

FOREST PATHOLOGY AND FOREST MANAGEMENT
IN
BRITISH COLUMBIA

by

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FOREWORD

Losses in forest production from diseases are insidious and often unrecognized or disputed. Recent estimates by the Canadian Forestry Service, although admittedly crude, generally have ranked disease-caused losses of timber volume ahead of those caused by fire and insects. Losses include wood decay in standing trees and reduced growth or quality of trees infected by parasites or other debilitating diseases. Management of infected forests requires specialized training and field experience to detect diseases and prescribe suitable treatments. Several common tree diseases such as root diseases, cankers and dwarf mistletoes are expected to become increasingly important as forestry practise becomes more intensive and younger stands are managed. Although techniques to treat disease-infected forests are limited or at times lacking, and new or improved methods are desirable, available techniques are being implemented wherever appropriate to prevent or reduce disease losses, and thus increase timber supplies.

This report contains an overview of forest pathology - the science and management of forest tree diseases - and a brief description of some activities undertaken by the Ministry of Forests in British Columbia. The report is necessarily general in nature and is intended only as an introduction to forest pathology.

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INTRODUCTION

In 1980 the Ministry of Forests formally organized a forest pest management section as part of Protection Branch at Victoria and in all Regions of the Province. This increased emphasis on forest insect and disease management followed from recent analyses. These identified and estimated substantial losses of timber from forest insects and diseases and suggested that wood supplies could be increased in short and long-term periods by improved forest protection. Although losses from diseases were estimated to equal or exceed those caused by fire, diseases previously had received little emphasis in management. Insects and forest fire are easily recognized by many people, and the need to protect forests from them is obvious. However, tree diseases are little known and often puzzling to many people, even forest workers. At present our knowledge of forest losses for most diseases is lacking or very limited, and development of more effective or efficient management treatments is needed.

The purpose of this report is to briefly define forest pathology, describe some of the major forest diseases in B.C., and outline some forest management activities undertaken by the Ministry.

DEFINITIONS AND SCOPE

What is forest pathology? Generally all aspects of tree diseases including research, diagnosis of causes, trials of control methods, establishment of management demonstrations, and incorporation of improved methods into practice.

Concepts and definitions of tree disease are many and varied. Disease has been defined as a prolonged disturbance to the normal function or structure of a tree which results in recognizable injury, reduced growth, poorer quality or death. An agent which causes a specific disease is termed a pathogen. The cause of a disease is established by a set of rules called Koch's postulates. Many forest tree pathogens are fungi which, as described further, derive their nourishment from trees. Other pathogens include dwarf mistletoes which are green seed-plants and in a few instances, bacteria, mites or other organisms. Insects and fire are excluded as pathogens. Several non-living (abiotic) agents also injure trees including air pollution, climatic stress, e.g. drought, lightning, and frost.

Tree diseases result from various interactions of pathogens, trees, and their environments. In many situations, a pathogen or disease is favoured by environment, particularly air temperature or moisture. For example, cool wet weather in May-June often leads to abundant needle disease because spore dispersal of fungi and infection of foliage are favoured. On the other hand, environmental factors such as dry weather also can limit diseases. At some stages in the growth of trees certain environmental features can be either too abundant or deficient and can cause injury or disease. Seedlings with succulent tissues and small roots often are killed by excessive heat or drought. Environmental factors can also weaken a tree sufficiently to enable fungi which usually are only slightly pathogenic, to cause disease. Diseases or pathogens also can be directly affected by other organisms. For example,

fungi which cause root diseases, often compete with other soil-inhabiting fungi which potentially are control agents.

Although certain fungi which cause tree diseases are considered to be pests, most forest fungi are innocuous or beneficial. Many fungi live only on dead trees and other plant materials, decay these remains and recycle their mineral constituents. Other fungi form a beneficial association with tree roots. Special structures are formed called "mycorrhizae". These literally are "fungal roots" which often enable trees to grow on otherwise inhospitable, nutrient-poor sites. They improve the ability of a tree to absorb necessary minerals and defend against diseases.

Forest pathology in comparison to agricultural plant pathology, faces special challenges due to the nature of forests. Forest trees are genetically diverse, occupy many environmentally different sites, and must grow for many years before reaching a usable size. In coastal B.C. trees may grow to merchantable size in 40 to 60 years and in the interior of B. C. up to 120 years or more in some locations. During these periods trees are subject to numerous pathogens and situations which could lead to disease. Recently the practice of forestry in B.C. has intensified with extensive plantings of often single species (monocultures), thinnings, fertilization, and genetic selection. From previous history and experience with agriculture crops, it seems likely that intensive forestry will improve forest yields but also could make trees more subject or vulnerable to diseases.

