THEME ADDRESS—PATHOLOGY PROTECTION AGAINST TREE DISEASES ¹

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INTRODUCTION

The provision of adequate staff and facilities for surveys and research to afford protection against tree diseases is a comparatively recent development in Canada. This is evident when it is realized that in 1941 there were only four trained forest pathologists in the Federal Service, three in Ottawa and one in British Columbia. Since then the professional staff has increased to 40 located in six laboratories across Canada. The development of the first laboratory in any way qualified to study important disease problems began in British Columbia in 1942. It is significant that the only university appointment in forest pathology in Canada to offer post-graduate instruction on tree diseases is at the University of British Columbia, and was established with financial assistance from Powell River Limited. In 1946, the Ontario Department of Lands and Forests requested the assistance of Federal pathologists on disease problems. This resulted in the formation of a laboratory at Toronto. In the following years greater recognition was given to the importance of pathological research with the result that the staff has increased considerably and has acquired excellent accommodation in a laboratory constructed by the Department of Lands and Forests at the Southern Research Station, Maple. Almost simultaneously with the Ontario development, other laboratories were established at Fredericton, N.B., Saskatoon, Sask., and Calgary, Alta.

Few forest pathologists have been employed by the Provincial Governments and industry. From 1930 to 1951 the Quebec Government supported a small staff in forest pathology. In 1952, this group was transferred to the Federal Service. The Ontario Provincial Pathologist is now located at the Maple laboratory and collaborates with the Federal staff. On occasion, the Ontario Department of Lands and Forests has appointed foresters to assist in disease research. A significant development has been the appointment of a pathologist to the research staff of the Kimberly-Clark Corporation and its Canadian affiliates.

GENERAL ASPECTS OF THE DISEASE PROGRAM

It is of importance to mention that the research approach varies in different disease problems. The papers on fire protection to be presented at this

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meeting emphasize the importance of prevention and suppression, or direct control on the one hand, and the role of silviculture and management on the other. These procedures also form the broad basis for protection against diseases.

The possibilities of prevention and control are of first importance when dealing with introduced diseases, since during the past 50 years a number of foreign pathogenic fungi which have caused heavy losses in our native susceptible trees have been introduced into Canada. This hazard exists since our trees may lack any inherent resistance to attack by these foreign organisms. Because of known values, direct control measures may also be applied as a protection against the diseases occurring in nurseries, plantations, and in ornamental or shade trees. Similar action is necessary to prevent the damage to trees which is caused by the poisonous fumes emitted from certain types of industrial smelters.

In the extensive natural forests of Canada it is unlikely that direct control measures could be used for protection against the many endemic diseases which result in serious depletion. Indeed, the degree of protection from these diseases will depend upon current forest practices, hence the importance of silviculture and management to disease protection. The important consideration in relation to these endemic diseases is the definite possibility of affording greater disease protection without requiring any great modification in present operational practices. The procedures being developed as the result of pathological research demonstrate this possibility, and will be referred to in more detail later in this paper.

PROGRESS IN DISEASE PREVENTION AND CONTROL

Experience has proved that diseases of minor importance in other countries could result in serious damage if they become established on susceptible hosts in Canada. International committees, including United States, European, and Canadian representatives, have been organized to consider these problems. Quarantine measures have been established and rigid inspections are required at Ports of Entry to prevent the importation of diseased stock which could constitute a menace to our native trees. In Canada, it is the function of the Plant Protection Division, Science Service, to make the necessary inspections and administer import regulations, which are included in the Canadian Destructive Insect and Pest Act. Disease inspections made by the Forest Biology Rangers as part of the National Forest Insect and Disease Survey provide an excellent detection service to discover the presence of new diseases and the spread of known diseases to new localities.

Very limited research has been undertaken in Canada on the chemical control of diseases affecting ornamental and shade trees. However, many studies of this nature have been made in the United States and in general the control measures recommended for a disease there are equally applicable under Canadian conditions. Recent studies at the Saskatoon Laboratory have led to promising results for the chemical control of seedling diseases which are resulting in serious losses in the forest nurseries of Saskatchewan.

White Pine Blister Rust

White pine blister rust is the most important foreign disease causing depletion in a tree species of commercial importance in Canada. A more

cautious approach has been made here than in the United States in carrying out extensive direct control operations on this disease. It was concluded that a policy for general control should not be recommended until more information was available on the possible spread and intensification of the disease as determined by regional differences in the biological behavior of the causal organism, in the incidence of the alternate host, and in the ecological characteristics of white pine stands. Research on these objectives has been made and is continuing in Ontario and Nova Scotia and the results demonstrate that in certain stands control would be economically feasible, on the basis that the funds obtained from the salvage of fatally infected trees would be more than adequate to cover the costs of *Ribes* eradication. Recently, direct control measures have been applied to a small number of stands in these provinces, and it is probable that the amount of this work will increase in the future, particularly in Ontario.

