A View of Forest Pathology Research in Canada

by

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Abstract

Losses due to diseases are an important part of forest pest depletion, therefore much is expected from forest pathology research. Examples of recent accomplishments in forest disease protection include a vastly increased knowledge in the field of root and butt rots as well as in control methodologies and in the predictability of such problems; the development of control strategies for scleroderris canker through increased surveys, improved diagnostic methodologies and new control techniques; the establishment of white pine blister rust hazard zones; and the publication of user-friendly technical bulletins. As the pool of forest pathology researchers has changed little in recent years, the task ahead is enormous when compared to expectations. However, acquired knowledge, the application of new technologies, and the more common acceptance of the integrated pest management (IPM) concept should allow for significant strides forward in forest disease control. Finally, it is suggested that forest pathologists take the lead in promoting a concept of forest health to promote better integration of forest disease protection with forest stand productivity and survival.

Résumé

On attend beaucoup de la recherche en pathologie forestière pour parvenir à réduire les pertes dues aux maladies dans les forêts. Comme exemples de réalisations récentes dans la protection contre les maladies des arbres mentionnons l'augmentation substantielle des connaissances dans le domaine des caries des racines et des souches ainsi que dans les méthodes de lutte et de prédiction de ces problèmes; la mise au point de stratégies de lutte contre le chancre scléroderris avec de meilleurs relevés, l'amélioration des techniques de diagnostic et l'utilisation de méthodes plus efficaces de lutte; la description de zones de risques d'infections par la rouille vésiculeuse du pin; et la publication d'excellents bulletins de vulgarisation scientifique. Avec un potentiel de recherche en pathologie forestière pratiquement inchangé depuis plusieurs années, la tâche à accomplir est imposante si l'on veut satisfaire quelque peu les attentes dans le domaine. Par contre, les connaissances nouvelles, l'utilisation de nouvelles technologies et la mise en application plus courante du concept de la lutte intégrée contre les ravageurs devraient permettre d'autres progrès importants en pathologie forestière. On conclut en suggérant que les pathologistes forestiers prennent l'initiative dans la promotion du concept de santé des forêts, afin de pouvoir bien concilier la protection contre les maladies avec les objectifs de vigueur et de productivité des forêts.

Introduction

The forest industry is of extreme importance to the economy and the social welfare of Canada. The forest resource of Canada covers about 45%, or 453 million ha, of the total area of the country. About 62% of the 398 million ha of inventoried forest land is considered productive and suitable for supporting industrial forest (Forestry Canada 1988). In 1987, these forests supported an industry that produced \$38.3 billion of goods with a net foreign exchange totalling \$18.3 billion, a greater contribution to Canada's economy than the combined earnings of agriculture, fisheries, mining, and fuels (Canadian Institute of Forestry 1989). The forest industry also provides direct and indirect employment for about 840 000 Canadians.

Even if the forest is renewable, it is not inexhaustible. Cutting, overcutting, at times no or mismanagement, forest pests (including insects, diseases and fires), and recently air pollution, may all have a negative effect on growth and thus on the overall productivity of the forest. This is today's situation without considering the threat of climate change that may conceivably displace and dramatically change whole forest types. Actions to counter any of these depletion factors are urgently needed.

The Canadian Council of Forest Ministers looked closely at this situation a few years ago and it endorsed "A National Forest Sector Strategy for Canada", (Canadian Council of Forest Ministers 1987). Forest protection was an important concern of the Council. "Failure to invest in protection will jeopardize future benefits from the forest. Furthermore, the level of protection should be appropriate to the value of the resources and the level of investment in its management."

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Recently, the CIF published its "Policy on Integrated Forestry Pest Management" (CIF 1989). In addition to supporting the forest pest protection recommendations contained in the national forest sector strategy, the Institute stresses the need to integrate management and control measures: "The Institute supports integrated use of carefully executed and environmentally conscious pest management practices where they are required to achieve accepted forest production goals". It also supports an increase in integrated pest management training in all university and technical forestry schools in Canada.

