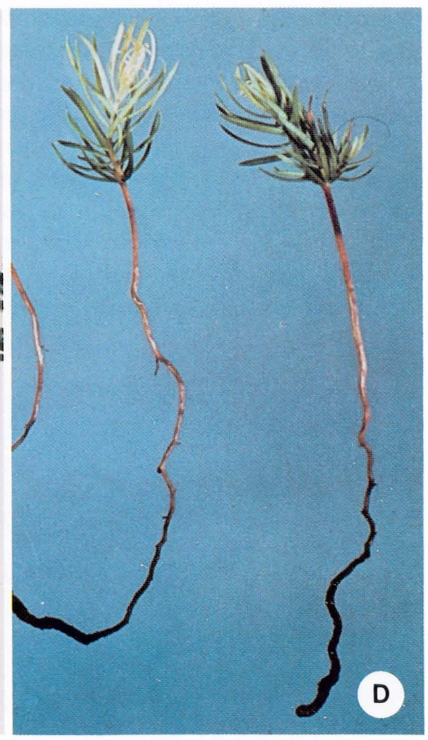
[1] Consult provincial or federal plant quarantine officials regarding the most recent regulations for growing and shipping species affected by these two insects. See the footnote to the section on aphids for information on the life history and bionomics of the balsam woolly aphid. Similar information on the shoot moth is given by: J.W.E. Harris and D.A. Ross. 1973. European pine shoot moth. Forest Pest Leaflet No. 18, Pacific Forest Research Centre, Environ. Can., Victoria, B.C.

DISEASES AFFECTING SEEDS, ROOTS OR ROOT COLLAR AREA



Diseases affecting seeds, roots or root collar area:

A. Seed fungus
B. *Fusarium* root rot
C. Post-emergence damping off
D. Corky root disease
E. Pre-emergence damping off (no symptoms, therefore not shown)



DISEASES AFFECTING SEEDS, ROOTS OR ROOT COLLAR AREA

Damping-off

Damping-off is a general term applied to the rotting of seeds and succulent seedlings. There are two stages: pre-emergence damping-off and post-emergence damping-off, which, respectively, affect seedlings before and after emergence. In British Columbia, both types are primarily confined to bareroot nurseries as they are mainly caused by soil-borne fungi (mostly *Fusarium* or sometimes *Pythium*). The relative scarcity of other well-known damping-off fungi, such as *Rhizoctonia, Phytophthora* and *Cylindrocladium*, and the presence of antagonistic microorganisms probably accounts for our relatively low damping-off losses. However, some losses do occur each year in all nurseries throughout the province and they are occasionally severe in fields with heavier soils and long histories of nursery or agricultural use. While most pre-emergence losses are caused by soil-inhabiting fungi, at least part of the germination failures usually attributed to poor seed viability, in bareroot and container nurseries, may be caused by seed-borne fungi (see next chapter).

Hosts and Damage

All locally grown seedling species suffer from both stages of damping-off. Failure of germinants to emerge

Figure 5. Symptoms of post-emergence damping-off. Note the rotted stem at groundline.

Damping-off

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1+0	Late spring and early summer	Yes	Yes	No	No

is the only above-ground evidence of pre-emergence damping-off; indeed, damage may go unnoticed unless it is severe or confined to patches. Cool, wet or compacted soil, which reduces germination and emergence rates, increases losses from this disease. High humidity, overcrowded seedling stands, and succulent stems which are susceptible to the disease, are some conditions favoring disease spread.

The main symptoms of post-emergence damping-off (Fig. 5) are rotting of the stem slightly above and below groundline and subsequent toppling of the shoot. The latter sometimes dries out and blows away. If the seedling has been attacked during emergence, only the hypocotyl crook will be visible and will fail to develop. Seedlings are susceptible to this disease until their stems become woody, usually 4 to 6 weeks following emergence. Ordinarily, only random seedlings in a drill row (Fig. 6) are affected but, under ideal conditions, the pathogen may spread and kill small patches of seedlings. Post-emergence damping-off of container-grown stock is uncommon, and its occurrence can be traced usually to pathogen-contaminated soil mix or water or to seed-borne fungi.

Life History

Most damping-off fungi are unspecialized pathogens with similar life histories. Frequently, the same pathogen can be isolated from several seedling species affected by either pre- or post-emergence damping-off. The pathogen overwinters and survives other adverse periods as thick-walled spores, usually in small root pieces and other organic matter. In spring, in proximity with seeds or growing roots, they germinate and infect. Several types of sexual and asexual spores may be produced and serve in disease spread while the seedlings are susceptible. Most damping-off fungi have only limited ability to grow through soil and, contrary to what many nurserymen believe, they usually survive on dead organic matter rather than on seeds and seedlings. Some pre-emergence damping-off fungi may also be seed-borne.

Figure 6. Post-emergence damping-off of yellow pine showing random distribution of diseased seedlings.

Control

Control is best based on prevention rather than on cure. Although seldom practiced, the first and best prevention is to select a nursery site with a light soil because disease is invariably less prevalent and control, if required, is easier. Rapid germination, which reduces pre-emergence damping-off losses because the germinants escape the pathogen, may be achieved by: (i) spring sowing stratified seeds, (ii) covering with non-compacting sand or grit, and (iii) sowing when soil temperature and moisture are optimum for germination. Some practices place the pathogen at a nutritional or survival disadvantage, e.g., maintaining or adjusting (by adding lime or sulfur) pH to between 4.5 and 6.0, thus hindering growth of some pathogens but not of seedlings, and bare fallowing between crops, which promotes depletion of pathogen food bases. Addition of nitrogenous fertilizers to young germinants promotes succulent growth and increases susceptibility, but adequate soil fertility levels, especially of phosphorus, potassium and calcium, will promote development of woody tissues resistant to post-emergence damping-off. Overcrowding of seedlings, high humidity and poor air-circulation or drainage all favor post-emergence damping-off; thus, regulation of sowing densities and watering alleviates disease development and spread. Increasing sowing densities to compensate for anticipated damping-off losses is not recommended.

Preplant pelleting or dusting of seeds with a fungicide is used for pre-emergence damping-off control in bareroot nurseries. Unfortunately, when disease incidence is low or moderate, as in most British Columbia nurseries, the fungicide's phytotoxic effects frequently exceed the prevented losses. Fungicide treatment of seeds may be ineffective because: (i) the active spectrum of most fungicides is too narrow to be effective against the numerous kinds of damping-off fungi, (ii) resistant fungal populations develop as the pesticide eliminates the more susceptible strains, and (iii) the fungicide is soon leached off the seed; thus, if conditions favoring damping-off are prolonged, protection against attack is too brief. The harmful effects of seed-applied fungicides are often more prominent in container than in bareroot nurseries because the biological and chemical "buffering capacity" of container growing media is very low. Their use on container-sown seeds can produce phytotoxicity symptoms that can be confused with post-emergence damping-off.

Fungicide drenches are sometimes applied to control pre- and post-emergence damping-off. For reasons mentioned above, they are seldom effective; moreover, they are expensive to apply and dosage rates are often environmentally unacceptable. Soil fumigation is a standard practice in many North American bareroot nurseries, but because of its expense and harmful effects on mycorrhizal fungi, it probably can be justified only in bareroot nurseries with multiple pest problems, e.g., damping-off, insects and weeds. The simplest solution is to choose a better nursery site or grow seedlings in containers.

Selected References

Bloomberg, W.J. 1971. Diseases of Douglas-fir seedlings caused by *Fusarium oxysporum*. Phytopathology 61: 467-470.

Lock, W., J.R. Sutherland, and L.J. Sluggett. 1975. Fungicide treatment of seeds for damping-off control in British Columbia forest nurseries. Tree Planters' Notes 26(3): 16-18, 28.

Salisbury, P.J. 1954. A review of damping-off of Douglas-fir seedlings in British Columbia. Forest. Chron. 30: 407-410.

SEED FUNGUS

This seed-borne pathogen was first reported in Ontario in 1964 on fall-sown pine seeds which had failed to germinate. It was next identified as an important pathogen in Britain on Sitka spruce seeds imported from western North America. Based on its asexual spore stage, the fungus was named *Geniculodendron pyriforme* Salt but, subsequently, *Caloscypha fulgens* (Persoon) Boudier was found to be the fungus' sexual state and taxonomically this name has priority.

Hosts and Damage

In British Columbia, the pathogen has been found in about 25% of all stored spruce (Sitka, Engelmann, white, and Engelmann x white hybrid) and some Douglas-fir and grand fir seedlots. The fungus is pathogenic to seeds of these and several other conifers. Exact losses have not been determined for local nurseries, but the fungus causes significant pre-emergence losses in Ontario and British bareroot nurseries. Losses in container nurseries should be less severe because intercavity spread by the fungus would be difficult.

Since diseased seeds do not germinate, the disease has no aboveground symptoms; thus, a cursory diagnosis might not differentiate this problem from pre-emergence damping-off. However, the contents of *C. fulgens*-killed seeds are firm and mummified, whereas seeds destroyed by damping-off have rotten contents.

Life History

Caloscypha fulgens inhabits forest duff; consequently, cones picked from the ground, especially from squirrel caches, may contain diseased seeds. Incidence of infected seeds depends upon several factors, especially the length of time cones are on the ground. Because the pathogen is known to spread during stratification (Fig. 7) and in seedbeds, low levels of diseased seeds are also important. Seeds of some species likely escape fungus infection because their cones are collected directly from trees or, as in the case of lodgepole pine, the cones are tightly closed. Neither sexual nor asexual spores play any apparent role in inoculation; rather, they probably serve only in fungus dissemination. Within infested seedlots, 1 to 35% of the seeds are infected and it is from these seeds that the fungus spreads during stratification. The problem can intensify further if moist, stratified seeds are cold stored at the nursery prior to sowing. Additional spreading and killing can occur following seed sowing, particularly during prolonged periods of cool, wet weather.

Control

Sowing non-infested seeds provides the most effective means of prevention but this is not always practical. Within infested seedlots, fungus spread is confined to the post-storage period

Seed fungus

Principal, locally-grown hosts	Host age and season when damage appears: Age	Season	Type of nursery stock: Bareroot, Coastal	Bareroot, Interior	Container, Coastal	Container, Interior
Abies grandis, *Picea* spp., *Pseudotsuga menziesii*	Seed	Spring to early summer	Yes	Yes	Yes	Yes

because very low storage temperature and moisture prevent growth of *C. fulgens*. Optimum temperature for growth of the pathogen is 20 ° C; thus, stratifying seeds at the lowest temperature possible, e.g., 1 or 2 ° C, helps to hinder pathogen growth. Shortening the stratification period also reduces disease risk because even at 1 or 2 ° C, appreciable fungus growth occurs after 3 to 4 weeks. In comparison with stratification in sand or other media, fungus spread is less when seeds are naked-stratified. Since the fungus inhabits forest duff, such material should not be added to seedbeds, e.g., to provide mycorrhizal inoculum, without first ensuring that it is free of the pathogen.

In Britain, adding a fungicide to the water used to soak seeds prior to chilling has reduced pathogen spread during stratification. Applying a fungicide to seeds prior to sowing has proved to be beneficial in Ontario and Britain and this procedure is currently being followed in local nurseries. Because the pathogen attacks only dormant seeds, sowing of infested seedlots should be delayed until soil temperatures are high enough for rapid germination. This practice is very important when seedlots have not received a presowing fungicide dusting. This recommendation applies to bareroot and container operations, especially when container cavities are multiple sown to compensate for low seed viability.

Figure 7. Mycelium of the seed fungus growing on stratified Sitka spruce seeds.

Selected References

Salt, G.A. 1974. Etiology and morphology of *Geniculodendron pyriforme* gen. et sp. nov., a pathogen of conifer seeds. Trans. Brit. Mycol. Soc. 63: 339-351.

Sutherland, J.R. 1979. The pathogenic fungus *Caloscypha fulgens* in stored conifer seeds in British Columbia and relation of its incidence to ground and squirrel-cache collected cones. Can. J. Forest Res. 9: 129-132.

Fusarium Root Rot of Douglas-fir

Figure 8. Random seedlings of Douglas-fir affected by *Fusarium* root rot.

This disease, caused by the fungus *Fusarium oxysporum* von Schlechtendahl ex Fries, was one of the earliest to receive local attention. It occurs only in bareroot nurseries and is more prevalent in older, coastal nurseries with heavier soils. The relatively short cropping histories and generally lighter soils of interior nurseries probably account for the rarity of *Fusarium* root rot there.