The studies also show that on some areas supporting excellent stands of white pine, serious intensification of the disease has not occurred because of the relative absence of the alternate host. Experiments on silvicultural control are underway in these areas, involving a method of selective logging which will provide sufficient light for white pine reproduction and at the same time enough shade to prevent the widespread establishment of *Ribes*.

A discussion of the blister rust problem would not be complete without reference to the occurrence of this disease in the other provinces. Areas supporting excellent stands and regeneration of white pine have been observed in Newfoundland, New Brunswick, Quebec, and British Columbia (Interior region). In several instances the results of preliminary disease surveys have shown a heavy incidence of the disease on pine correlated with an abundance of the alternate host. On occasion, these findings have been sufficient to discourage further considerations for control. Many of these areas would support excellent stands of white pine if the trees were protected from blister rust. Before deciding against the application of control measures, it is necessary to obtain an evaluation of the crop potential and compare this with the cost of control. The economic standards recently incorporated in the policy for blister rust control in the United States would form a good basis for this work in Canada. When necessary these standards could be modified to suit local conditions.

Dutch Elm Disease

The Dutch elm disease is another of foreign origin which is important in Quebec and Ontario. After discovery at Sorel, Quebec, in 1944, Federal and Provincial agencies in Quebec recommended that an attempt should be made to control the disease through the removal of all infected trees. However, despite the fact that municipal authorities and the public were most co-operative in destroying infected trees, the disease became more widespread and at present is established in the lower valleys of the St. Lawrence and Ottawa rivers. It has also been found sporadically across southern Ontario, being particularly serious in the vicinity of Windsor. In 1955, an infection centre containing a considerable number of diseased trees was found at Hamilton. Although, as in Quebec, the diseased trees have been removed after discovery, it is most improbable that all infected elms have been located. The results of studies on the chemical control of the insect vectors for this disease have shown that a thorough application of

a DDT spray to the trunk of a healthy tree will prevent beetles from entering and introducing spores of the causal fungus. Similar treatment of diseased trees will prevent beetles either from entering or emerging.

TREE SELECTION AND BREEDING FOR DISEASE RESISTANCE

A tree selection and breeding program to obtain strains of white pine resistant to blister rust is under way in Ontario and British Columbia. In Ontario, this work is undertaken in co-operation with Dr. C. C. Heimbürger, Forest Geneticist, Ontario Department of Lands and Forests. It has been observed that a small number of white pines have remained healthy in heavily infected stands and plantations. This suggests that these trees may be resistant to the disease. Cuttings from a number of selected rust-free trees have been propagated vegetatively and inoculated with the blister rust fungus. The cuttings of some clones have remained healthy after inoculation and this is encouraging, since, in addition to the resistance factor, these clones should retain the growth characteristics of the original trees. Controlled pollination studies are in progress to develop resistant pines. A number of American investigators are also engaged in selection and breeding programs on this problem. An exchange of information and testing stock is maintained with these agencies.

Recently, selection and breeding studies have been initiated in Quebec to develop an elm resistant to the Dutch elm disease. Pathologists co-operate with personnel of the Federal Experimental Farms Service in this research, but it is too early yet to report on the results. Breeding studies for resistance to the Dutch elm disease have been in progress for a much longer period in Holland and in the United States. A number of the most promising hybrids produced in Holland are being tested in Quebec.

The control of a disease through breeding of a resistant strain is a long-term project involving a number of important factors additional to the problem of disease resistance. For example, it may be very difficult to produce a resistant tree with desirable growth characteristics. Attainment of resistance and desirable growth characteristics does not solve the problem since there are a number of instances to illustrate that the newly developed hybrids may be seriously attacked by other organisms which are known to be of minor importance to the parent trees.