Large volumes of wood fibre could certainly be harvested from the forests through increased protection and salvage. For example, the most recent report on insect and disease losses made by the Forest Insect and Disease Survey Unit of Forestry Canada estimates an average depletion of close to 110 million m³ of wood annually, with diseases accounting for about 42% of the losses (Canadian Forestry Service 1982). These estimates are conservative because only the losses owing to important pests were evaluated. But can research in forest pathology provide the knowledge and the means required to prevent or substantially reduce this lost depletion?

What is Forest Pathology?

A simple definition is: "Forest pathology is the branch of botanical science that deals with diseases of forest trees for the purpose of preventing or controlling such diseases" (Boyce 1961). The question then arises "Can we prevent or control forest diseases today?" The answer is yes. But it has to be qualified. We have acquired the knowledge to control and prevent partly or completely many diseases, but to do so economically opens the door to discussion. Also, we may ask when or to what extent a disease is controlled, because we are dealing with changing living organisms and a changing environment while our interests, and thus our needs, are also rapidly changing. In 1983, Whitney *et al.* published "Impact and Control of Forest Diseases in Canada", which was based on a report prepared in 1982 by a committee that had reviewed the forest pathology research program of Forestry Canada (formerly the Canadian Forestry Service (CFS)) with the aim of improving forest productivity in Canada. The information gathered during this review was not restricted to CFS activities, and as the authors state in their report: "The sample was considered to represent a cross-section of opinion of forest pathologists and forest managers in Canada". The article presents a relatively complete view of research accomplishments and of research needs in forest pathology in Canada up to 1982. This article concentrates on the years 1982 to 1989 inclusive.

Recent Research Accomplishments

Pathology research accomplishments made during the last eight years have not revolutionized forest protection nor did they greatly increase overall forest productivity. However, increases in knowledge and improvements in control measures have been made in some fields of forest pathology and some trends in research and development have become more visible. Examples are given below.

Root and Butt Rots

Research on root and butt rots has reached maturity in recent years. This has always been a very difficult, and for many, a somewhat unattractive area of research. But good and patient work has been going on and this effort seems

to have resulted in a much better knowledge of the effect of these rots on forest productivity, greater knowledge of the spread pattern of some causal organisms, and even the development of predictive capabilities of spread and consequently of management alternatives. Examples of this progress are found in recent articles by Whitney (1988, 1989) and Whitney and MacDonald (1985) on the identification and importance of major root rots, and on the effect of the causal organisms on spruce and fir, particularly in Ontario. In western Canada, articles by Bloomberg (1983a, 1983b, 1987) and Bloomberg *et al.* (1980a, 1980b) bring the knowledge on *Phellinus weirii* root rot one step further, offering capabilities of a simulation model for predicting disease spread and effect. In eastern Canada, an extensive study of stem decays of conifers in Newfoundland, involving the federal and provincial governments and industry, is concluding (Can. For. Serv. 1988).

Across Canada, and across the world, forest pathologists are deciphering the local *Armillaria* root rot situation as recent information has revealed the existence of distinct biological species (Anderson and Ulrich 1979, Anderson 1986) of this widespread and destructive fungus. What was until recently known as *A. mellea* is now described as the *A. mellea* complex. Clearly defined biological species of *Armillaria* are now known. With this new information comes a great potential for prediction of impact and thus possible control of this root rot, because these species often have a clearly defined distribution in the forest as well as distinctive pathogenetic capacities. Several recent Canadian articles deal with this subject (Morrison *et al.* 1985, Berube and Dessureault 1988, 1989, Blenis *et al.* 1988, and Dumas 1988). The positive effect of this research could be particularly important in an integrated pest management (IPM) program related to reforestation.

Scleroderris Canker

Scleroderris canker has been a worrisome and stressful problem across Canada in the early to mid-1980s. This disease was already causing much damage in young pine plantations in eastern Canada when a more destructive race (called the European race) of the causal fungus was discovered in New York State in 1976 (Dorworth and Krywienczyk 1975, Dorworth *et al.* 1977). It was infesting and even killing mature pine stands within 3-4 years after infection. Canadian forest pathologists were asked by forest managers and plant quarantine personnel whether this new race would come into Canada and what to do if it did. This problem was as new and unexpected for forest pathologists as it was for managers. The identification of the "race" was uncertain at that time because the techniques for identifying it were cumbersome, lengthy, and not completely reliable.