EFFECT ON TIMBER SUPPLIES

Management of B.C. forests to prevent or reduce disease-caused losses was emphasized recently because of predicted future shortages of timber supplies. Immediate and future yields of timber potentially could be increased if losses to disease could be reduced.

Recently the Canadian Forestry Service made a preliminary estimate of losses on B.C. forest land caused by various diseases. Several diseases including nursery diseases and others such as white pine blister rust were excluded. Total losses including killed trees and reduced growth from both insects and diseases were estimated at 25 million cubic meters per year, an amount equal to 2-3 times the average annual volume loss to forest fire. The total loss was equivalent to about one-third of the total volume harvested in 1981. Loss to disease was 16 million cubic meters (65 per cent of the total loss). Prior to the recent dramatic outbreak of bark beetles, disease-caused losses were 10 times larger than those caused by insects.

Most of the losses to insects were from mature trees killed, and much of this loss is potentially salvageable. Although disease losses from mortality were considerable, most of the disease-caused loss was from reduced growth and wood decay which is not recoverable. In many instances, prevention or reduction of disease-caused losses appears very feasible, and long-term gains in supplies should be possible if effective treatments were consistently applied. An outstanding example is dwarf mistletoe, a parasite of hemlock, Douglas-fir, larch and pine, which, as described later in this report, could be controlled substantially by applying sanitation at time of harvest.

MAJOR TREE DISEASES

a. Wood Decay

A major source of timber loss identified was decay of living, overmature trees. Wood decay was estimated by Inventory Branch, Ministry of Forests at 10 million cubic metres per year, approximately one-half of all disease losses.

Several studies to determine the amount of wood decay or "cull" in standing trees have been undertaken by Inventory Branch throughout the Province. External signs or indicators of decay have been identified. As a standard practice, these indicators are recorded in forest inventory surveys and timber-cruise volumes are reduced accordingly.

In many widespread areas of the Province old, living trees have extensive wood decay. For example, in the Interior Cedar-Hemlock Zone, also known as the Interior Wet Belt, hemlock and cedar age 200 years or more often are unmerchantable because of decay. Many of these stands are not producing usable timber and often they must be rehabilitated by clearing and planting.

Wood decay is caused by fungi. A fungus is made up of microscopic threads, termed hyphae, that secrete enzymes, dissolve wood materials, and absorb the constituent sugars, etc. Hyphae penetrate into tree trunks via dead branches or wounds. In the dead core (heartwood) of a tree trunk, they slowly break down wood to obtain their nourishment. Eventually a fungus usually grows a "fruiting" body on the outside of a decayed tree. Fruiting bodies can be conks which usually are hard and woody or mushrooms, which are soft and sometimes edible. Conks and mushrooms produce spores that usually are spread by wind. Under favourable conditions spores that land on dead branches, wounds, or stumps, germinate and form hyphae. Other fungi such as

Phellinus weirii that cause wood decay of trunks and roots, spread from tree to tree by root contacts.

Wood decay is usually confined to the dead heartwood of a tree trunk that was formed previous to infection. A small amount of wood decay does not impair tree growth or other functions. Even trees with only a narrow, outer ring of sound sapwood can survive. However, extensive decay of roots, trunk or branches structurally weakens a tree, and eventually leads to windthrow or collapse. Extensively decayed tree trunks are unmerchantable and often shatter when felled.

In future, young forests managed on a 60-120 year rotation should have less decay. However surveys of some young plantations have indicated potential losses of up to 10-15% of total yields.

Several methods are used to prevent or reduce wood decay. For example, spacing or thinning operations are done early in the life of a tree or stand. Generally, because of tree resistance, only wood laid down by a tree before wounding is subject to decay. Thinning of older trees is done in late summer, autumn or winter to avoid damaging the tender bark in spring. Coastal trees with wounds of 0.1 m² area or larger usually become extensively decayed and if they will not be harvested within 15-20 years, they usually are cut during thinning. During thinning in coastal areas, stumps 10 cm diameter and larger of western hemlock and balsam (Abies spp.) are dusted with borax, a household cleaner. This prevents spores of a wood-decay fungus, Fomes annosus, from germinating, invading root systems, and rotting wood of adjacent live trees. The fungus is common in B.C. Forests, and experience in Europe and southeastern U.S.A. indicates that if stumps are not treated, wood decay will increase dramatically in succeeding rotations. These practices should reduce future losses caused by wood decay.

b. Dwarf mistletoes

Dwarf mistletoes are specialized parasites of several forest tree species. They reduce growth and increase mortality of infected trees. Mistletoes were estimated to cause losses of 3 million cubic meters of wood volume per year during the period 1977-1981.