Hosts and Damage

Douglas-fir is the principal host, but hard pines and larch are sometimes also killed. Only 1-year-old stock is affected, regardless of the host. Shoot symptoms appear on random seedlings in drill rows (Fig. 8) as early as mid-July, i.e., when post-emergence damping-off is declining, and may continue to appear until late fall. The disease is frequently more prevalent in certain seedbeds or seedlots. Disease losses vary annually, but up to 15% of coastal Douglas-fir can be killed. Initial symptoms are most evident on the shoot and include chlorosis of terminal needles, followed by all needles gradually wilting, often turning purplish, then becoming brown and drying out (Fig. 9). The shoot tip frequently bends into a shepherd's crook. Since the stem is woody, it remains upright, a characteristic distinguishing this disease from damping-off. Although shoot symptoms are the first to be noticed, they actually indicate a root problem. Diseased root systems have few laterals and the remaining roots are often dark, swollen, and lack an actively growing tip. The bark and cortex of affected roots can be easily stripped away to expose the darkened cambium. Usually the disease is fatal, but sometimes it destroys only the primary root, resulting in a deformed root system and stunted shoot. These seedlings almost always turn out as culls.

Life History

This disease is caused by a form of the same fungus that frequently causes damping-off; thus, many aspects of the life history are similar. For example, the pathogen overwinters as chlamydospores in small pieces of roots or organic matter and when seedling roots grow near these spores, germination occurs and the pathogen enters the roots. However, development is delayed until later in the growing season, when larger and more crowded seedlings are under stress, e.g., from mois-

Fusarium root rot

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Pseudotsuga menziesii, hard pines, *Larix* spp.	1+0	Mid to late summer	Yes	Yes	No	No

ture and nutrient deficiency. The fungus then grows rapidly throughout the root system and destroys it. Warm soil temperatures favor disease development.

Control

Heavy soils favor the pathogen, supposedly because of the slower decomposition rate of the pathogen's food bases (e.g., root pieces) in such soils. The disease can be most effectively prevented by locating nurseries on lighter soils. Bare fallowing between seedling crops reduces losses by increasing the rate at which the pathogen exhausts its available food. Removal of appreciable amounts of root pieces left on the field following seedling lifting also reduces the food base, as does removal of diseased seedlings during hand-weeding. Sawdust mulching and irrigation, which reduce soil temperatures, may also be helpful.

Figure 9. Douglas-fir seedling showing advanced shoot symptoms of *Fusarium* root rot.

To date, fungicides have not proved to be very effective, probably because the pathogen enters very young plants and symptoms do not develop until much later. By then, especially if disease detection relies on shoot symptoms, the disease has advanced beyond control. Soil fumigation is too expensive to be used solely for controlling the disease. In those bareroot nurseries where *Fusarium* root rot seriously limits production, the nurseryman should consider growing seedlings in containers. However, *Fusarium*-infested soil can normally be used for transplants.

Selected References

Bloomberg, W.J. 1971. Diseases of Douglas-fir seedlings caused by *Fusarium oxysporum*. Phytopathology 61: 467-470.

Lock, W. 1973. *Fusarium* root rot of Douglas-fir nursery seedlings. Forest Pest Leaflet No. 61, Pacific Forest Res. Centre, Environ. Can., Victoria, B.C.

Corky Root Disease

This disease is caused by the nematode *Xiphinema bakeri* Williams. Most plant-parasitic nematodes are small, 0.5 to 2 mm long, vermiform animals belonging to the phylum Nematoda. Those that damage conifer nursery seedlings are soil inhabitants and feed on non-woody roots and mycorrhizae. Corky root is the only important nematode-caused disease in local nurseries. The pathogen and the disease are confined to coastal, bareroot nurseries. Corky root normally occurs in nurseries established on recently cleared forest lands. *Xiphinema bakeri* is indigenous to most coastal forests and when these forests are converted to nursery production, the pathogen numbers increase. The nematode populations rarely reach damaging levels on the first crop; however, subsequent crops are severely damaged, especially if cropping is continuous.

Hosts and Damage

Locally, the disease affects seedlings of the spruces (Sitka, white, Engelmann), western hemlock and Douglas-fir. The latter is most sensitive to *X. bakeri* feeding. Symptoms (Fig. 10) first become noticeable on Douglas-fir about midway through the first growing season, when the secondary needles of random seedlings become somewhat chlorotic and the shoot slightly stunted. Diseased taproots have few if any laterals, are dark, swollen and often club-tipped, but they are not rotten. Patches of affected seedlings become evident as the symptoms develop and eventually these patches coalesce (Fig. 11) to form patches 5 to 65 m in diameter.

Seedlings affected in their first growing season fail to recover and are culled when lifted. Two-year-old stock (Fig. 12) and transplants may also become diseased if *X. bakeri* populations are large. When diseased, seedlings such as spruces, with small root systems, often frost heave. The fungus *Cylindrocarpon destructans* (Zinssmeister) Scholten frequently invades diseased roots, but the nematode is the primary pathogen. Corky root disease prevails in soils which are sandier, less fertile and have a lower nutrient holding capacity than disease-free soils. The sandier soils are physically better suited for *X. bakeri* population buildup. Thus, the two prerequisites for optimum disease development are large numbers of the pathogen and low soil fertility.

Life History

The life cycle consists of eggs, four juvenile stages and adults. Only the latter are sexually mature; males are rare. The last three pre-adult stages and adults feed on roots. Eggs are laid in the summer, total populations peak in early fall and the nematodes overwinter primarily as eggs and juveniles. Almost all of the nematodes are present in the upper 10 cm of soil around the roots.

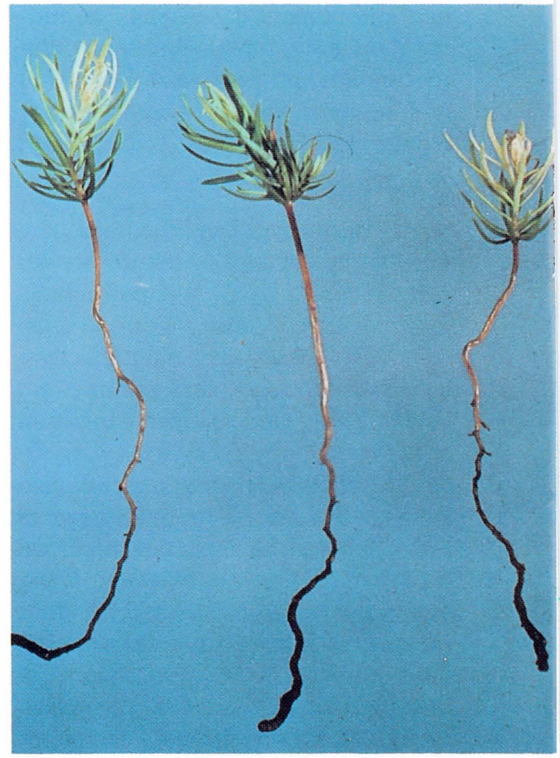


Figure 10. Douglas-fir (1 + 0) seedlings showing symptoms of corky root disease.

Control

Nematode numbers are reduced to non-damaging levels by starvation, heat and desiccation. Therefore, losses from corky root can be eli-

Corky root

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Picea spp., *Tsuga heterophylla*, and especially *Pseudotsuga menziesii*	1 + 0 2 + 0	Mid-season of first year for 1 + 0 stock, continues on 2 + 0 stock	Yes	No	No	No

minated by bare fallowing, surveying fallow fields in June or July to detect *X. bakeri* populations, and disking or rototilling infested soils during the hot, dry part of August and September. To prevent introduction of the pathogen into disease-free nurseries, fill and other potentially infested soil amendments should be checked for *X. bakeri*. Seedlings, especially diseased ones, should not be transferred among nurseries.

Pre-plant nematicides or soil fumigation can be used, but they are expensive and often adversely affect seedling growth. Because local soil temperatures normally limit their application to late summer or early fall, nematicide use often results in loss of seedling production for a year.

Figure 11. A field of 2+0 Douglas-fir seedlings showing symptoms of corky root disease.

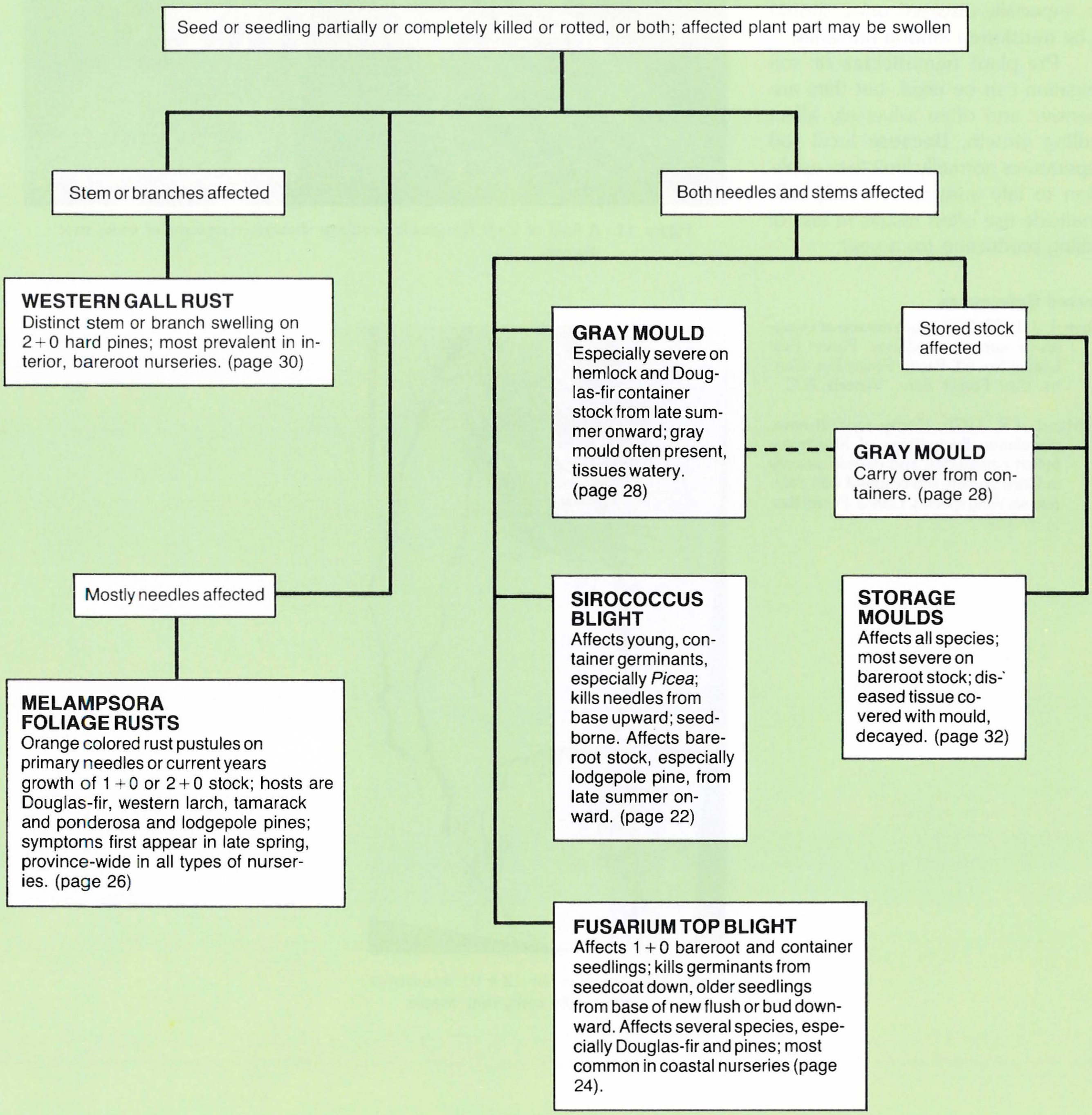
Figure 12. Douglas-fir (2+0) seedlings affected by corky root disease.

Selected References

Sluggett, L.J. 1972. Corky root disease of Douglas-fir nursery seedlings. Forest Pest Leaflet No. 53, Pacific Forest Res. Centre, Can. Forest. Serv., Victoria, B.C.

Sutherland, J.R. 1975. Corky root disease: population fluctuations of *Xiphinema bakeri* nematodes, and disease severity in forest nursery soil cropped with different seedling species. Can. J. Forest Res. 5: 97-104.