ROLE OF SILVICULTURE AND MANAGEMENT IN DISEASE PROTECTION

Diseases Caused by Endemic Organisms

Mention has been made of the importance of silviculture and management to protection against the many endemic diseases that result in mortality in trees of all ages. Before considering any specific type of endemic disease it may be desirable to outline briefly a number of general considerations which are common to and basic for the present research approach to these problems. Healthy, vigorous seedlings, plantations, and forests occur when the silvical^a and biological requirements are favorable for tree growth. The causal organisms

^a The definition for silvics as used in this paper is taken from the British Commonwealth Forest Terminology, Part 1, 1953, as follows: "The study of the life history and general characteristics of forest trees and crops, with particular reference to environmental factors, as the basis for the practice of silviculture".

of endemic diseases are present under these conditions, and may be expected to cause normal depletion. Indeed, many of these organisms, e.g. the wood-destroying fungi, are beneficial and essential to the maintenance of soil fertility through their activity in the deterioration of organic material. Serious depletion from an endemic disease may be interpreted as the result of a condition which arises when the silvical requirements of the host and/or the biological requirements of the pathogen are such that they favor the development of disease. As will be seen later, climatic influences, soil characteristics, age and composition of the stand, and disturbances such as partial cuttings are some of the factors which influence disease development.

A primary objective in pathological research has been to determine the losses of economic importance that occur from endemic diseases in mature and overmature stands. Information on the distribution and intensity of the causal organisms of these diseases represents an important part of this work. The results demonstrate that the loss from a disease may vary considerably in different localities within the commercial range of a tree species. Further, the areas with a heavy incidence of disease may be defined on the basis of forest association or site. Therefore, it is possible to establish hazard ratings for a disease in the different forest associations occupied by a commercial species. These ratings will provide information on disease prevention and control since they will indicate the stands which should be cut first to obtain maximum yields and the areas most favorable for the future growth of a commercial species. The procedures developed as the result of this research may be incorporated in the plans covering the operation of forest management units.

The accomplishment of the objectives outlined will require the results of a great deal of research in addition to work of a survey nature to determine disease losses. Intensive studies are made on the biology of the pathogens to determine the conditions favorable to their development and epidemiology. Of equal importance is the information derived from investigations on the silvical requirements of trees and stands, since a deficiency in these requirements may predispose trees to serious losses from endemic diseases, and will indicate the type of silvicultural treatment required to obtain a profitable crop. Despite the fact that much of this research is of a long-term nature, progress has been made toward a solution of a number of our important disease problems. The present status of a few representative investigations will be outlined in the following paragraphs.

Seedling and Plantation Diseases

Forest nurseries have been established on land where the sandy soil has been considered unfit for the profitable growth of agricultural crops, for example, the Provincial Forest Nursery at Orono, Ontario. The initial crops of seedlings on the areas were low in vigor and predisposed to high mortality from damping-off which is caused by a number of endemic soil fungi. Chemical analyses of the soil demonstrated that its composition was quite different from that supporting vigorous stands of the species to be propagated in the nursery. Experiments were conducted on the application of different chemical fertilizers, and tests were made for the chemical control of damping-off. Although improvement in seedling growth and a reduced incidence of disease occurred

in some of the experiments, none were successful to the degree that they could be recommended for general practice. More recently, studies have been directed to the importance of the soil flora, since it is known that natural forest soils contain mycorrhizal fungi beneficial to tree growth, and other organisms antagonistic to the fungi causing damping-off. Nursery soils previously cultivated for agricultural crops may not have a normal complement of these organisms. Encouraging results on disease prevention together with vigorous seedling growth have been obtained by the fertilization of nursery soil with forest duff. Current research on this problem consists in developing cultural methods for the establishment of a normal soil environment in the nursery which will be similar to that occurring under natural conditions. This is in accord with the current European practice of establishing temporary nurseries within plantations showing excellent growth of the species to be propagated in the nursery.

Nutritional and physiological conditions arising from unfavorable soil and environmental conditions are important to the successful growth of plantations. For example, serious deterioration is occurring in 30-year-old plantations of white spruce on sandy soils in Quebec. In addition to the factor of poor growth leading to mortality, the weakened trees may, at any time, become heavily attacked by endemic organisms. Fertilization experiments are under way and intensive research has been initiated to determine the silvical requirements of white spruce. If fertilizers prove beneficial, the possibility of aerial application should be considered, since this method has met with some success on conifers in United States and Australia.

Diseases in Immature Stands

A number of endemic root diseases are killing trees in patches in stands of commercial size; for example, the dying of white spruce in the Candle Lake region of Saskatchewan. Soil studies have shown that within a stand differences occur in the soil profile, and the stand openings develop on areas with shallow profiles. It would appear that a critical age is reached in a stand when the volume of soil for root development is insufficient to support vigorous tree growth. This results in the death of the smaller roots, and trees weakened in this way are predisposed to further injury from root fungi and insects which later cause mortality. Current studies indicate that the shallow profile areas may be defined on the basis of site type and, if so, plans could be made for the prevention of heavy disease losses by cutting the stand on high risk areas before the critical age for disease development.