Dwarf mistletoes are angiosperm seed plants which although green, depend on living coniferous trees for their nourishment. They have developed an intricate and intimate life style. Dwarf mistletoe roots and strands live perennially inside living tree bark and wood, on stems and branches. Small, spindly, reproductive shoots which have no leaves nor phloem grow out from the infected bark. The shoots produce pollen and eventually seeds. Depending on the mistletoe, pollen is produced either in spring or autumn on "male" plants, and pollination of "female" shoots occurs by wind or insects in 2-3 weeks. Over the next 12 - 16 months, berries, each of which contains a single seed, mature. In late summer or autumn berries discharge explosively by the build-up of internal water pressure. Seeds are shot out to distances of up to 15 m, but most seeds strike nearby needles or branches. Seeds initially have a sticky gelatinous covering and adhere to needles. During subsequent rain, the sticky gel swells up, becomes slippery, and seeds slide down needles to branches. During the process many seeds fall off or lodge in unsuitable sites. As seeds dry, the gel tightly fastens seeds in place. Next spring, seeds germinate and if they are suitably placed, a small root penetrates into the tree bark.

If penetration is successful, a small swelling develops in 1 - 2 or more years. After another 1-2 years small aerial shoots grow out of the swollen area at the site of penetration. Flowers appear on the shoots 1-2 years later. Altogether, 3 - 4 or more years are needed for a new mistletoe plant to start producing new seed. From the point of penetration, mistletoe spreads 2-3 cm per year through bark tissue, and continues to grow as long as a branch or tree remains alive. Aerial shoots are produced continuously, and if eaten by insects or animals or knocked off, new ones can grow again.

As a mistletoe infection grows in size, a characteristic clump of tree branches, called a witches broom, often develops. Mistletoe spreads by seed dispersed within a tree crown, especially downwards, and in time numerous individual infections develop. Lateral spread to other trees through the canopy of an even-aged stand is usually slow - approximately 0.3 m per year.

Spread from tall trees to adjacent or understory smaller trees is faster, and trees 10 - 20 years age or more within 10 m distance are commonly infected.

Beginning in 1916 when one of the first comprehensive studies of dwarf mistletoes was reported by James Weir, many pathologists and other forestry workers have noted that dwarf mistletoes could be readily controlled by forest management. Features such as limited spread of seeds, recognizable infections and usual restriction of a dwarf mistletoe species to one tree species make mistletoes very manageable.

Control of mistletoe in forest operations now receives high priority. At time of harvest, cut block boundaries are laid out to prevent or reduce re-invasion of mistletoe. Infected trees 3m height or more, which could be potential overhead sources of mistletoe seed, are felled or destroyed. If dwarf mistletoe had infected numerous smaller trees established prior to harvest, the whole site is treated by a drum chopper, hand-clipping or prescribed fire. On good quality, intensively managed sites, mistletoe is controlled by destroying infected trees during spacing operations, favouring resistant species, and maintaining rapid tree growth to outgrow the spread of infection. Also periodic sanitation treatments are used to reduce mistletoe and maintain tree growth in managing forests where clearcut harvesting is undesirable.

In several areas of the Province further work is underway to implement or determine the need for mistletoe control. Management guidelines have been prepared for several Forest Regions. However the need for control treatments has been uncertain or questioned in some instances. Techniques are being demonstrated by field trials. Further research and surveys also are underway. Also present stumpage values from harvesting are very low and justification of some mistletoe control projects at costs of \$80 to \$100/ha or more is uncertain. A computer-based technique to estimate tree growth and yield on individual sites infested with pine mistletoe is being tested for B.C. conditions and it should help to evaluate specific situations. The technique also could be used in District or Regional surveys to estimate losses and determine priorities. The Canadian Forestry Service, Victoria has undertaken a study of the growth of mistletoe-infected trees in coastal hemlock forests to determine the effects of hemlock mistletoe and has developed a computer model to predict spread of hemlock mistletoe.

Further surveys of harvested areas and young stands are needed to determine how many and what size of mistletoe-infected trees could be left after logging.

c. Root Diseases

Many forests, especially young, second-growth forests of Douglas-fir in coastal B.C., are infected by root diseases. Without treatment, losses from these diseases probably will continue to increase. Recently the Canadian Forestry Service estimated that losses were three million cubic meters of wood per year, mostly due to tree mortality. A survey to determine actual losses is underway in Vancouver Region.

