LESSON 1 Introduction to Forest Pathology

LESSON OVERVIEW

CONTENT

This lesson serves to introduce you to many aspects of the study of forest tree diseases. It is organized into three sections. The first gives a brief overview of the discipline of forest pathology. We start by asking why you would want to know about tree diseases. The answer to that question determines to a large extent how the whole field is approached. We then introduce some of the terminology that is used when speaking about diseases, and explain how we can determine that a certain condition is in fact a disease.

In the second section we deal with the fungi, the group of micro-organisms that is responsible for most tree diseases. Habitat requirements, reproduction, and fungal classification are discussed. We also discuss bacteria and viruses as disease-causing agents.

In the last section we deal with the major abiotic causes of tree damage and disease. These include frost, drought, heat, and flooding. This list could be extended to include air pollution, pesticide damage, and problems in tree nutrition. These subjects, however, are dealt with in other courses, although you will see that they are very relevant to a group of diseases known as "declines," the last topic in this section.

READING

Specific reading assignments are suggested in each section.

LESSON STUDY INSTRUCTIONS AND ASSIGNMENT

Complete each section in turn, answering the self-testing/review questions associated with each before proceeding to the next.

In this lesson there is no assignment to be submitted for marking.

COMMENTARY

SECTION 1

FOREST TREE DISEASES

reading

Start by reading Chapter 1 of Manion (1991) "Tree Disease Concepts," then study the material that follows in this manual. To test your understanding of the material in this section, answer the self-testing/review questions before proceeding to the next section.

WHY STUDY TREE DISEASES?

The most common reason that we study tree diseases is that they are often very damaging. You have already read in Manion how certain valuable species such as the American chestnut and several white pines are no longer commercially used in many areas because of introduced diseases. Many of our native diseases are also responsible for very large losses of wood. Hence it is not surprising that the most common definition of forest pathology is: "*The study of forest tree diseases for the purpose of predicting, and preventing or minimizing damage done by such diseases.*" Notice the practical slant in the definition: the interest lies in prevention or reduction of damage, and that will be the emphasis in this course.

Two important points, however, need to be considered before proceeding. First, the type and degree of damage caused by a disease is determined largely by the *purpose of management:* a disease that is detrimental in one situation may be neutral or even beneficial in another. For instance, dwarf mistletoes result in a marked reduction in growth of infected stands, and such infection is very common in western coniferous forests. In parks or areas used for watersheds, however, that may not matter in the least. The landscape remains forested, and the purpose for which the area has been set aside is well served, and hence there is no damage in such situations.

The second point is that most pathogens are integral members of our forest ecosystems. They play their own particular and, sometimes, important role in ecosystem processes, such as nutrient cycling. Sometimes they direct the course of succession. In fact, it is slowly being recognized that pathogens may produce substantial benefits, largely because they act as major agents or causes of diversity in forested landscapes. In order to make the best forest management decisions then, both the damage and possible potential benefits must be considered.

Nevertheless, mitigation of damage remains an important reason for the study of tree diseases. Reduction of damage, however, does not necessarily imply that pathogens must be eliminated. The presence of pathogens does not matter so long as damage is avoided.

The techniques used to reduce damage consist, in the main, of making the environment unsuitable for disease, or of avoiding the use of tree species in ecological situations in which they are susceptible to disease. Hence forest pathology must be understood as a *branch of*

silviculture. Mitigation of damage by disease must be integrated with all the other objectives of silviculture, or else it will not succeed.

Notice that this course is called *forest* pathology, not *tree* pathology — this underscores our focus on the role and management of diseases at the level of forest stands or ecosystems. An understanding of how diseases develop on individual trees is necessary, but we extend this interest in a larger perspective. This course will not deal much with diseases of shade trees for two reasons: first, the value of individual shade trees greatly exceeds that of forest trees, and hence it is possible to use control techniques that are not economically viable in forests; second, many shade trees are planted well outside their native range, and all of them occur in greatly altered environments — hence environmental stress plays a much greater role in shade tree pathology than in forest pathology.