Research on race identification technique was accelerated at Great Lakes Forestry Centre (GLFC) (Dorworth *et al.* 1982) and initiated at Laurentian Forestry Centre (LFC) (Benhamou *et al.* 1984). Special surveys were begun across Canada by the Forest Insect and Disease Survey (FIDS) unit of Forestry Canada to detect the disease (i.e. the new race of the fungus) and possibly eradicate the pathogen if found.

The first such infection centre was found in southern Quebec in 1978 (Lachance 1979). Disease development was light in this plantation. Complete sanitation of the plantation was done with the hope of eradicating the infection. Additional surveys in the area located nine more infected plantations which were also cleaned of visible disease material. Close

monitoring during the subsequent years suggested successful eradication as no further infection centers were found in and around these plantations. The European race of the fungus was subsequently found in Newfoundland (Singh *et al.* 1980) and in New Brunswick (Magasi 1982), and then on a large scale, again in Quebec (Laflamme and Lachance 1987). Meanwhile, research on means of differentiating races of the fungus carried out in Ontario and Quebec was productive. The reliability of serological testing was improved while a new identification method, using electrophoresis, was developed (Ouellette *et al.* 1988). Electrophoresis has become the standard test for race identification.

Further research on causal fungal determination (Petrini *et al.* 1989) and disease control (Bergdahl and Ward 1984, Laflamme 1988) led to an integrated management system whereby disease detection, identification and control measures are synchronized, and apparently limit or reduce greatly the damage to pine plantations. As in most cases when biological organisms are involved, however, it is difficult to evaluate the role of other contributing factors, such as reduction in the number of planted pine seedlings and the possible effects of unfavourable weather conditions, in the apparently good control of the disease in recent years.

Other Advances

There have been other advances in forest pathology research (Rishbeth 1987). Some are the result of many years of research to understand a problem and finally to come up with a plan of action. Examples would be the establishment of predictive and somewhat preventive procedures, such as white pine blister rust hazard zones (Hunt 1983, Gross 1985, Lavallée 1986), which allow the manager to identify areas of sensitivity before planting specific species and take the necessary preventive measures if the susceptible species is planted. Control measures for blister rust have also been improved (Hunt *et al.* 1985). The production of highly informative and relatively practical bulletins and videotapes, such as "The Hidden Enemy" (Whitney 1988) on root rots, is another example of applied pathology research in recent years.

In a short paper, it is difficult to mention or evaluate properly all the recent progress in forest pathology research in Canada. Increases in knowledge, new technology development and applications are processes. Although breakthroughs or events that appear like breakthroughs sometimes occur, often we may simply be seeing the results of favourable circumstances that put into proper perspective several bits of knowledge and technology acquired gradually through individual research efforts.

The Research Pool Today

Active Forest Pathologists

Using the Whitney *et al.* (1983) article as a starting point, I recently canvassed 10 leading forest pathologists covering all regions of Canada to determine the number of forest pathologists devoting a major portion of their time to research today compared with 10 years ago (Table 1). Apparently the numbers have not changed greatly, but there has been a noticeable shift from basic laboratory research to highly applied field studies. This change appears to be mainly the result of a relatively recent decision by the British Columbia Forest Service (Forest Health Division) to have a forest pathologist in each of their seven regions/districts. Their ranks cover a wide range of training and they are involved mainly with

Table 1. The number of active* forest pathologists in research in Canada

Provinces or Regions	Institutions	Fall 1989	Fall 1979
British Columbia	Government	17	13
	Universities	1	1
Prairies	Government	2	3
	Universities	2	1
Ontario	Government	6	8
	Universities	2	2
Quebec	Government	4	5
	Universities	1	1
Maritimes	Government	1	2
	Universities	1	1
Newfoundland	Government	2	3
	Universities	0	0
Total		32	34
		7	6

*Excludes forest pathologists by training or by title who are not currently active or closely involved with research — basic or applied.

site specific operational problems. Hopefully, this will result in significant acquisitions of knowledge in field pathology.