One of the most prominent and troublesome root diseases is yellow laminated root rot of Douglas-fir and other species caused by the fungus Phellinus weirii. Another fungus Armillaria mellea, is especially common in interior B.C., and causes Armillaria or shoestring root rot. Other root diseases are blackstain root disease caused by Ceratocystis (Verticicladiella) wageneri of coastal Douglas-fir and interior lodgepole pine, and tomentosus root rot caused by Polyporus tomentosus of spruce and other tree species in interior B.C.

As a "typical" example, Phellinus root rot is described with some details for the other diseases.

Generally root disease begins when roots of a young tree contact an old stump or large root previously colonized by a root disease fungus. Phellinus can survive 30 - 50 years or more in fir stumps 60-80 cm in diameter. Some old Douglas-fir trees apparently tolerate infection by Phellinus, but their roots and the lower part of their trunks become infected and decayed, and thus they harbour the root-disease pathogen. Most fungi spread along the surface of roots and progressively kill and decay the attacked wood. Armillaria mellea also spreads by means of small threads called rhizomorphs (root-like structures) which can grow from a stump through soil, and penetrate into bark tissue. Black stain root disease is spread by beetles that bore into bark of young roots and introduce spores of the fungus. Rate of spread of a disease through root tissue, and rate of killing, depend on the tree species attacked and in some instances on individual tree resistance. Spread of Phellinus, from stumps and along roots between adjacent trees, results in distinctive pockets of dead and dying trees. These pockets, also called infection centres or patches, are persistent and expand at a rate of 20-80 cm per year.

Several trees are resistant to certain diseases. For Phellinus root disease on Douglas-fir, hardwoods and western red cedar are immune to attack. However Phellinus can quickly colonize cedar roots when trees are cut. Pines are more tolerant to Phellinus attack and although usually they are not killed, their roots frequently are decayed. Roots of infected pines are somewhat weakened and thus the trees are susceptible to windthrow. More importantly tolerant tree species allow Phellinus to persist in soil in the absence of susceptible Douglas-fir. Some Douglas-fir trees although susceptible to Phellinus are able to grow adventitious roots, and thus remain apparently healthy with no crown symptoms for several years. However, the

butts of these trees are extensively decayed, and they are susceptible to windthrow.

Some root-disease fungi form fruiting bodies - conks or mushrooms - on a killed tree, and spores are dispersed to initiate new infections. Phellinus occasionally grows flat crust-like conks on the underside of fallen trees but spores from these conks apparently are not important in spreading the fungus.

Root disease by Phellinus appears to be one of the most important problems facing second-growth management of Douglas-fir in coastal B.C., but inventory data is lacking. An intensive, stratified survey to determine incidence of root disease, effects on timber supplies and correlations with ecological features was initiated in 1982 in the Vancouver Region. Surveys are also needed in southern interior B.C. where Phellinus and other root diseases are common. A program for intensive personnel training including field workshops to detect and identify root diseases is under development.

Control treatments for root diseases need further development, but prevention or reduction of root disease seems feasible in many instances. One approach is to pull or push out infected stumps and large roots.

Several stump removal trials have been established in several areas of the Pacific northwest by U.S. agencies and in B.C. by the Ministry in cooperation with Canadian Forestry Service and Industrial companies. Preliminary 12-year results in B.C. indicate that stumping is very successful if stumps and large roots are removed. Stumping is limited, however, to sites where expected benefits in tree growth will justify an initial cost of up to \$500 - \$700 per ha to remove stumps. Furthermore, stumping operations have to be planned and conducted carefully to avoid severely damaging soil. Stumping is not feasible on steep sites nor on fine-textured nor moist soils. Further machinery

development and trials are needed to develop more efficient, economical and less-damaging methods of stump extraction.

The most promising approach to reduce root disease is to plant or select resistant species for infected sites. Canadian Forestry Service and other researchers have determined several promising species. Trials to determine resistant species are needed, especially in southern interior B.C. where there often are several species which could be planted or selected in thinning operations on individual sites.

Other methods to treat infected sites are needed. Several chemical fumigants, biological antagonists of root-disease fungi, and other methods of destroying or inactivating infested stumps and roots are known. Further applied research, trials and demonstrations are needed to develop operational methods. Methods to treat small infection centres are being developed to use in conjunction with juvenile spacing operations.

Judging by experience in other forested areas of the world, and in agriculture, root diseases will probably become more troublesome and important in B.C. as forest management intensifies.

d. Stem Diseases

Another important group of diseases are various rusts and cankers of tree stems and branches. Young trees are killed, and plantations often are substantially infected. Data on amount of loss expected from these diseases are lacking. A recent survey of rusts and Atropellis canker of young lodgepole pine in interior B.C. suggested that on some sites losses from mortality could reduce final yields by up to 5%.