If forest pathology is concerned with preventing damage, and if damage occurs only if goals of management are not met because of disease, then the goals of management need to be clearly stated, or it will not be possible to design and implement useful disease prevention and control measures. If we don't know what we are trying to achieve by our interventions in the forest (i.e., if goals are not clearly stated), it will not be possible to determine whether any particular intervention is good, bad, or indifferent.

In discussing goals, though, we touch on a central problem in North American forest management: in the past, the goal was simply to produce quality timber without loss of the long-term productive capacity of the land. Elsewhere in the world (for instance in China or in the subtropical plantation forests of Eucalypts and radiata pine) that goal is still overriding, although in these areas of the world, as well as in North America, concerns are being expressed about the environment and other forest values. Debate rages on about what can, might, or should be the goals of temperate and boreal forest management, and I won't add my opinions on the matter (after all, this is a course in forest pathology), but we must recognize that the outcome will also define the practice of forest pest management

In the course of those debates, the issue of forest health in natural and managed forests is often raised. Some have said that all disease troubles arise from human intervention, and that in perfectly natural forests trees are vigorous enough to withstand the onslaught of disease. In this view, disease is seen as a symptom of inappropriate human intervention in natural forest ecosystems. As you study the material in this course, you will see that this is an overly simplistic view, and, in fact, quite mistaken.

A more subtle issue arises from the use of the word "health" (as in "healthy forests"). A decade ago, the term denoted a forest that was essentially free of diseases and insects, or at least one in which diseases were not damaging. Since that time it has been widely recognized that diseases play a role in natural ecosystems. The term "healthy forest" is

now sometimes used in its old way, but at other times is used to denote a forest in which diseases play their natural role. That natural role can include significant losses in volume and value. If the definition of a healthy forest is simply a forest in which diseases play their natural role, then "natural" and "healthy" are synonymous, and the word "healthy" is devoid of any specific meaning. I believe that debates about the proper use of forests are poorly served by such an ambiguous use of the term "forest health," and that it is best to avoid the term altogether.

Definitions of Terms

In preparation for discussion of the course material, keep in mind the following definitions of terms commonly used in the study of tree diseases:

pathogen An organism able to cause disease. Hence *pathogenicity* – the ability to cause disease, and *pathogenic* – disease causing.

disease A chronic or fatal malfunctioning of one or more parts of a plant as a consequence of invasion by foreign organisms or from unusual environmental conditions, resulting in reduced growth, death, malformation, or loss of quality. Note the distinction between *pathogen* and *disease*: the former is the cause, the latter is the result.

etiology The development of a disease over time, from the viewpoint of the host. Thus the etiology of a disease is a description of how the various symptoms and signs develop over time.

saprophyte A micro-organism (e.g., decay fungus) that lives on dead organic matter.

parasite An organism that lives on a live host for at least part of its life cycle. Two types to note are obligate and facultative.

obligate parasite A parasite that is confined to living tissues except for inactive resting stages. These parasites include rusts, dwarf mistletoes, mildews and viruses.

facultative parasite A parasite that is able to survive, grow and reproduce on both living and dead tissue. Sometimes the host tissue is killed just ahead of the advancing pathogen (as in the case of many of the bark and root pathogens); in other cases, the host tissues die some time (weeks to months) after invasion, either at a time of stress for the host or when the pathogen begins to reproduce (as with many needle diseases).

sign Visible (macro or micro) evidence of the pathogen itself, usually its reproductive structures.

necrosis Death of tissue.

symptom — An abnormal host condition resulting from the attack by the pathogen. Common symptoms include resinosis, chlorosis, hypertrophy, hyperplasia and brooming. Many other symptoms, some obvious and some subtle, might present. Note that symptoms can refer both to conditions on individual trees and also to stand level phenomena, such as group dying in root disease openings.

resinosis — A symptom wherein excessive resin production results in resin soaking tree tissues as well as resin exudation.

chlorosis — A symptom that presents as yellowing of foliage.

hypertrophy — A symptom in which there is swelling or gall formation that occurs because of abnormal increase in cell size.

hyperplasia — A symptom that presents as swelling or gall formation as a result of an abnormal increase in cell number.

brooming — A symptom that shows up as a production of abnormal clumps of branches.