DISEASES AFFECTING SHOOTS



Diseases affecting shoots:

A. Western gall rust
B. Gray mould
C. Storage moulds
D. *Melampsora* foliage rusts
E. *Sirococcus* blight
F. *Fusarium* top blight

DISEASES AFFECTING SHOOTS

Sirococcus Blight

This disease is caused by the fungus *Sirococcus strobilinus* Preuss, which affects conifers throughout the North Temperate Zone and occurs throughout British Columbia. The fungus was first found here in 1965 and about 5 years later appeared on lodgepole pine nursery seedlings. Subsequently, it has been isolated from diseased seedlings in coastal and interior nurseries. It is more prevalent on container-grown than bareroot stock.

Figure 13. *Sirococcus* blight symptoms on container-grown spruce seedlings. Note that needles are killed upward from the base.

Hosts and Damage

Sitka and white spruce and lodgepole and ponderosa pine seedlings are affected. In contrast to the condition in forests, western hemlock nursery seedlings are rarely attacked by the pathogen. Disease symptoms and time of their appearance differ for container-grown and bareroot seedlings. With container stock, *Sirococcus* normally attacks very young seedlings (Figs. 13 and 14) and kills the primary needles from the base upward. Depending upon how far the disease has progressed, the upper portion of the needles may be green. Killed tissues are light to reddish brown. Dead seedlings remain upright. Examination with a hand lens of the inner base of diseased needles often reveals the small, irregularly rounded, light butterscotch-colored pycnidia (Fig. 15); these dar-

Sirococcus blight

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Picea spp.,	1+0	Spring and early summer	No	No	Yes	Yes
Pinus spp.	1+0 2+0	Late summer Fall through spring	Rare	Yes	Rare	Rare

ken with age. Diseased seedlings occur randomly, but are normally confined to specific seedlots. This indicates that the pathogen is seed-borne or that susceptibility varies among provenances, or both. In the laboratory, 1 to 2% of the germinants of certain seedlots become diseased from seed-borne inoculum. Thus, additional mortality, sometimes reaching 30% in certain seedlots, is probably attributable to secondary spread of the pathogen.

Symptoms usually appear in late summer through the fall on 1 + 0 bareroot seedlings or in the spring on 2 + 0 trees. The fall symptoms may be confused with early frost damage. Generally, the pattern of symptom development, color of diseased tissues, presence of pycnidia, and distribution of affected trees is the same as for container seedlings. Whereas *Sirococcus* blight normally results in mortality of container-grown seedlings, it usually kills only part of the shoot on bareroot trees; a lateral branch then takes over as the terminal shoot (Fig. 16). The desiccated terminal shoot of dead seedlings may assume a crozier-shape. With lodgepole pine, the pathogen's spread can often be traced from the primary needles with their attached seedcoat to the base of the epicotyl and upward on the stem and secondary needles.

Life History

There is evidence that *S. strobilinus* is seed-borne; thus, initial disease centers probably develop from this inoculum and perhaps from spores introduced from outside the nursery. Secondary spread is via pycnidiospores produced on diseased tissues and disseminated in rain and irrigation water. Infection occurs through young needles and is favored by cool, moist conditions and low light intensity, all of which often occur simultaneously in container nurseries, probably accounting for the higher *Sirococcus* incidence. Because the pathogen has no other known spore forms, it is assumed that each new disease outbreak originates from pycnidiospores introduced on

Figure 14. *Sirococcus* blight-killed container spruce seedlings showing dark pycnidia on the needles.

Figure 15. Pycnidia of *Sirococcus* on diseased, 2 + 0 lodgepole pine seedling.

Figure 16. *Sirococcus* blight symptoms on bareroot spruce. Note that the leader was killed in the preceding year and a lateral has become dominant.

seeds or otherwise. In California, diseased trees and cones adjacent to nurseries are known *Sirococcus* sources.

Control

Since infested seedlots are probably the major source of *Sirococcus* inoculum in local nurseries, particularly in container operations, records should be kept of all seedlots with a history of blight. Prior to sowing, these seedlots should always be dusted with a fungicide or have the fungicide added to the water-soak used before stratification. When infested seedlots are sown, they should be watched closely for symptoms and when these appear, a fungicide spray should be promptly applied to prevent further spread. Diseased seedlings should be rogued and burned when practical. Disease spread can be alleviated by reducing the humidity and, in greenhouses, perhaps by increasing temperatures. Increasing illumination may also be helpful, as seedling susceptibility is greatest at low light intensities.

Selected References

Smith, R.S., Jr., A.H. McCain, M. Srago, R.F. Krohn, and D. Perry. 1972. Control of *Sirococcus* tip blight of Jeffrey pine seedlings. Plant Dis. Rep. 56: 241-242.

Wall, R.E., and L.P. Magasi. 1976. Environmental factors affecting *Sirococcus* shoot blight of black spruce. Can. J. Forest Res. 6: 448-452.

Fusarium Top Blight

Although top or needle blights can be caused by numerous fungi, such as species of *Rosellinia*, *Pestalotia*, *Alternaria* and *Botrytis*, the most common pathogen locally is a strain of *Fusarium oxysporum* von Schlechtendahl ex Fries. This discussion is therefore limited to *Fusarium* top blight. This disease, one of the first to plague seedlings in British Columbia forest nurseries, has been known at Duncan since the early 1940s. Its importance has now lessened, perhaps because of cultural practice changes.

Hosts and Damage

The disease primarily affects bareroot Douglas-fir, but sometimes attacks other species, especially pines, during their first growing season in bareroot or container nurseries. In containers, the problem can frequently be traced to seed-borne inoculum. Up to 20% of the crop has been lost in 1 + 0, bareroot Douglas-fir. Top blight is most widespread in coastal nurseries, probably because the weather favors dis-

Figure 17. *Fusarium* top blight on Douglas-fir container seedlings. In this case, inoculum was not seed-borne.

ease development and the heavy soils in some of these nurseries are advantageous to *Fusarium* survival.

Damage can occur either before or after seedcoat shedding. On germinants, rot first appears at the junction of the seedcoat and cotyledons and spreads downward to the stem. Seedling mortality usually follows, although some seedlings may survive if all the cotyledons are not diseased. The commonest form of top blight occurs from about the middle to the end of the first growing season. The first symptoms consist of purplish, then brownish discoloration near the base of the succulent, terminal growth or bud and adjoining needles. The pathogen progresses downward, killing all or part of the stem and needles (Fig. 17). Ordinarily, diseased seedlings occur at random but with crowding and humid conditions, the fungus can spread to adjacent seedlings. Affected seedlings remain upright. Under humid conditions, the pathogen sporulates on diseased stems (Fig. 18) and needles. Environmental, especially climatic, factors obviously affect top blight incidence as the disease may be prevalent in several nurseries for a year or two and then virtually disappear for several years.

Life History

The pathogen's life history is unknown. Supposedly, it overwinters and survives other unfavorable periods as chlamydospores within pieces of organic material. Except where it is seedborne, the source of fungus inoculum is unknown. There is good evidence that seedlings must be predisposed by unfavorable weather or other stresses for disease to develop. This seems plausible, as preliminary evidence indicates that the top blight *Fusarium* occurs in equal abundance on shoots of both healthy and diseased trees.

Control

Control recommendations are at best empirical because the biology and ecology of the pathogen are largely unknown. Since seedlings in older nurseries with heavier soils seem to suffer most from top blight, losses can be decreased by locating nurseries on lighter, pathogen-free soils. Regulating seedling densities and watering to reduce seedling stress and ambient humidity are probably worthwhile. Reducing or removing seedling stress factors should decrease top blight incidence. Herbicide damage apparently increases seedling susceptibility. Bare fallowing and cultivation between bareroot crops should help because the pathogen probably survives in pieces of organic matter in the soil. Fungicide treatment of seeds should reduce losses where inoculum is seed-borne. In container nurseries, roguing and destroying diseased seedlings should help reduce disease spread, especially when fungicide sprays follow. Sprays may also be useful in controlling the disease in bareroot nurseries.

Figure 18. *Fusarium* top blight pathogen sporulating on stem of killed Douglas-fir seedling.

Selected References

Buckland, D.C. 1947. Investigations on the control of *Fusarium* top blight of Douglas-fir seedlings. Can. Dept. Agricul., Victoria, B.C., Unpublished report.

Salisbury, P.J. 1951. Investigations on the control of damping-off and top-blight of Douglas-fir seedlings at the Duncan forest nursery in British Columbia in 1948 and 1949. Can. Dept. Agricul., Victoria, B.C., Unpublished report.

Fusarium top blight

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Pseudotsuga menziesii, sometimes other species	1+0	Spring through fall	Yes	?	Yes	?

Melampsora Foliage Rusts

Only two foliage rusts regularly occur in British Columbia forest nurseries, i.e., conifer-aspen rust (*Melampsora medusae* Thuemen) and conifer-cottonwood rust (*M. occidentalis* Jackson). They derive their common names from the fact that they require at least one conifer and one *Populus* spp. host to complete their life cycle. Since susceptible *Populus* are rarely grown in local forest nurseries, emphasis here is on how these diseases affect conifers. Both rusts occur predominantly in bareroot nurseries, perhaps because container growing facilities tend to exclude rust spores. Other foliage rusts, such as fir-willow rust (*M. abieti-capraearum* von Tubeuf) and larch-willow rust (*M. paradoxa* Dietel & Holway), could be bothersome, especially if bareroot production of their conifer hosts is increased.

Hosts and Damage

Conifer hosts for *M. medusae* are Douglas-fir, western larch, tamarack and ponderosa and lodgepole pines; trembling aspen is the *Populus* host. Douglas-fir, black cottonwood and balsam poplar are hosts for *M. occidentalis*. The rusts occur throughout the province wherever their hosts are present.

Figure 19. Aecia of *Melampsora occidentalis* on Douglas-fir needles.

Both rusts produce yellow-orange, spore-producing pustules on foliage of their hosts (Figs. 19, 20 and 21). On conifer needles, these appear in late spring through mid-August and on *Populus* leaves in early summer to late fall. On the latter, the rust is most abundant on the underside of the leaves; corresponding chlorotic spots are present on the upper leaf surface. On conifers, symptoms are confined to the current year's foliage and often to the primary needles of rising 1+0 seedlings. Affected needles are usually killed and shed in the fall. Shoots of severely affected seedlings are killed. Disease intensity on individual seedlings and within nurseries is greatest near diseased *Populus* hosts. The scarcity of such trees near local nurseries probably accounts for the low level of *Melampsora* damage.

Life History

Melampsora medusae and *M. occidentalis* both require their *Populus* and coniferous hosts to complete their life cycle. The rusts overwinter as teliospores on dead *Populus* leaves on the ground. These spores germinate in the spring, producing wind-borne basidiospores, which results in infection of conifer foliage. About 2 weeks later (late spring), masses of yellow-orange aeciospores are produced on needles

Melampsora foliage rusts

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Pseudotsuga menziesii,	1+0	Early to mid-summer	Yes	Yes	Yes	Yes
Pinus contorta,	2+0					
P. ponderosa,						
Larix laricina,						
L. occidentalis						

of the coniferous host. They serve as inoculum for infection of live *Populus* leaves during the summer. Approximately 2 weeks later, urediniospores (in yellow-orange pustules) are produced on the leaves. These spores serve as inoculum for rust spread and intensification on *Populus* throughout the summer. In late summer, teliospores (the overwintering spores) are again produced on *Populus* leaves, completing the rust's life cycle.

Control

Elimination of *Populus* hosts in the immediate vicinity of conifer nurseries breaks the rust's life cycle and usually gives adequate disease control. When *Populus* cannot be eliminated, where feasible, their fallen leaves can be raked and destroyed to eliminate the overwintering spores, i.e., the inoculum for conifer seedlings. If neither of these procedures is practical, germinants and new growth of 2+0 seedlings can be protected with fungicidal sprays.

Figure 21. Uredinia of *Melampsora occidentalis* on black cottonwood leaves.

Figure 20. Aecia of *Melampsora medusae* on lodgepole pine seedling.

Selected References

Hunt, R.S. 1978. *Melampsora* foliage rusts in British Columbia. Forest Pest Leaflet No. 49, Pacific Forest Res. Centre, Environ. Can., Victoria, B.C.

Ziller, W.G. 1974. The tree rusts of western Canada. Publ. No. 1329, Can. Forest. Serv., Dept. Environ., Ottawa.