Since 1920-30, one of the most damaging stem diseases has been blister rust of western white pine. This rust fungus spreads by spores which infect wild currants or gooseberry shrubs and white pine. In 1911 it was brought into B.C. on imported pine seedlings from a nursery in Europe, and also on several occasions into eastern USA and Canada. The disease subsequently killed many thousands of trees but recently the disease, although still common and damaging, appears more manageable. Possibly the most susceptible trees were killed, and now a more resistant population of white pine has been naturally selected. Programs to purposely select and breed western white pine to improve tree resistance to blister rust were initiated in the U.S.A. and eastern Canada, and seeds of resistant stock recently have been made available. Trials with USA seed have been established in B.C. and are being monitored.

Another promising feature for management of white pine is that blister rust infections which kill trees, occur mostly on lower branches. The blister rust fungus penetrates first into needles and then spreads through bark of branches to the main stem. Infected bark is killed within 1-2 years. Results from recent studies indicated that it is feasible to protect young white pines especially during spacing operations on level sites by pruning off lower branches. Any trees with active rust infections on main stems are cut.

Western white pine is a particularly desirable species because it is resistant to Phellinus root disease, and grows faster than Douglas-fir or other trees in many locations. Although management of white pine currently is at a low ebb, especially in coastal B.C., there are good prospects for more intensive use of the species particularly in Phellinus - infested sites.

Other stem rusts and canker diseases are potential threats, especially to young lodgepole pine forests and plantations throughout interior B.C. Rusts usually spread from woody or herbaceous plants to pines. One disease, western gall rust, spreads solely from pine to pine. Rust diseases cause canker-like infections on branches and stems. Cankers, if extensive or girdling the trunk, can kill a tree. Generally, they are most damaging on young trees. Present forest management includes careful selection of planting stock for particular areas to avoid introducing highly susceptible trees, and selection of individual trees during thinning operations to leave the least-diseased and presumably more resistant trees.

At times rust infection can be confused with animal damage. Rodents seem to prefer chewing rust-infected bark, and rust-infections usually have most bark chewed off. Rusts usually can be distinguished in early summer by orange "blisters" of spores in the bark around the edge of an infection. Surveying and spacing operations in infected stands therefore usually are conducted in early summer.

Other stem and branch cankers are caused by various fungi. Trees growing on unfavourable sites or injured by drought, frost or hail often are attacked. Often little can be done to alleviate these diseases. In some instances, damage can be prevented by planting or selecting the best-suited trees for a particular site. Heavily diseased trees are removed during thinning operations.

e. Foliage and cone diseases

A variety of other fungi attack tree foliage and cones. Several needle "casts" and blights are common in some years following wet weather suitable for spore dispersal and infection of new foliage. Some protective, fungicidal chemical sprays can be used in ornamental nurseries, Christmas tree plantations, tree seedling nurseries and seed orchards, but at present none can be used in Crown-land forests. In ponderosa pine forests, a needle disease caused by the fungus Elytroderma deformans causes large, dense clumps of branches called witches brooms. In recreation sites these brooms could be pruned off to maintain or improve tree growth.

Spruce cone rust frequently is common and damaging in northern interior B.C., and occasionally it damages a large proportion of a good cone crop. Collection of spruce seeds is a vital part of the interior B.C. silviculture program. There are some fungicidal sprays which could be used in seed orchards to protect trees.

The overall Provincial impact of needle and cone diseases is unknown. As the proportion of young trees increases with more intensive forest management, more severe disease outbreaks can be expected. Management techniques need to be developed.

hazards based on decay, injury, and growth rates, evident from external signs and internal borings. Park managers have to weigh the hazards of tree failure against intrinsic values per tree. In some instances removing potential targets (people and property) instead of trees is preferable.

SUMMARY

This review has described some of the important tree diseases in forest management, and, hopefully, has shown why forest diseases are important in Ministry programs. With the planned increase in intensity of forest management in B.C., disease reduction and prevention will likely become even more important. Disease treatments are an important and essential part of silviculture, and they promise long-term benefits. A major strategy for improved protection is preventative establishment and maintenance of forests. For example, many disease problems will be avoided or minimized for several decades by planting mixtures of resistant species in areas of known infestations. Thus detection of diseases, surveys and appraisals of their effects, and development and use of effective and economical management techniques are the major challenges for forest pathology in B.C.

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