The parasitic habit of pathogens needs some comment. For almost all of them, some time elapses between initial invasion and the appearance of the first signs or symptoms. This is called the **latent period.** Those that can live for long periods within their host without causing any symptoms are called **endophytes.** Many facultative parasites invade and spread in their host until that host is killed. At that time, newly dead host tissues that are not already occupied by the parasite are quickly invaded by a large array of saprophytes. These saprophytes are usually strong competitors that prevent further spread of the original facultative parasite. Sometimes the original facultative parasite is replaced quickly. More often, it builds a protective layer around the domain that it occupied at the time of death of the host and survives within that domain for many years

THREE GROUPS OF DISEASES

Tree diseases can be divided into three broad groups. The first of these consists of diseases caused by **abiotic agencies,** such as frosts or toxic substances. The damage done by such agents may result in subsequent invasion and further damage by various weak pathogens, but plants usually recover if the abiotic cause is removed. The resulting disease, that is, the characteristic set of signs and symptoms, usually consists of the damage done by the abiotic agent, modified by subsequent pathogen invasion.

A second group of diseases is caused by the **invasion of pathogens** which disrupt normal plant processes. Particular environmental conditions are usually required for infection and/or disease development, but such environmental conditions are not, by themselves, damaging.

The last group of diseases is known as **declines.** Symptoms of declines usually include reduction in leaf area and reduced growth, developing into dieback of the crown and eventually tree death. Typically, a single biotic or abiotic cause cannot be identified. Rather, declines appear to result from a combination of chronic stress factors such as drought, nutrient stress, atmospheric pollution, all persisting over several years. If trees under such stress are then exposed to an acute stress factor such as frost or other severe climatic condition, they are unable to respond in the normal fashion, and begin to decline. Various weak fungal parasites, which normally do not affect the tree species in question, can then invade and speed the decline. Various combinations of such adverse events, in different orders, can all lead to the same decline condition in a particular host species.

Declines and common abiotic agents of disease are discussed in Section 3 of this lesson. The common biotic agents that cause disease include viruses, bacteria, fungi, nematodes, and vascular plants. Of all these, the fungi constitute by far the largest group of tree pathogens. Section 2 deals mainly with the fungi, although bacteria and viruses are also discussed.

There are literally thousands of species of fungi that occur naturally in forests. Some play essential roles, such as the mycorrhizal fungi. Others colonize and digest all kinds of dead organic materials. Living plant tissues are seldom sterile. The external surfaces (the **phytoplane**) are colonized by communities of micro-organisms shortly after they are formed. One can also isolate micro-organisms from within healthy, living tissues. Diseased tissues usually harbour large numbers of micro-organisms. Hence, very important questions arise: How do we distinguish between pathogens and other micro-organisms? How do we determine that a particular micro-organism is responsible for the disease being considered? The latter question can be answered by following a series of four experimental steps, which together are known as "**Koch's postulates.**"

Koch's Postulates

1. The suspected pathogen must be present whenever the disease appears. (Remember that a disease is defined by a set of symptoms and signs.)
2. The pathogen must be isolated in pure culture, identified and characterized.
3. The pathogen must be inoculated on healthy plants of the same species and variety, and produce the typical disease symptoms on these. Controls are very important here.
4. The pathogen must be re-isolated from such inoculated plants and shown to be the same one that was used to inoculate them.