Gray Mould

Figure 22. Gray mould-affected (right-hand-side) and healthy, container-grown Douglas-fir.

The importance of this disease has steadily increased as more seedlings are grown in containers. The disease occurs in nurseries throughout the province and provides a classic example of how new pest problems can arise with technological change.

Hosts and Damage

Botrytis cinerea (Fries) Persoon, is an ubiquitous fungus with a wide host range; locally, it is very damaging to western hemlock and Douglas-fir seedlings. Pines and spruces seem to be less affected by gray mould, perhaps because their more upright growth habit provides a less favorable microclimate for disease development. Symptoms may appear any time from late summer onward until stock is shipped for outplanting. Initial symptoms include watery-moulding and killing of lower needles, or sometimes of the leader, branches and stem (Fig. 22). Tan or brown-watery lesions often develop on affected organs. As the disease progresses, the symptoms move upward and the disease can eventually kill the entire shoot. Frequently, webs or masses of gray-brown mycelium and spores of the pathogen are present on dead tissue, thus the name gray mould. The disease appears not to harm roots. Besides affecting seedlings in the nursery, the disease can cause additional damage if affected seedlings are cold-stored. This topic is discussed in the chapter on moulding of stored seedlings.

Life History

The pathogen probably overwinters as mycelium or sclerotia in old plant debris, but the exact sequence of events is not known for local container nurseries. *Botrytis* conidiospores, which are usually air-borne, are probably produced on dead plant material within the nursery or adjacent fields and forests and are either drawn or blown into nurseries by ventilation fans or wind. The fungus may also be introduced on seeds, as it can easily be isolated from them. Irrigation water could also contain gray mould spores.

Botrytis cinerea normally becomes parasitic after establishing a food base on dead or dying plant material. Tissues damaged by fertilizer or frost are known avenues for infection. *Botrytis* may also enter seedlings early in the growing season via senescent needles. Disease development and spread are favored by cool, moist conditions, dense foliage and crowded stands, all of which prevail in the fall and winter. The disease usually starts on and spreads from senescent, dead, injured

Gray mould

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Pseudotsuga menziesii, Tsuga heterophylla, other species only slightly affected	1+0	Late summer onward	Rare	Rare	Yes	Yes

or lower needles which are abundant. When succulent leaders are attacked, the disease can move downward.

Control

Cultural and fungicidal controls are presently used, alone or combined, against gray mould. The former are aimed mostly at making greenhouse conditions unfavorable for the disease; e.g., humidity is lowered by decreasing or ceasing watering, improving ventilation, regulating temperature or any combination of these. Dead, especially *Botrytis*-infected, plant material should always be removed from container sites to reduce gray mould sporulation.

Protectant and eradicant (systemic) fungicides are used to control gray mould. Factors related to their efficiency include timing of application, thoroughness of coverage and, in the case of certain systemic fungicides, buildup of *Botrytis* strains with fungicide tolerance. No fungicide, however, will completely control the disease unless the environmental conditions favoring disease development are also changed.

Selected References

Ellis, M.B., and J.M. Waller. 1974. *Sclerotinia fuckeliana* (conidial state: *Botrytis cinerea*). CMI Desc. of pathogenic fungi and bacteria. No. 431. Commonwealth Mycol. Inst., Kew, Surrey, England.

Pawsey, R.G. 1964. Grey mould in forest nurseries. Brit. Forest. Comm. Leaflet No. 50.

Western Gall Rust

This disease is caused by the fungus *Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka. The term "rust" designates both the disease and causal fungus. To date, the rust has been found in most bareroot nurseries where its hosts are grown. Although recent disease losses have been small, infected nursery stock can disseminate the rust to disease-free areas. Infection of nursery seedlings often occurs on the main stem; thus, if diseased stock is outplanted, the gall continues expanding and the tree dies, or may suffer wind breakage.

Hosts and Damage

Hosts are two- or three-needle (hard) pines, of which only lodgepole and ponderosa pines are grown locally. Since there is an interval between infection and development of conspicuous galls (Fig. 23), the disease is rarely noticed on stock until late in the second growing season, or it may go undetected until the lifted trees are graded or after they are outplanted. Locally, in recent years, seldom more than 1%, and often none of the stock, have been affected. Since seedlings are not killed, the only direct losses are the culling of lifted stock. Because these losses have been inconsequential, the disease has been largely ignored; however, western gall rust epidemics are cyclical and the potential for serious losses always exists.

Figure 23. Western gall rust on 2 + 0 lodgepole pine seedlings.

Life History

In spring and early summer, masses of orange-yellow spores are produced by and released from galls on diseased trees. When these wind-dispersed spores land upon succulent tissue of the current year's shoots or needles, they germinate, especially during rainy periods, and the germ tubes penetrate the host. The rust stimulates proliferation of the host's tissue so that 1.5 to 2 years later irregular rounded to pear-shaped swellings appear. These woody, perennial galls grow and release spores (Fig. 24) annually, which are capable of causing re-infection of pines. Consequently, no alternate hosts are involved in this rust's life cycle. Eventually the stem or branch dies. Since the interval between infection and sporulation exceeds the usual period that most seedlings are in the nursery, except perhaps some transplants, there is no danger of disease spread among nursery seedlings; rather, all inoculum originates from older infections on trees outside the nursery.

Because of the interval between infection and sporulation, it is obvious that (i) the galls seen on 2-year-old trees originate from infections occurring early in the first growing season, and (ii) trees infected during the second year will be symptomless while in the nursery. The importance of these

Western gall rust

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Pinus contorta, *P. ponderosa*, other hard pines	2 + 0	Mid to late summer	Yes	Yes	?	?

Figure 24. Masses of spores, color can vary from white to yellow, produced by western gall rust on 2 + 1 lodgepole pine.

seedlings is that they mask the true incidence of the disease in the nursery and also allow infected trees to be outplanted unknowingly.

Control

Since spores are blown into the nursery from outside, all gall-rust-infected pines should be cut for 275 m around the nursery. The unreliability of current prediction techniques makes fungicidal spraying of nursery seedlings impractical. Diseased seedlings should always be culled to lessen spread of the disease to new areas.

Selected References

Hiratsuka, Y., and J.M. Powell. 1976. Pine stem rusts of Canada. Forest. Tech. Report 4, Can. Forest. Serv., Dept. Environ., Ottawa.

Ziller, W.G. 1974. The tree rusts of western Canada. Publ. No. 1329, Can. Forest. Serv., Dept. Environ., Ottawa.

Moulding of Stored Seedlings

Figure 25. Bareroot Douglas-fir seedlings affected by storage moulding.

Moulding of stock in storage is a major problem in British Columbia, and its importance has increased as the seedling storage period has lengthened. The latter has occurred primarily because (i) the enormous increase in seedling production in recent years has prevented lifting and shipping all trees precisely when they are needed for outplanting; (ii) greater demand for high elevation provenances often means storing the stock until snow melt is complete in late spring, and (ii) of the indirect effect of increased production of container-grown stock, especially western hemlock, together with poor frost-hardiness of the species for fall planting. Storage often allows further development of gray mould that starts in the containers. Moulding of stored seedlings is particularly important because it damages trees in which 1 or 2 years of time and money have already been invested. Stored trees are the nurseryman's final product and are at their maximum pre-shipping value.

Hosts and Damage

All seedling species are affected, pines apparently less so than others. Initial evidence (Fig. 25) of the disease includes presence of cottony, usually grayish, mould on the lower needles, especially on seedlings within the storage bundles. These symptoms gradually progress upward on the shoots. If string is used to tie seedlings together in bundles, the mould may be most noticeable around it. As the disease moves upward, stems and needles become watery and decayed, and affected needles normally fall off. Sometimes, after prolonged storage, moulding appears at numerous points scattered over entire seedlings. Other symptoms that may appear on all or part of the stem and branches include water-soaked lesions, bark that strips off easily, and dead, butterscotch-colored cambium. Bundles of diseased seedlings may emit a musty odor and also small clouds of mould spores. Symp-

Moulding of stored seedlings

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species, but pines least affected	1+0 2+0	When stored	Yes	Yes	Yes	Yes

toms can appear any time after storage begins, but usually the amount and probability of damage occurring are proportional to the length of the storage period. Sometimes fungus growth occurs on roots of stored seedlings, but these moulds are seemingly equally prevalent on roots of healthy and mouldy seedlings. To date, in British Columbia, the amount of moulding damage has not been correlated with subsequent outplanting survival. However, trees with advanced stem and branch decay and defoliation (Fig. 26) probably survive poorly and seedlings with low to moderate damage may be more affected than are healthy seedlings by site, weather and other factors.

Life History

Fungi in the genera *Fusarium*,. *Rhizopus, Aspergillus, Penicillium, Epicoccum, Cylindrocarpon*, and numerous non-sporulating forms, are representative of the fungi that are commonly isolated from mouldy tissues of bareroot stock. Container seedlings usually yield only *Botrytis cinerea*. Ordinarily, these fungi live on dead or dying organic matter and only become pathogenic under favorable conditions. These fungi are ubiquitous, thus inoculum originates from those microorganisms already present on seedlings, in soil particles deposited onto shoots during lifting, or in soil adhering to roots of bareroot seedlings. None of the moulding fungi have any specialized spores for survival, reproduction or inoculation related specifically to their role in moulding.

Control

Moulding losses are better prevented than controlled. Some preventive measures include: (i) always storing stock for the shortest period possible, (ii) periodically examining a representative quantity of each seedlot of stored stock, and (iii) immediately shipping stock showing initial moulding. The latter stock should receive special care to prevent further moulding in transit and prior to outplanting. Seedlots containing significant quantities of dead organic matter, e.g., frost-killed or fertilizer-burned foliage, should be monitored closely because moulding fungi use this material as food bases to move to healthy tissues. Transplants seem to be very susceptible to moulding, especially if they have been lifted and stored as 2+0 stock, not shipped, transplanted late, then lifted and re-stored as 2+1 transplants. Such seedlings are probably in a weakened condition and therefore are more susceptible to moulding. There is also some evidence that the risk of moulding decreases as seedling frost hardiness increases. As mentioned earlier, gray mould which has become established in the container nursery can develop further in storage; thus, such stock needs daily inspection. Storing seedlings at 1 to 2° C, as practiced locally, reduces moulding damage by severely limiting growth of most storage moulds. Their growth can be completely stopped by dropping the storage temperature to -2 to -3° C. For stock that can withstand frozen storage, such a temperature regime provides excellent control of moulding. To date, species originating from the interior of the Province seem best suited to subfreezing storage. Contrary to popular belief, wetting seedling foliage prior to storage may be beneficial in preventing moulding. Proper care of stock after it leaves storage is important because moulding can occur during shipping and prior to outplanting.

Most attempts at fungicidal control of storage moulds have involved single or multiple applications of either systemic or protective fungicides, or both, at various pre-storage intervals; however, the results, especially with the protectants, have been erratic. Although expensive and time-consuming, conditions sometimes necessitate removing trees from storage, dipping them in a fungicide, and re-storing them.