Mention should be made of the effects that silvicultural cuttings, e.g. thinnings, may have on the abnormal development of endemic diseases. For example, one of the most important problems of immature coniferous stands and plantations in Western Europe is a root disease caused by *Fomes annosus*. Although this fungus is present in an endemic state in unthinned stands, it causes heavy mortality in thinned areas. It is evident that the freshly cut stumps of the thinned trees provide excellent infection courts for a rapid, general distribution of the fungus in the stand. The fungus spreads quickly from the stumps into the roots of the thinned trees and from there into the healthy roots of adjacent crop trees. During the summer of 1955, this disease was found in thinned plantations of red pine at St. Williams, Ontario. Pre-

liminary studies indicate that the stumps of the thinned trees are serving as infection centres for the spread of the disease into the residual pines.

Hypoxylon canker is an endemic disease which may result in 30 per cent mortality in young aspen stands. Some years ago a thinning experiment was conducted in a heavily-stocked stand in Ontario to encourage better growth and to offer disease protection through the removal of the infected trees. It soon became evident that the experiment was a failure since the sudden opening of the stand resulted in severe sunscald injury followed by infection with Hypoxylon canker which killed a high percentage of the crop trees.

The Fomes root disease and Hypoxylon canker problems are representative of many which demonstrate that man's interference with the natural development of the forest may lead to serious losses from endemic diseases. This is particularly true when a treatment is applied to a stand without acquiring first basic information concerning its silvical requirements and the behavior of the organisms normally associated with it.

Diseases of Mature and Overmature Forests

The forest industry in Canada has been operating largely in mature and overmature stands, in which heavy decay losses have occurred. Forest land has a potential maximum yield which may be achieved with an optimum stocking at the age of maturity. Ultimately, in evenaged stands or in the old surviving trees in overmature stands, an age is reached when the decay increment exceeds the growth increment, resulting in non-productive stands or trees. In evenaged stands it is necessary to determine the pathological rotation which will provide the greatest recovery of sound wood. In overmature, unevenaged forests it is necessary to determine the percentage of the net merchantable volume per acre which is recoverable from trees in which the decay increment now exceeds the growth increment as a basis for the establishment of priority of cutting on a stand basis. This percentage will vary with the stand and age since the amount of decay will be dependent upon such factors as forest composition and site.

A considerable number of decay studies have been undertaken and are being continued to obtain the objectives outlined. Several have demonstrated that an increased utilization of diseased trees is possible owing to their content of sound, high-grade wood. Knowledge of decays, which are commonly hidden, and their development have proved to be essential in the preparation of accurate inventories. The value of decay studies for disease prevention by forest management has been recognized and the procedures developed as the result of pathological research are now being applied by industry and the British Columbia and the Ontario Departments of Lands and Forests.

Large areas of forest are frequently killed as the result of fire, insects, and windstorms. A number of studies have been made to determine the rate of deterioration of killed stands in order that valuable timber may be salvaged before various organisms make such an operation unprofitable.

NON-INFECTIOUS DISEASES

Frequently, abnormalities occur in trees which are not primarily attributable to attack by organisms. An understanding of these and the formulation of

remedial measures is dependent upon a knowledge of the silvicultural requirement of trees and stands. The bulk of the evidence to date on the birch die-back problem has supported the view that the disease was caused primarily by climatic changes. For example, as supporting evidence it has been proved that yellow birch rootlets are more sensitive to temperature increases than those of sugar maple. The latter species showed no widespread deterioration comparable to that in birch, though frequently growing in the same stands.

Differences in the moisture regimes of healthy and diseased trees may be of significance in the study of non-infectious diseases. After the differences are measured, their importance may be recognized by comparison with the normal patterns of moisture movement and storage in trees. However, the results of current research on these aspects of tree physiology demonstrate that serious gaps occur in our present concepts of the water relationships of large woody stems, indicating the need for more research on the normal anatomy and physiology of forest trees.

SUMMARY

A solution to many of the important disease problems will not be possible until more information is accumulated on the silvical requirements of trees and stands and on the behavior of the disease-causing organisms. Canadian literature contains little information on these important aspects of forestry. Therefore, it may be expected that much of the research on disease problems will be of a long-term nature, and that sound recommendations for prevention or control will not be available until a better knowledge is obtained on the basic factors influencing the host-parasite relationships within a forest.