These simple rules suffice in many situations to identify the pathogen responsible for a particular disease. Things will often be more complex, however. For instance, obligate parasites cannot be isolated in pure culture, thus requiring a modification of the rules. Even more important

is the fact that Koch's postulates ignore the role of the environment. Thus a disease may be "caused" by a certain pathogen, but only under special environmental conditions (such as growing season frosts). What then is the cause?

Most pathogens have a tremendous reproductive potential. Fungal spores are produced in large numbers and deposited on all plant surfaces. The mere presence of a pathogen, however, does not mean that a disease will occur. Usually conditions necessary for infection are limiting. Since most pathogens are present all the time and everywhere in the forest, management of diseases is usually aimed at creating an unsuitable environment for them. In the case where vectors play a role, control can sometimes be achieved by making the environment unsuitable for the vector.

All this can be summarized by the "disease triangle" (see Fig. 1.1). The three vertices of the triangle all interact, and that interaction must be understood as having a time dimension. Thus the environment affects the condition of the host in both the long and the short run. The long run determines such things as tree vigour and carbohydrate reserves, and these in turn affect the way that the host reacts to short term conditions such as droughts, as well as its ability to mount effective defense reactions. The environment affects the pathogen in similar ways and, in addition, very specific conditions are usually required for spore release, dispersal and infection. Since the pathogen normally lives on the host, the condition of the host may affect the spore-producing ability of the parasite. Much of this course consists of elaborating the important interactions for specific diseases among host, pathogen and environment.

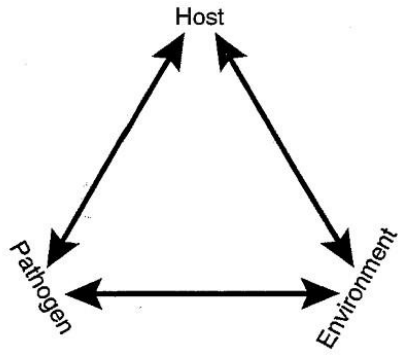

FIGURE 1.1
The disease triangle.

It is helpful to expand the disease triangle to a three sided pyramid, in which the fourth vertex represents humans (see Fig. 1.2). This calls attention to the fact that human actions have at times had a profound influence on host, pathogen and the environment in ways that change the interactions between them drastically. For instance, the creation of fully stocked, single species plantations shortly after clearcutting/stand destruction promotes survival and spread of certain root diseases, and the consequent damage they cause. At the same time, of course, disease epidemics have played an important role in human civilization, showing that the relationships operate both ways.

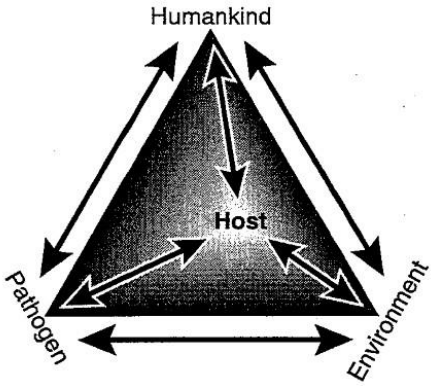

FIGURE 1.2
The disease pyramid.

SECTION ASSIGNMENT

Self-Testing/Review Questions

Test your understanding of the material in this section by attempting to answer these questions. Do not proceed to the next section until you are satisfied with your proficiency in this section.
Do *not* send your answers to the tutor for marking. If you continue to have difficulty with a question after you review the relevant material, you may wish to discuss it with your tutor.

1. What is the difference between a disease and a pathogen? Does the first always require the second?
2. What, approximately, is the loss in wood volume in Canada attributable to diseases in relation to the annual harvest?
3. What is the relationship between control of diseases and silviculture?
4. Give some examples of diseases that are damaging in some management contexts, but not in others.
5. List some essential functions of fungi in forest ecosystems.
6. List Koch's postulates. Why are they necessary to establish pathogenicity of an organism?
7. Give an example of relationships along each of the six edges of the disease pyramid.