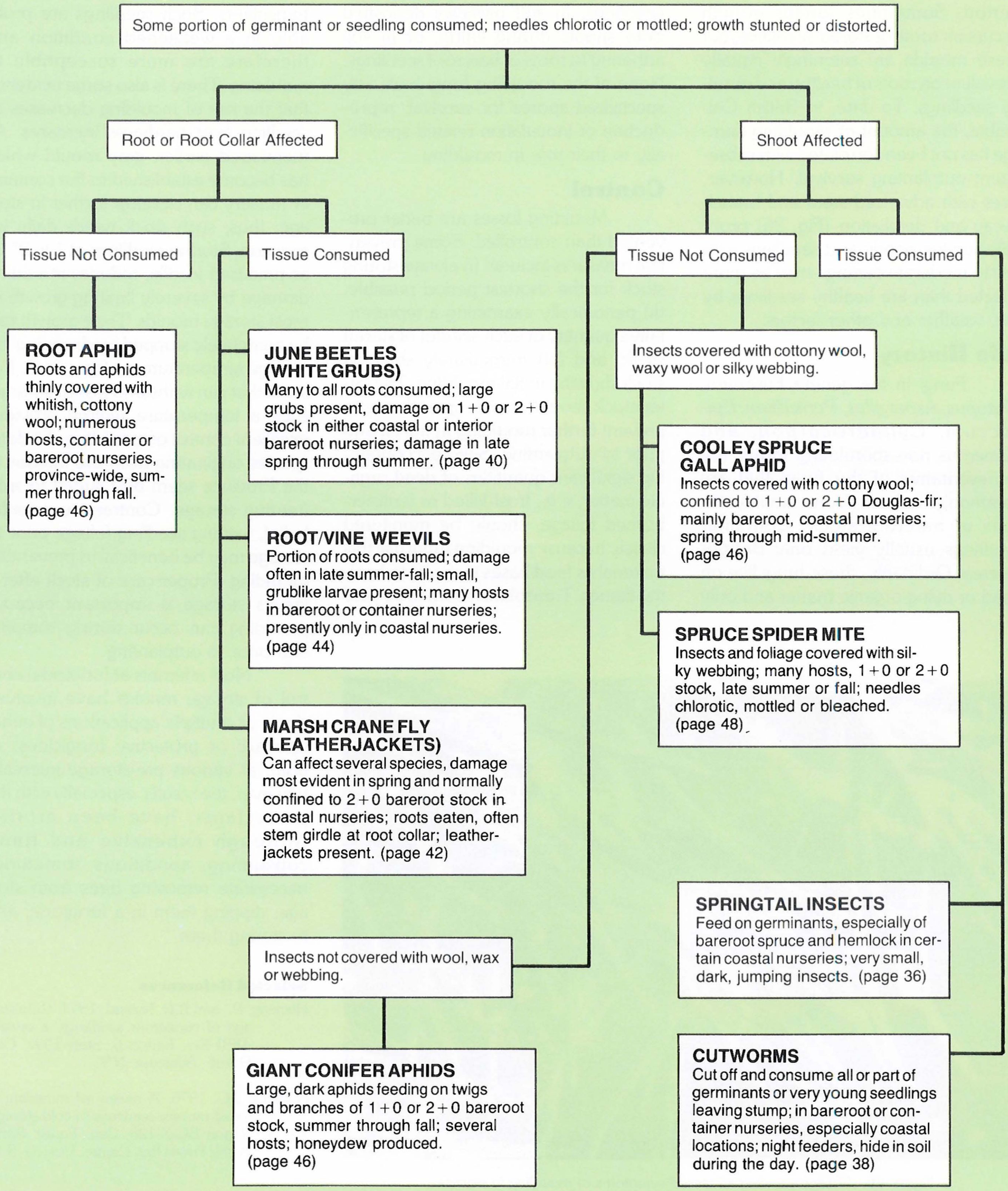
Figure 26. Foliage showing advanced symptoms of moulding in storage.

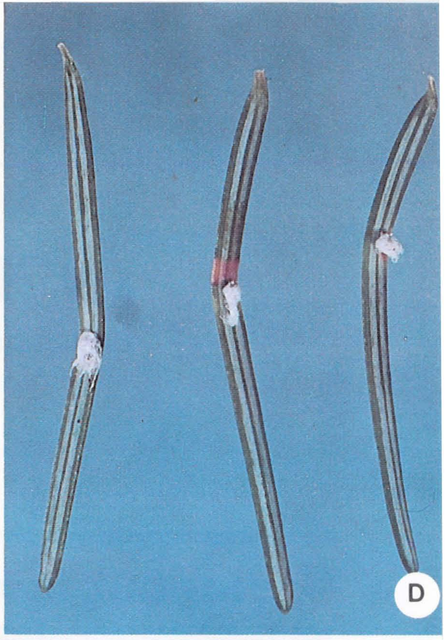
Selected References

Hocking, D., and R.D. Nyland. 1971. Cold storage of coniferous seedlings: a review. AFRI Res. Report 6, State Univ. Coll. Forest., Syracuse, N.Y.

Hopkins, J.C. 1975. A review of moulding of forest nursery seedlings in cold storage. Report BC-X-128. Can. Forest. Serv., Pacific Forest Res. Centre, Victoria, B.C.

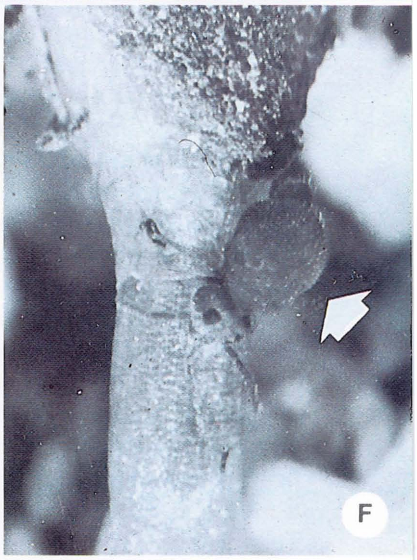
INSECT DAMAGE





Insect damage:

A. Root aphid
B. June beetles (white grub)
C. Root/vine weevils
D. Cooley spruce gall aphid
E. Spruce spider mite
F. Springtail insects
G. Giant conifer aphids
H. Marsh crane fly (leatherjackets)
I. Cutworms



INSECTS AND ALLIED PESTS

Springtail Insects

These tiny insects (order Collembola) have an appendage-like structure on their abdomen which allows them to jump through the air for several centimeters. Their common name, springtail, originates from this peculiar behavior. Springtails (Fig. 27) are abundant in most soils throughout the world. They feed on a wide range of living and dead plant materials. Locally, *Bourletiella hortensis* (Fitch) appears to be the only collembolan affecting seedling production. It has been found in nurseries at Duncan, Surrey, Chilliwack, Salmon Arm and Telkwa.

Figure 27. Springtail (at arrow) feeding on germinant (courtesy of V.G. Marshall).

Hosts and Damage

Studies demonstrated that *B. hortensis* reduces emergence of spruce (Engelmann, Sitka and white) and western hemlock. Other seedling species are potential hosts because the insect feeds on a wide range of plants elsewhere. Feeding on spruce and hemlock germinants is confined to the period between emergence and seedcoat shed (Fig. 28) and causes either a lesion or mortality. Seedlings with lesions may become deformed. It is not known if mortality is caused by feeding or if the wounds serve as entry points for pathogenic fungi. Feeding on seedlings is apparently coincidental, as the insect has no preference for living, higher plant tissues. The environment of container nurseries is nonconducive to *B. hortensis*; thus, damage is confined to bareroot nurseries.

Life History

Under coastal British Columbia conditions, *B. hortensis* apparently overwinters as eggs and the popula-

Springtail insects

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Picea spp., *Tsuga heterophylla*	1+0	Spring and early summer	Yes	Yes	?	?

tions peak in mid-July, then decline to nil levels by mid-September. Collembola do not undergo metamorphosis; consequently, except for smaller size and lack of sexual maturity, juveniles look much like adults, which are about 1.5 mm long and appear to the naked eye as blackish to dark green. The antennae are about half as long as the body and the abdomen is globular.

Control

Insecticidal treatments to control *B. hortensis* have not resulted in substantial improvement in seedling stands, especially when herbicides, which were also toxic to the springtail, were used. Cultivation of fallow-infested soils may help destroy eggs.

Figure 28. Spruce seedlings affected (four, right-hand-side) and unaffected (two, left-hand-side) by *Bourletiella hortensis* (courtesy of V.G. Marshall).

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Edwards, C.A., and G.W. Heath. 1965. The principles of agricultural entomology. C.C. Thomas, Springfield, Illinois.

Marshall, V.G. 1978. Gut content analysis of the collembolan *Bourletiella hortensis* (Fitch) from a forest nursery. Rev. Ecol. Biol. Sol 15: 243-250.

Marshall, V.G., and S. Ilnytzky. 1976. Evaluation of chemically controlling the collembolan *Bourletiella hortensis* on germinating Sitka spruce and western hemlock in the nursery. Can. J. Forest Res. 6: 467-474.

Cutworms

Larvae of several types of moths (order Lepidoptera) occur incidentally in forest nurseries and, although they often cause cutworm-like damage, they are not true cutworms. This designation applies only to larvae of moths in the family Noctuidae, of which the red-backed cutworm [*Euxoa ochrogaster* (Guenee)], the dark-sided cutworm [*E. messoria* (Harris)] and the variegated cutworm [*Peridroma saucia* (Hübner)] are probably the most frequently encountered and most damaging in local forest nurseries.

Hosts and Damage

Cutworms (Fig. 29) feed on a wide variety of field and garden crops. No species of locally grown conifer seedlings are known to escape injury. Container-grown and, especially, bareroot nursery seedlings are affected in both coastal and interior nurseries. Damage is confined to very young, succulent seedlings before their stems become woody. Cutworms feed on foliage, tender roots or stems, the latter often being clipped off (Fig. 29) at or just above ground line, leaving a short stump. All or part of the cut-off shoot may be consumed. Often, several consecutive drillrow or adjacent container seedlings are damaged. Feeding is usually done at night and the cutworms hide during the day. They can often be found hiding slightly below the soil surface near damaged seedlings. Because of their voracious appetite, even low numbers of cutworms can cause considerable damage. Adults, i.e., moths, cause no damage.

Figure 29. Typical cutworm and cutworm-damaged seedling (cut off at groundline).

Life History

The life histories of *E. ochrogaster* and *E. messoria* are similar. Both insects pass through one generation per year. Overwintering occurs as eggs, which are laid on the soil or on plant debris. Eggs hatch in mid- to late-spring, giving rise to larvae. Pupation occurs in the soil in early summer and adults (moths) are active from July to

Cutworms

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1+0	Spring and early summer	Yes	Yes	Yes	Yes

September, when egg laying occurs. Females lay up to 1,000 eggs each. Larvae, which hatch the following year, are soft, thick-bodied and dull-colored with shiny heads. They are about 4 cm long when fully grown and characteristically assume a curled position, especially if disturbed. Adults, commonly called Miller moths, are woolly, thick-bodied, mottled, brown to gray and about 2 cm long. When at rest, the wings are folded over the back, creating a dart-like appearance. Adults are nocturnal and feed on pollen and nectar of certain herbaceous plants.

The number of *P. saucia* generations per year varies according to climate. In warmer areas, there may be three or more generations yearly. Locally, only one or two normally occur, but this may increase in certain localities in years with a favorable climate. The spring generation is the most destructive because its occurrence coincides with the germination period of most plants. Each generation passes through egg, larva, pupa and adult stages; overwintering probably takes place in the pupal stage. Fully grown larvae (Fig. 30) are smooth skinned, pale gray to dark brown and about 4 cm long. The body is marked on the upper surface with a single line of four or more yellowish orange dots and two lines of linear black marks bordered with a broken yellow or orange line. Adults are similar in appearance to those of the Miller moth.

Control

Fallow bareroot fields should be kept weed-free to reduce egg-laying females. Greenhouses can be insect-proofed to exclude female moths. In container nurseries, small outbreaks can be controlled by removing the cutworms from the soil and destroying them by hand. In both bareroot and container nurseries, poison baits with natural attractants, such as apple pomace or bran, may be used to kill larvae. Sometimes it may be necessary to use insecticides, but where damage is not widespread, the spraying can be confined to those areas where seedlings have been damaged. Sprays applied late in the day or in the evening are most effective.

Figure 30. Variegated cutworm *Peridroma saucia* (scale in mm).

Selected References

Banham, F.L., and J.C. Arrand. 1970. Recognition and life history of the major insect and allied pests of vegetables in British Columbia. Bulletin 70-9, B.C. Dept. Agricul., Victoria.

Furniss, R.L., and V.M. Carolin. 1977. Western forest insects. Misc. Publ. No. 1339, Forest Serv., U.S. Dept. Agricul., Washington, D.C.

June Beetles

Seedlings in local nurseries have occasionally been damaged by white grubs which are June beetle larvae. June beetles found in British Columbia include *Phyllophaga errans* (LeConte), *P. fusca* (Froelich) and the ten-lined June beetle, *Polyphylla crinita* LeConte (also known as *P. perversa* or *decemlineata*). The larvae, damage and life histories of all three are similar, but since the latter of the three species is probably the most common and destructive, it will be emphasized here.

Figure 31. Douglas-fir seedlings damaged by June beetle larvae (white grubs).