A concurrent decrease occurred, however, in the number of traditional forest pathology researchers in government institutions, thus the apparent stability in the research pool may not be satisfactory. The need for new knowledge and new control measures in forest pathology is increasing and becoming more pressing while the number of researchers is not growing proportionately. This situation must also be analyzed in the light of the great decrease of researchers in forest pathology that occurred during the 'seventies, particularly within Forestry Canada. Questions are being asked about a similar situation occurring in the United States (Kelman 1987).

Publications

To see whether there had been noticeable changes in the number or in the subjects of articles published, I surveyed all the forest-pathology-related articles in the Canadian Journal of Forestry Research from 1981 to 1989 (Table 2). So that my selection would be relatively uniform, I included only those that dealt with or that were related to diseases or to the health of trees. I excluded articles dealing with modified growth rates, or strictly with general tree or stand vigour. It was generally difficult to classify an article in one field only; however, I based my decision on the main object of the paper. For example, an article was classified in epidemiology if its main concern was the reaction of the biological causal agent to surrounding conditions; to disease-insect-environment complexes if more than one causal agent seemed to be involved; and to environmental damage if no living causal agent was dominant.

The overall forest pathology research output does not seem to have changed significantly. Also, the proportion of articles by Canadian authors has remained fairly high in recent years compared with the early eighties. The survey also suggests increasing interest in biological control (for diseases), disease-insect-environment complexes, and genetics and disease resistance, although admittedly the supporting data are skimpy. Relative to the number of pages printed, the number of articles published yearly has remained stable or has slightly decreased. In the United States, the journal Plant Disease, published by the American Phytopathological Society, has noted a decline in recent years in the use of its

Table 2. Number of articles in forest pathology published in the Canadian Journal of Forestry Research, from 1981 through 1989

Forest pathology related topics	1981	1982	1983	1984	1985	1986	1987	1988	1989 +
Control, including biological control	0	1	0	0	1	2	1	1	1
Disease-insect-environment complex	0	0	0	0	2	1	1	2	0
Abiotic problems	3	3	1	2	1	4	4	1	3
Epidemiology	3	4	4	2	4	5	0	5	4
Evaluation of damage and losses	3	3	1	3	5	4	5	4	2
Genetics and disease resistance	0	0	0	1	0	3	3	1	1
Host-parasite relationships	0	3	0	1	1	6	1	4	1
Mycorrhizae	2	2	1	0	1	0	4	0	1
Seed and nursery diseases	1	0	2	2	0	0	0	3	1
Others (predisposition, survey methods, descriptions, modeling, etc.)	2	7	1	0	1	1	2	2	5
Total	14	23	10	11	16	26	21	24	19
Articles with at least one Canadian author (% of yearly total)	5(35.7%)	4(17.4%)	2(20.0%)	4(36.4%)	6(37.5%)	10(38.5%)	8(38.0%)	13(54.2%)	5(26.3%)
Tota number of pages per journal volume	860	1039	1270	*954	1201	1397	1630	1662	1500 +

* The journal goes metric: Page Size Increases.

+ Partial Results: December Issue not included.

pages by phytopathologists (Sinclair 1989). One explanation suggested is the increasing proportion of reports submitted by plant pathologists to diverse journals of applied research and of allied sciences.

Looking Ahead

Is there a bright future for forest pathology in Canada? Yes, but this future may not be as spectacular as it will be important and useful. Forest protection and integrated pest management are seen as very real means of reducing overall forest depletion and even of increasing forest productivity. On the other hand, when we talk about integration, we have to think about a new or expanded concept of protection. Here, ironically, to be at the forefront of forest protection, forest pathology in its strict sense may have to take a lower profile. The classical "forest disease" concept should now be replaced by a "forest health" concept that includes, in addition to loss of growth, an increase in productivity and in disease resistance through improved health! This concept should also be flexible enough to include stand disturbances as a positive reaction to some stresses.