Hosts and Damage

Adult *P. crinita* feed on conifer foliage without doing much harm. Larvae, on the other hand, can feed on and severely damage the roots of many kinds of plants, including conifers. White spruce has been damaged at Prince George and Douglas-fir at Surrey, but white grubs have such a diversified host range that the seedling species affected may only be coincidental. Cultural practices and the June beetle's life cycle normally preclude damage on container seedlings. Bareroot seedlings can be affected at any age, but especially as 1 + 0 and 2 + 1 stock. Lighter soils are more conducive to white grubs, and seedlings growing on such soils, therefore, are more likely to be damaged. Damage normally occurs in late spring through summer, when white grubs voraciously feed on roots. Frequently, the main stem of seedlings or transplants is cut off slightly below the soil surface (Fig. 31), so that affected seedlings can easily be pulled from seedbeds. White grubs can easily be excavated around the roots of damaged seedlings. Shoots of damaged seedlings turn brown and dry out. Grubs often move from one seedling to another, affecting several adjacent drill or transplant seedlings. Damage in fields with long cropping histories is usually confined to a specific crop, based on age and species, within definite sections of a field or nursery. Such "pockets" of white grubs are related to the proximity of food for the adults, i.e., large conifers in or near the nursery, upon which adults feed. In fact, damage in nurseries with long cropping histories seldom occurs farther than 275 to 375 m from the tree upon which adults feed. Grasses are excellent white grub hosts; thus, seedlings in nurseries recently established on former sod areas frequently suffer damage, and distribution coincides with that of the plowed-under sod. Depending upon environmental and other factors affecting the insect's development, white grub damage may peak at 3 or 4 year intervals. Because of climate, insect life history and previous cropping history factors, damage may be acute, seedling losses of up to 30% being common.

June beetles

Principal, locally-grown hosts	Host age and season when damage appears: Age	Season	Type of nursery stock: Bareroot, Coastal	Bareroot, Interior	Container, Coastal	Container, Interior
All species	1+0 2+0 2+1	Anytime	Yes	Yes	No	No

Life History

Depending mainly upon climatic factors, the life cycle requires 3 or 4 years for completion. The following is based on a 3-year cycle, common in coastal British Columbia. Grubs and adults overwinter in the soil and in late June and early July adults emerge on warm evenings. They fly to and feed and mate on the foliage of large conifers in or adjacent to the nursery (but probably not nursery seedlings). About dawn, the beetles return to the soil; these flights are repeated daily for 2 to 3 weeks. Females deposit their large (3.4 x 2 mm), slightly oval, creamy-white eggs in the ground, 7 to 30 cm deep, close to food plants. Eggs hatch after 2 to 6 weeks and the larvae feed for the remainder of the growing season on organic matter and roots near the soil surface. During winter, they commonly descend deeper into the soil, even under coastal conditions, to escape freezing soil temperatures. The following spring, larvae move toward the surface and feed on roots. This migration pattern is repeated in the two ensuing winters and springs until early to midsummer in the third year of development, when larval growth is completed and pupation occurs in cells about 10 cm below the soil surface. Under coastal conditions, the pupal period is about 5 weeks, but the adult beetles remain in the ground until early summer of the following year, when they emerge, feed and lay eggs.

White grubs have curved, milky-white, thick bodies with three pairs of prominent legs and darker, chitinized heads and mouths. The hind part of the body is smooth and shiny, the body contents showing through the skin (Fig. 32). There are two rows of minute hairs on the underside of the last segment that distinguish white grubs from similar looking larvae. The length of white grub larvae increases from 0.3 when hatched, to 0.9, 2.5 and 3.1 cm by the first autumn, the second autumn and when fully grown, respectively. Figure 32 shows an adult ten-lined June beetle. It is about 2.5 cm long and mottled gray-brown, with longitudinal stripes and prominent antennae. Adults of the most common species in the Interior are about 2 cm long and shiny, dark brown.

Control

While there are several possible controls for white grubs, only a few are practical in forest nurseries. Nursery managers should familiarize themselves with the local 3- or 4-year peak population cycle, in anticipation of possible grub damage. Adults are readily attracted to light traps and these may be used to monitor population levels. Areas that have been in sod for 2 or more years and are to be converted to forest nursery, and infested, fallow soils in long-established nurseries should be shallow ploughed and frequently disked in early summer to reduce white grub populations. Sometimes, preplant soil fumigation may be needed to rid an area of grubs, but fumigants are expensive and often cause undesirable effects on the growth of subsequent seedling crops. Insecticide drenches are sometimes applied to infested seedbeds. Their use is expensive and may be ineffective because of the difficulty of effectively distributing the material throughout the soil. In addition, the short-lived efficacy of many of today's insecticides necessitates repeated applications.

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Downes, W., and H. Andison. 1940. Notes on the life history of the June beetle *Polyphylla perversa* Casey. Proc. Entomol. Soc. Brit. Col. 37: 5-8.

Figure 32. June beetle larva, white grub (left) and adult of the ten-lined June beetle.

Marsh Crane Fly

Larvae of the marsh crane fly (*Tipula paludosa* Meigen) are known as leatherjackets because of their tough leather-like skin. In British Columbia, this introduced pest was first found in 1965, in Vancouver area lawns, where it probably arrived on roots of ornamentals imported from Europe. Subsequently, it has spread to other coastal areas in southern British Columbia and northern Washington.

Hosts and Damage

Although crane fly larvae are primarily pests in lawns, pastures and forage crops, they may also damage young seedlings and transplants of other crops, such as forest nursery seedlings. Locally, damage on the latter has been confined to one outbreak on 2+0 bareroot Sitka spruce at the Surrey nursery. However, there is no reason to suspect that other seedling species are not susceptible. Because of the insect's life cycle and the local practice of bare fallowing between crops, damage is almost exclusively restricted to 2+0 bareroot stock. Cold winter temperatures also confine the insect to coastal areas. Since container seedlings are ordinarily shipped as 1+0 stock, it is unlikely that leatherjacket damage would be noticed on them unless the seedlings were held through the winter until March or April of the following year. Leatherjackets girdle the stem above and below the soil line and may consume some of the upper roots (Fig.33). Damage is most likely to be noticed in March or April, when the larvae are growing rapidly and feeding voraciously. Girdling prevents water transport to the shoot, which dries out, resulting in needle browning and eventual drop. In lawns, pastures and forage crops, larvae may emerge from the soil during warm, cloudy days in March and April to feed on grass blades, but it is not known if similar feeding occurs on forest nursery seedlings. If it does, needle damage is probably insignificant. The dense seedling canopy would hinder detection of the leatherjackets and their damage. Adult crane flies cause no damage because they do not feed.

Figure 33. White spruce seedlings damaged by larvae (leatherjackets) of the marsh crane fly.

Life History

Under coastal British Columbia conditions, the marsh crane fly completes one generation per year, passing through egg, larva, pupa and adult stages. Each female lays up to 280 black, shiny eggs (1 x 0.4 mm), mainly at night, from mid-July to late Septem-

Marsh crane fly

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Picea sitchensis, potentially all species	2+0	Early spring	Yes	No	No	No

ber. Adults are most abundant during late August and early September. Eggs are laid on the soil surface or at depths of less than 1 cm, and when newly laid, are extremely susceptible to desiccation. Eggs hatch 11 to 15 days following oviposition, and the gray, legless larvae (3 mm long), called leatherjackets (Fig. 34), begin feeding immediately and continue to do so throughout the fall and during warm periods in winter. The larvae usually are found in the upper 3 cm of soil. Larvae grow rapidly in spring and reach their full length of about 4 cm by April or May. About mid-May, they stop feeding heavily and feed lightly until they pupate about mid-July. Pupae are brown, spiny and about 3.3 cm long and remain underground for about 2 weeks before working their way to the surface, where the empty pupal case is often left protruding from the soil by the emerging adult. Adults emerge after sunset and mate immediately. They resemble giant mosquitoes (Fig. 35) and have a grayish brown body, about 2.5 cm long (not including legs), two narrow wings and very long (17 to 25 mm) brown legs. Adults are weak fliers. Males live about 7 days; females 4 to 5. Mild winters, cool summers and rainfall averaging about 600 mm favor the pest.

Figure 34. Damaged white spruce seedlings and leatherjackets (larvae of the marsh crane fly).

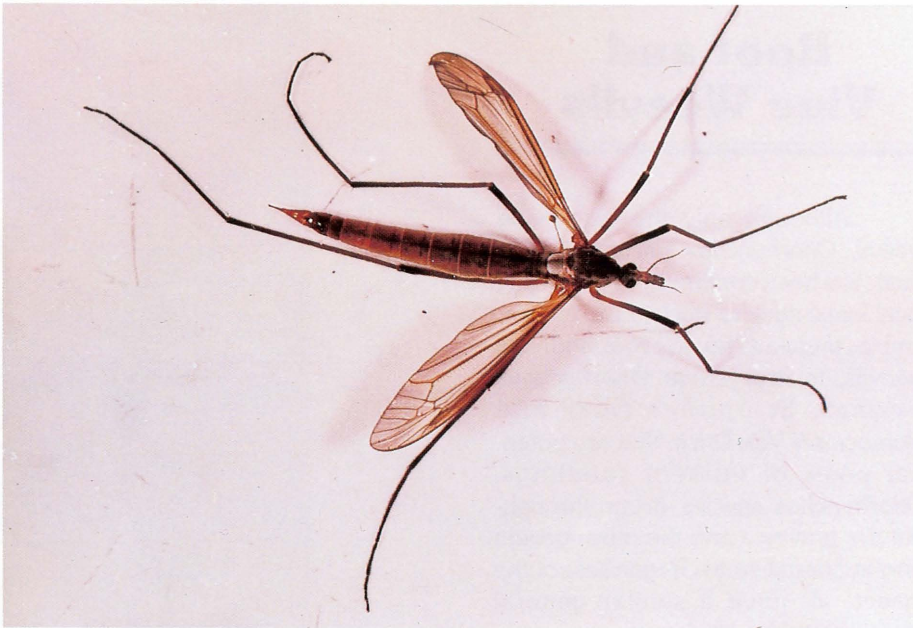

Figure 35. Adult (female) of the marsh crane fly.

Control

Seedbeds in the vicinity of areas where damage has occurred during the previous spring or where large numbers of adults have been seen in August or September should be checked for leatherjackets. This is best done in early spring by treating several 30 cm^2 plots in the suspected seedbeds with 1 cup of an insecticide drench (consult an entomologist for a recent recommendation) which will cause the leatherjackets to squirm out of the soil so they can be counted. Although data are unavailable for forest nurseries, insecticide drench treatments are recommended for lawns with 20 or more leatherjackets per 30 cm^2.

Adult crane flies can also originate from lawns, pastures, fields of forage crops and grassy banks of drainage ditches adjacent to nurseries, especially if any of these contain wet areas. Insecticide sprays against adults are of no value because crane flies do not feed and they mate and lay their eggs shortly after emerging. Since larvae readily accept baits, it may be worthwhile to apply these to seedbeds in March and April, when larvae are foraging above ground on warm, cloudy days. Larvae can also survive in fallow soil by eating decaying roots or weed roots; thus, when these areas are infested they can be disked during the early part of summer to keep them weed-free and also during the dry portion of summer and fall to kill the larvae, which are very susceptible to desiccation. Crane flies prefer wetter soils; thus, the drainage of areas with habitual outbreaks should be checked and, if necessary, improved. Fortunately, control may not be necessary in future, as natural insect and disease enemies of the crane fly seem to be increasing.

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Wilkinson, A.T.S., and H.R. MacCarthy. 1967. The marsh crane fly, *Tipula paludosa* Mg., a new pest in British Columbia (Diptera: Tipulidae). J. Entomol. Soc. Brit. Col. 64: 29-34.

Root and Vine Weevils

Although only the black vine weevil, *Otiorhynchus sulcatus* (Fabricius), has been confirmed as damaging local forest nursery stock in British Columbia, there are several root and vine weevils, in the genera *Otiorhynchus* Germar, *Sciopithes* Horn and *Nemocestes* Van Dyck, that are potential pests of nursery seedlings. *Otiorhynchus* species occur throughout the province and the other genera only in coastal areas. Regardless of the insect, all have a similar general appearance and life history.

Hosts and Damage

Root and vine weevils damage many woody, broadleaf and conifer plants, including ornamentals, small fruits and nursery seedlings. All seedling species grown in forest nurseries are liable to attack. Damage (Fig. 36) occurs in bareroot and especially container nurseries where 1+0, and sometimes 2+0, seedlings are affected. To date, damage has largely been confined to seedlings in coastal nurseries. Adult weevils cause slight damage by feeding on the foliage margins. Their presence may go undetected because they feed at night and hide under mulch, boards and so forth during the day. The most important damage is caused by the larvae, whose feeding on roots and below the root collar cuts the supply of water and minerals to the shoot, resulting in reduced seedling vigor or mortality. The latter may result from chronic or severe feeding. Heavily damaged seedlings can easily be lifted from the container rooting medium or seedbed. Damage often goes unnoticed until root damage is severe. In bareroot and container nurseries, damage from larval feeding is usually most evident in late summer through fall. Container stock may also be damaged

Figure 36. Douglas-fir container seedlings damaged by root/vine weevil larvae.

Root and vine weevils

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
All species	1+0 2+0	Late summer through fall	Yes	?	Yes	?

throughout the winter, if it is kept where soil temperature is warm enough to allow larval activity.

Life History

The life history of all local root and vine weevils is similar. The following generalized life history is based on outdoor, coastal conditions, where all species pass through one generation per year; however, the timing and number of generations per year may be different in heated greenhouses. Overwintering occurs as larvae or adults. Oviposition by overwintered adults begins as early as May. Summer adults which develop from overwintering larvae appear about the end of May to early July. Both overwintering and summer adults oviposit for about 7 weeks and all oviposition ceases by September 1. All adults are females, unable to fly, varying in color from gray to black and in length from 0.3 to 1.2 cm, and are typical weevil-shaped (Fig. 37). Eggs are laid mainly beneath duff, mulch or the soil surface and have a 10- to 20-day incubation period. Larvae are up to 1.3 cm long, slightly curved, creamy white with brown heads and have no legs (Fig. 38). Overwintering larvae pupate in earthen cells during the spring and early summer, emerging as summer adults.

Figure 37. Adult root/vine weevil.

Control

Although adults do little damage, control is based on killing them or preventing them from laying eggs. In bareroot and container nurseries, surveys should be made to detect overwintering and summer adults. Within 3 weeks of finding them, i.e., before they oviposit, an insecticide should be applied to the foliage of the seedlings to kill feeding adults. Foliar sprays should remain toxic for a minimum of 48 hours. Weevil baits or pit-fall traps may aid in detecting adults. Feeding damage is not conspicuous enough on conifers to be useful in determining the presence of adults. However, since damage is very noticeable on certain broadleaf hosts, such as rhododendron and azalea, it may be worthwhile, especially in container nurseries, to place some potted plants of these hosts around the nursery to monitor for adults. Larvae-infested containers can be dipped in insecticide, but this is costly and requires the use of toxic, long-lived chemicals.

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Gerber, H.S., N.V. Tonks, and D.A. Ross. 1974. The recognition and life history of the major insect and mite pests of ornamental shrubs and shade trees of British Columbia. Bulletin 74-13, B.C. Dept. Agricul., Victoria.

Nielsen, D.G., M.J. Dunlap, and J.F. Boggs. 1978. Controlling black vine weevils. Amer. Nurseryman 147: 12, 13, 89-92.

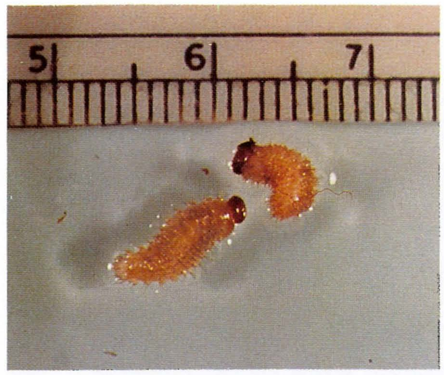

Figure 38. Larvae of root/vine weevil (scale is in cm and mm).

Figure 39. Giant conifer aphids (*Cinara* sp.), at arrow, on spruce seedling terminal.

Aphids

In general, aphids (order Homoptera) are small, gregarious insects with soft, pear-shaped bodies ranging in color from green, yellow, black to colorless. Their long, slender legs allow for slow movement. Most species possess a pair of tubelike, truncate or pore like structures on the dorsal, posterior section of the body. Adults may be wingless or possess four transparent, delicate wings.

The aphids most likely to be found in local forest nurseries are several species of giant conifer aphids (*Cinara* Curtis), a mycorrhizal-feeding aphid [*Rhizomaria piceae* (Hartig)] and the Cooley spruce gall aphid [*Adelges cooleyi* (Gillette)]. Although nursery managers must follow quarantine regulations to prevent spread of the balsam woolly aphid, this pest is not included here because it is unlikely to be a problem in forest nurseries[2].

Hosts and Damage

Each tree species grown in local nurseries is a host for at least one species of giant conifer aphid (*Cinara* spp.). Great numbers of these large, dark-colored, long-legged aphids (Fig. 39) feed gregariously on twigs, branches or roots, where they may cause foliage chlorosis. They characteristically produce copious amounts of honeydew on which sooty moulds grow. *Cinara* spp. are commonly attended by ants.

Recorded hosts of the mycorrhizal-feeding aphid (*R. piceae*) include Douglas-fir, western hemlock and Sitka and white spruces. Locally, the aphid has been found only on container-grown white spruce at Prince George. The small colonies of these mostly wingless aphids are covered with cottony wax (Fig. 40). To date, no definite damage has resulted from these aphids in local forest nurseries.

Sitka, white and Engelmann spruces and Douglas-fir are hosts for Cooley spruce gall aphid; however, damage has been observed only on bareroot Douglas-fir in coastal nurseries. *Adelges cooleyi* feeds on new needles and shoots of Douglas-fir, causing them to twist and yellow (Fig. 41). When aphid populations are large, branch tips may be killed or seedling shoot-growth stunted. The aphids are covered in tufts of white, cottony wool (Fig. 42). The insect causes large, cone-shaped galls to form on spruce, but neither these nor other signs of damage have been noted on spruce seedlings.

Life History

The life history of aphids, including the ones discussed here, is complex. In general, most aphids pass

Aphids

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Many species, but depends upon aphid species	1+0 2+0	Anytime, but depends upon aphid species	Yes	Yes	Rare	Rare

[2] Consult provincial or federal plant quarantine officials regarding the most recent regulations on growing and shipping species of *Abies*. The life history and bionomics of *Adelges piceae* are given by: J.W.E. Harris. 1978. Balsam woolly aphid. Forest Pest Leaflet No. 1, Pacific Forest Res. Centre, Environ. Can., Victoria, B.C.

Figure 40. White wool (left) of root aphid on container-grown white spruce, and enlargement (right) showing the aphids.

Figure 41. Twisting and distortion of needles of Douglas-fir seedling caused by Cooley spruce gall aphid.

through several generations per year. Populations fluctuate widely and quickly. Some juveniles hatch from eggs, while others may be born alive. Overall, the appearance of adults and juveniles is similar, except for size. Parthenogenesis, development of an unfertilized egg, is common; however, the last seasonal generation is usually sexual. Overwintering is usually in the egg stage. Some aphids complete their life cycle on two kinds of plants. Even this relationship may be optional; e.g., the Cooley spruce gall aphid normally requires Douglas-fir and spruce to complete its life cycle, but certain wingless

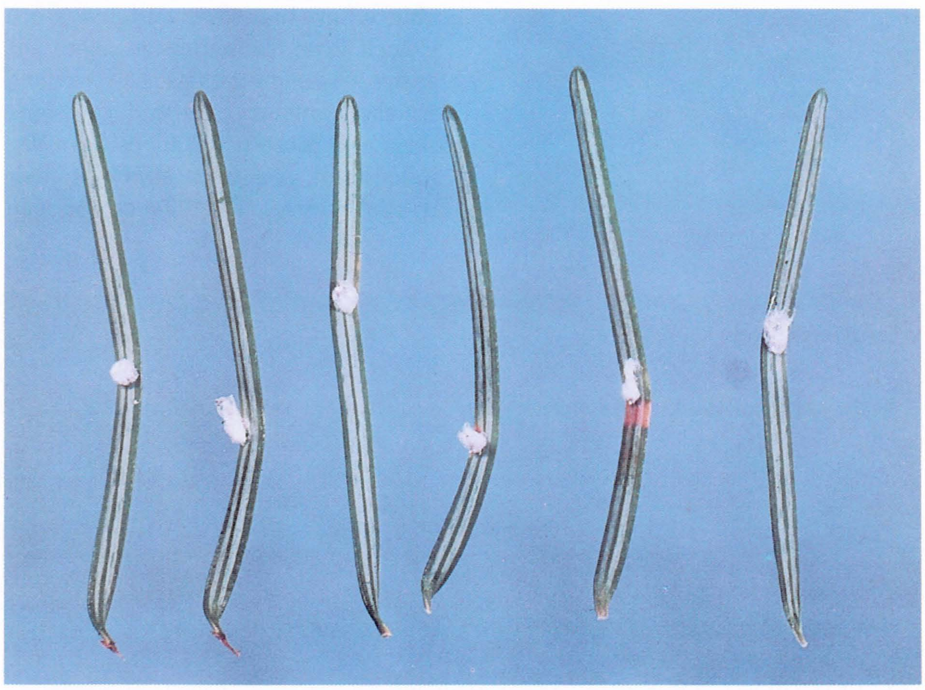

Figure 42. Symptoms and white, cottony wool of Cooley spruce gall aphid on Douglas-fir seedling.

generations may live only on spruce or Douglas-fir.

Control

Most aphids do so little damage in forest nurseries that a prevention program is probably not worthwhile. Predicting aphid outbreaks is difficult in nurseries because population buildup is often fast and erratic. It is impossible to exclude aphids, as they are frequently windblown into the nursery. All of these facts justify waiting until the populations have been detected before applying controls such as insecticidal soaps. The probability and intensity of *A. cooleyi* outbreaks may be decreased by not having spruce in windbreaks or the nursery periphery immediately adjacent to Douglas-fir seedbeds.

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Spruce Spider Mite

Many species of spider mites (order Acariformes), distributed throughout the North Temperate Zone, attack a wide variety of crop plants. Only the spruce spider mite, *Oligonychus ununguis* (Jacobi), has damaged seedlings in British Columbia forest nurseries.

Hosts and Damage

The spruce spider mite feeds on the foliage of several conifers, including, of local importance: cedars (arborvitae), Douglas-fir, firs, hemlocks, larches, pines and spruces. It inserts its stylet-like mouthparts into needles and tender twigs and sucks out the cell contents, causing a mottled, bleached discoloration and subsequent drying of the needles (Fig. 43). Severely affected foliage turns dingy yellow to dull, rusty brown and the needles drop off. Immature and adult mites spin a fine, silk webbing around and amid the needles of infested twigs. The abundance of this webbing (Fig. 44), especially noticeable when branches and twigs are viewed from the underside, increases as the season progresses. The webbing usually contains eggs and cast mite skins and protects the mites from dislodgement and from some of their natural enemies. The mites can be seen by tapping an infested twig over a white sheet of paper.

To date, spruce spider mite damage has been recorded on bareroot and container stock in coastal nurseries. However, the potential for damage is probably greatest in interior nurseries because hot, dry conditions favor the pest. Low host vigor, host crowding, and absence of natural enemies also enhance spider mite outbreaks. Consequently, damage in local nurseries is most likely to occur, as in cases to date, in late summer to early fall, when seedlings are often being stressed for water and nutrients to induce dormancy.

Life History

There are five stages in the life cycle, i.e., egg, larva, two nymphal stages and adult. Overwintering is in the egg stage. Eggs are pale yellow when laid and gradually become reddish brown. During a warm, dry season, hatching begins in late spring to early summer. Development of larvae and nymphs requires about 3 to 6 days, respectively. Newly hatched larvae are pink, becoming needle-green after feeding. They have three pairs of legs. Nymphs are mottled, needle-green to dark-green. Like the adults, they have four pairs of legs. Nymphs develop into adults by early summer and the latter may live up to 30 days. Adults are very small (0.4 to 0.6 mm long), dark-green to dark-brown, and move about fairly rapidly. Each female lays as many as 50 eggs. There may be up to seven suc-

Spruce spider mite

Principal, locally-grown hosts	Host age and season when damage appears		Type of nursery stock			
			Bareroot		Container	
	Age	Season	Coastal	Interior	Coastal	Interior
Several species	1+0 2+0	Late summer to early fall	Yes	?	Yes	?

Figure 43. Mountain hemlock seedlings damaged by the spruce spider mite.