Cowling and Horsfall (1980) defined disease "as an alteration of normal function induced by continuous irritation". This appears to be a condensed version of Bateman's (1978) definition in the same treatise series where the author says that the plant becomes diseased as opposed to healthy when the alteration goes "beyond the range of easy tolerance" of the plant. We need to keep in mind a much broader view than the tolerance of an individual plant. With today's advances in knowledge and technology (e.g. gene manipulation), with

forest managers' expectations (e.g. IPM), and with forecasted severe forest stresses and consequent disturbances (e.g. greenhouse effects, climate change), there is clearly an urgent need for forest health experts, in addition to traditional forest pathologists. Recently, the Society of American Foresters chose as its national convention theme "Healthy Forests, Healthy World". This idea is not new, as there have been previous (Tammen and Wood 1977, Browning 1983) and still are discussions on this subject (Lockwood 1985). A degree in plant health has been suggested for the practitioner in plant pathology. As a group, however, forest pathologists are likely the most apt to fill that task. This was also suggested by Browning (1983) when he stated that: "Many disciplines have a rightful claim to a part of plant health using my broad definition, but the philosophy of the healthy plant belongs to plant pathology (Sic.)."

The need to promote a unifying concept of forest health is also apparent in the scientific literature. As I mentioned above, while surveying articles in forest pathology in the Canadian Journal of Forest Research, I selected only those that dealt directly with diseased plants; I then excluded articles that dealt with modification of growth rates or with tree or stand vigour. The division was difficult, and by doing so I had to set aside several articles dealing with tree health. Examples are: "Effects of different vesicular-arbuscular mycorrhizal fungi on growth of *Fraxinus americana*" (Furlan *et al.* 1983); "White ash seedling growth response to ozone and simulated acid rain" (Chappelka and Chevone 1986); "Effect of aluminum on the growth of sugar maple in solution culture" (Thorton *et al.* 1986); "Loblolly pine seedling root anatomy

and iron accumulation as affected by soil waterlogging" (McKevlin *et al.* 1987); and "Radial trends in cation ratios in tree rings as indicators of the impact of atmospheric deposition on forests" (Bondietti *et al.* 1989). These articles show how or to what extent plants or forests are affected by given factors but with no reference to them as being diseased. In a context of tree or forest health, defining the thin line where a plant becomes diseased is hardly necessary. One could only say for most situations "the healthier the better!", or its corollary "the less healthy a plant or a forest, the more acute the problem".

Beside promoting or acting within this concept of forest health, forest pathologists will have to spend much time on evaluating the effect of diseases or disturbances on the forest ecosystems. Thus, survey and impact evaluation methodologies will have to be developed or improved, as well as the modelling of ecosystems to develop predictive tools, such as the Geographical Information Systems (GIS) or other expert systems. More knowledge of disease-insect-environment complexes is a must for good prediction. Disease or problem diagnosis should also be improved through immuno-assays utilizing polyclonal and/or monoclonal antibodies and through DNA probe technology.

Control, whether direct or through IPM, will remain a primary objective of forest health protection. Research on biological control should be accelerated. Studies will have to be carried out on antagonism, competitive inhibition and hyperparasitism either between microorganisms or between microorganisms and plants as well as on ecological factors that affect or regulate these interactions.

Biotechnology will come into play (Hubbes 1987). Beside the aspects mentioned above in relation to problem diagnosis, molecular genetics should help to improve disease resistance and forest productivity and even the capability of trees to survive and grow well in modified environmental conditions.

Finally, society in general and forest managers in particular must realize and accept that diseased or relatively unhealthy trees or forests are and will always be part of the normal forest ecosystems. And all the more so, when man causes unnatural disturbances, either voluntarily through exploitation and management, or partly non-voluntarily through air or other environmental pollution. Forest pathologists and economists must work together to define an acceptable "disease threshold", a concept required in any IPM system, where biological life has enough room to both maintain relatively healthy ecosystems while, at the same time, being able to recycle its nutrients and adjust its ecosystems to the environmental constraints to continue to perpetuate itself.

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