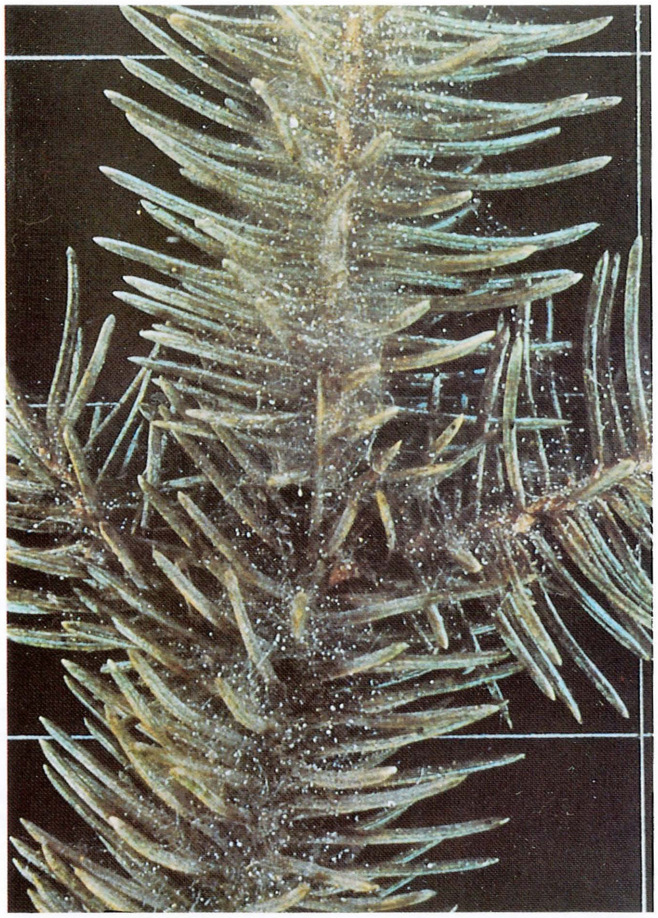

Figure 44. Webbing of the spruce spider mite on affected foliage (courtesy of G.B. Neill).

ceeding generations of mites per season, i.e., about one new generation each 15 days. Larvae, nymphs and adults all feed, the spring generation tending to feed on old foliage and subsequent generations on current foliage. Overwintering eggs are laid in autumn under loose bud scales and bases of needles. Because no seedlings are usually available for overwintering sites, spider mite outbreaks in container nurseries probably originate from mites that are windblown into the nursery. Outbreaks in bareroot nurseries could originate from the same source and also from overwintering eggs.

Control

Preventive programs are probably not practical in forest nurseries; however, spider mite populations on trees around the nursery should be monitored, particularly during long, warm-dry summer periods, because these mites can be windblown into the nursery. Where practical, e.g., in small outbreaks, affected seedlings can be washed daily with a strong stream of water to wash away the mites and break up the webbing protecting them and their eggs. Sometimes, miticide use may be necessary, especially where water washings might be undesirable, such as in large outbreaks or where the water might break dormancy of stock destined for storage or shipping. When using a miticide, check current recommendations; insecticides are usually ineffective against mites.

Selected References

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DISEASES, INSECTS AND INSECT ALLIES OF MINOR IMPORTANCE IN BRITISH COLUMBIA FOREST NURSERIES

Pathogen (and disease caused)	Host records	Type(s) of nursery(ies)	Season(s)	Remarks	Reference (where pertinent)
NEEDLE TIP DIEBACK *Alternaria* spp.	Engelmann spruce White spruce	Interior, container Coastal, container	Fall Winter	Could affect many hosts of all ages, in all nurseries, and throughout the year.	—
ROOT ROT *Cylindrocarpon* spp.	White spruce	Interior, bareroot	Summer	As above; seedlings usually must be predisposed by other factors before they are affected by this fungus.	C.M.I., Mycol. Paper No. 104.
SHOOT TIP BLIGHT *Diplodia pinea*	Ponderosa pine	Interior, container	Summer	Other hosts possible, could affect seedlings of all ages in all nurseries.	Plant Dis. Rep. 60:269-270.
SHOOT BLIGHT *Pestalotia* spp.	Amabilis fir Larch	Coastal, bareroot Interior, container	Fall Summer	As above.	—
NEEDLE DIEBACK *Phoma* spp.	Many pines and spruces, western hemlock, cedar	Several localities, container and bareroot	Spring through late fall	More prevalent on container seedlings, often confused with *Sirococcus*.	—
SHOOT BLIGHT *Phomopsis* spp.	Western hemlock	Coastal	Winter	As for *Diplodia pinea*.	Can. J. Bot. 46: 601-603.
ROOT ROT *Pythium* spp.	White spruce	Coastal and interior, bareroot and container	Summer and Fall	As above; sometimes originates from peat in containers.	—
NEEDLE BLIGHT *Rosellinia heterotrichioides*	Douglas-fir	Coastal, bareroot	?	Could affect bareroot stock in coastal nurseries especially during cool, wet periods.	U.S.D.A. Agricul. Handbook No. 470.
LEADER OR BRANCH DIEBACK *Sclerophoma pithyophila*	Lodgepole pine Sitka spruce	Interior, bareroot Coastal, container	Fall Summer	As for *Diplodia pinea*; usually affects stressed seedlings.	Plant Dis. Rep. 58:94-95.
SMOTHERING FUNGUS *Thelephora terrestris*	Many	Several	All	Seldom kills seedlings; also forms mycorrhizae.	U.S.D.A. Agricul. Handbook No. 470.
Insects and Allies					
ORANGE TORTRIX *Argyrotænia citrana*	Spruces Lodgepole pine Western hemlock	Coastal, bareroot and container	Summer	Incidental pest causing minor defoliation; could feed on many seedling hosts.	U.S.D.A. Forest Serv., Misc. Publ. No. 1339.
THRIPS *Thysanoptera*	Western red cedar Lodgepole pine	Coastal, container Interior, container	Summer	Causes malformation and needle necrosis.	As above.

Glossary[3]

AECIOSPORE — one of several kinds of spores produced by a rust fungus. Formed in and released from a fruiting structure called an aecium (3).

ALTERNATE HOST — one or the other of the two unlike host plants parasitized by a heteroecious fungus such as a typical rust fungus (3).

ASCOMYCETE — a large group of fungi which are characterized by the free cell formation of spores, usually eight in number, in a saclike structure called an ascus (3).

ASEXUAL STAGE OR SPORE — either a vegetative stage or a reproductive stage in the life cycle of a fungus in which nuclear fusion is absent and in which reproductive spores are produced by mitosis or simple nuclear division. Synonym: imperfect stage (3).

BASIDIOMYCETE — a large group of fungi which are characterized by the production of spores, usually four, on a basidium (3).

BASIDIOSPORE — the spore produced by the sexual stage of the basidiomycetes (3).

BLIGHT — a general term for a plant disease causing rapid death or dieback (3).

CANKER — a definite relatively localized necrotic lesion primarily of the bark and cambium (3).

CHLAMYDOSPORE — a thick-walled asexual resting spore typically formed by many soilborne fungi (3).

CHLOROSIS — an abnormal yellowing of the foliage (3).

CHLOROTIC — abnormally yellow (3).

CONIDIUM (A) — asexual spore of a fungus, typically produced terminally on a specialized hyphae termed a conidiophore (3).

CULL — a seedling that is rejected because it does not meet certain specifications (3).

DECAY — the decomposition of plant tissue by fungi and other microorganisms (3).

DIEBACK — the progressive dying of stems and branches from the tip downward (3).

DISEASE — unfavorable change of the function or form of a plant from normal, caused by a pathogenic agent or unfavorable environment (3).

ENDEMIC — native to the country or region (3).

EPIDEMIC — pertaining to a disease that has built up rapidly and reached injurious levels (3).

FALLOW — cultivated land allowed to lie idle or unplanted during the growing season (3).

FUMIGATION — to apply vapor or gas to, especially for the purpose of disinfecting or destroying pests (3).

FUNGICIDE — chemical that is toxic to fungi (3).

FUNGUS (I) — an undifferentiated plant lacking chlorophyll and conductive tissues (1).

GALL — a pronounced swelling on a woody plant caused by certain fungi, bacteria, insects or nematodes (3).

GERM TUBE — the early growth of mycelium produced by a germinated fungus spore (1).

HOST — the plant on or in which a pathogen exists (3).

HOST RANGE — all hosts that a particular pathogen attacks (3).

HYPHA(E) — one of the filamentous threads that make up the fungus body (3).

HYPOCOTYL — that part of the axis of a developing embryo just below the cotyledons (3).

INFECT — to invade and cause a disease (3).

INFEST — to be present within an area (or plant or soil) in such numbers as to be a disease hazard (3).

INOCULATE — to place a pathogen on or in a host in a position in which it is capable of causing a disease (3).

INOCULUM — the spores, mycelium, sclerotia or other propagules of a pathogen which initially infect a host or crop (3).

INSECT — animal belonging to the class Insecta (definition by the authors).

INSECT ALLIES — insect-like or insect-related (definition by the authors).

LARVA(E) — a young insect differing fundamentally in form from the adult, typical of insects that undergo complete metamorphosis, as in Coleoptera, Hymenoptera and Diptera (2).

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[3] Numbers following the definitions indicate their sources:

1. Agrios, G.N. 1969. Plant pathology. Academic Press Inc., New York.
2. Furniss, R.L., and V.M. Carolin. 1977. Western forest insects. Misc. Publ. No. 1339, Forest Serv., U.S. Dept. Agricul., Washington, D.C.
3. Peterson, G.W., and R.S. Smith, Jr. 1975. Forest nursery diseases in the United States. Agricul. Handbook No. 470, Forest Serv., U.S. Dept. Agricul., Washington, D.C.

LATENT INFECTION — an established infection that does not show its presence (3).

LESION — a defined necrotic area (3).

METAMORPHOSIS — series of changes through which an insect passes in developing from egg to adult (2).

MOULD — any profuse or woolly fungus growth on damp or decaying matter or on the surface of plant tissue (1).

MYCELIUM — a mass of hyphae that forms the vegetative filamentous body of a fungus (3).

MYCORRHIZA(E) — a symbiotic association of a fungus with the roots of a plant (1).

NECROSIS — death of plant cells usually resulting in darkening of the tissue (1).

NEMATICIDE — a chemical compound or physical agent that kills or inhibits nematodes (1).

NEMATODE — generally microscopic, wormlike animals that live saprophytically in water or soil, or as parasites of plants and animals (1).

NYMPH — young stage of insects having incomplete metamorphosis, as in Hemiptera (2).

PARASITE — an organism living on and nourished by another living organism (3).

PARTHENOGENESIS — reproduction without male fertilization (2).

PATHOGEN — an organism that causes a disease (3).

PATHOGENIC — capable of causing a disease (3).

PERFECT STAGE — the stage in which the sexual spore stage is produced. Synonym: sexual stage (3).

PHYCOMYCETE — a group of lower fungi which includes the water moulds (3).

PHYTOTOXIC — a chemical that is toxic to plants (3).

PUPA(E) — the intermediate stage between the larva and the adult (2).

PYCNIDIOSPORE — an asexual spore or conidium produced within a pycnidium (3).

PYCNIDIUM(A) — an asexual type of fruiting body, typically flask shaped, in which asexual spores or conidia are produced (3).

ROT — see decay.

SAPROPHYTE — an organism using dead organic material as food (3).

SCLEROTIUM(A) — a firm, frequently rounded multicellular resting structure produced by fungi (3).

SEXUAL STAGE — the stage in the life cycle of a fungus in which spores are produced after sexual fusion. Synonym: perfect stage (3).

SIGN — the pathogen or its parts or products seen on the host plant (1).

SPORE — the reproductive structure of the fungi and other lower plants (3).

SPORULATE — to produce and release spores (3).

SUSCEPTIBLE — unable to withstand attack by an organism or damage by a nonliving agency without serious injury (3).

SYMPTOM — the evidence of disturbance in the normal development and function of a host plant, i.e., chlorosis, necrosis, galls, brooms, stunting, etc. (3).

SYSTEMIC — affecting or distributed throughout the whole plant body (3).

TELIOSPORE — the spore of the rust fungi from which the perfect stage of the basidium and basidiospore arise (3).

UREDINIOSPORE — one of the many spore stages produced by the rust fungi in their complicated life cycle. These spores are produced in a fruiting body called a uredinum (3).

UREDINIUM(A) — one of the many types of fruiting bodies formed by the rusts in their complicated life cycle. Urediniospores are formed in this fruiting body (3).

WILT — a type of plant disease characterized by the sudden loss of turgor and collapse of the succulent parts of the affected plants (3).

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published jointly by

Province of British Columbia

Ministry of Forests

Government of Canada
Canadian Forestry Service

Gouvernement du Canada
Service canadien des forêts

PRINTED IN CANADA FLEMING PRINTING LTD.