FOREST PATHOLOGY

LECTURE NOTES OF THE
FORESTS DEPARTMENT
OF WESTERN AUSTRALIA

FOREST PATHOLOGY

A Short Course for Trainees of the
W.A. Forests Department

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CHAPTER 1 - INTRODUCTION TO FOREST PATHOLOGY

The job of the forester is to grow utilizable trees in a given amount of time. To do this he must ensure that the trees in the forest maintain a reasonable rate of growth and a reasonable level of health from seedling to maturity.

The study of forest health is called Forest Pathology. This subject is defined as the branch of forestry concerned with the diseases of forest trees with a view to the prevention and control of these diseases.

THE IMPORTANCE OF FOREST PATHOLOGY

Diseases cause great losses from the forest every year. This fact is not always recognised, for losses due to disease are rarely spectacular and often invisible.

Losses due to disease in the forest are :

1. Reduction in the present value of the forest through the decay of standing timber and converted forest products.

2. Reduction in the future value of the forest through the damaging, weakening or killing of immature trees.

3. Reduction in the growth rate of the forest through the loss of volume increment on individual trees.

4. Reduction in the recreational value of the forest.

The maintenance of forest health is an important part of the forester's job and therefore the study of Forest Pathology is a fundamental part of the training of the young forester.

THE SCOPE OF THIS COURSE

The object of this course is to provide young foresters with an understanding of the principles of forest pathology.

The course has four sections :

1. The study of the nature of disease.

2. The study of diseases caused by non-living agencies.

3. The study of diseases caused by living organisms (including decay of wood).

4. The study of the principles of disease control.

FOREST ENTOMOLOGY

Forest Entomology is the study of the insects of the forest and the means of controlling insect pests both of forest trees and of forest products.

FOREST ENTOMOLOGY (continued)

The subject of Forest Entomology is not covered in this course as the essential aspects of the subject as they apply to W.A. forests is fully covered in "Forestry in W.A.", Chapter IV, Section 3. References to the subject are also included in the Suggested Reading List at the end of this course (page 20).

TERMINOLOGY : BASIC DEFINITIONS

Before proceeding with the course it is necessary to define several basic terms. These terms are an essential part of the "language" of forest pathology and the student must make every effort to thoroughly familiarise himself with their meaning and use.

ENVIRONMENT : the habitat, or surroundings, in which a forest tree lives. Influenced by the climate, the soils, the topography and the activities of man.

EPIDEMIC : a marked and rapid increase in the occurrence of a disease.

FUNGUS : a lowly organism, devoid of chlorophyll, which obtains its food requirements from other organic matter.

FUNGICIDE : a substance which is toxic (poisonous) to fungi.

HOST : a tree from which a fungus (or other parasite) draws its food requirements.

IMMUNE : an individual which is unable to be attacked by a disease-causing organism.

ORGANISM : a living thing, plant, animal or microbe.

MICROORGANISM : a minute organism, (e.g.bacteria).

PARASITE : an organism which lives on and is nourished by another living organism.

PATHOGEN : an organism capable of causing a disease.

RESISTANT : an individual able to withstand attack by a pathogen without serious injury - but is not immune to attack.

SAPROPHYTE : an organism which lives on and is nourished by the dead remains of another organism.

SUSCEPTIBLE : an individual unable to withstand the attack of a pathogen without serious injury.

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CHAPTER 2 - THE NATURE AND CAUSES OF FOREST DISEASE

Disease of a forest tree is defined as "any interference or disturbance of the natural life processes of the tree which results in abnormal functioning of the tree, deterioration of any of its parts, or death."

NORMAL TREE STRUCTURE AND FUNCTION

Before it is possible to understand the effects of disease on a tree it is essential to understand thoroughly the normal life processes of the tree.

The forest tree is a living plant of complex cellular structure and generally great size and age. It possesses roots, a trunk and a crown.

The roots perform two vital functions : anchorage and absorption. Water and nutrients (and to a certain extent, air) are absorbed from the soil by the tiny root hairs surrounding the roots, then transported through the thick bracing roots up through the sapwood of the trunk and out through the limbs and the branchlets to the leaves.

In the leaves, in the presence of chlorophyll and sunlight, the food supply necessary for tree growth is manufactured. Water from the soil and carbon dioxide from the air are combined into complex carbohydrates. These food materials are then transported, via the inner living bark, to the various living portions of the tree. Here they are used for the purpose of maintaining and building the tissues of the tree.

The oxygen which is required for the utilization of carbohydrates is drawn in from the air through the leaves, the bark and the roots.

The tree obtains its mechanical support from the dead heartwood tissue of the trunk. This tissue also functions as a storage place for food and water, and forms the log from which timber is sawn.

Tree growth occurs in two directions :

(i) Growth in girth. This arises from the cambium, a layer of living tissue occurring beneath the living bark. New layers of wood and bark cells are produced by the cambium each year.

(ii) Growth in Length. This occurs at growth tips on the ends of the roots and the shoots.

The reproduction of the tree is brought about by the fusing within special reproductive organs of male and female parts from separate parent trees. With Angiosperm trees, the reproductive organs are the flowers; with Gymnosperms, they are the cones. In both cases the result of the reproductive process is the seed, which contains the embryo of a new tree.

THE EFFECT OF DISEASE ON THE NORMAL TREE

The structure of the tree is designed so that the life processes of the tree may successfully take place and the end results of Growth and Reproduction can occur.

THE EFFECT OF DISEASE ON THE NORMAL TREE (continued)

When these life processes are in any way disturbed, the growth and reproduction of the tree is adversely affected.

For instance, if for any reason the roots of a tree become ineffective, the water supply to the tree is reduced or cut off. The leaves will then wilt and the production of food for the tree will stop. If the functions of the trunk are disturbed, the transport of water and minerals to the crown and the transport of food from the leaves will be disrupted. Similarly, disturbances to the leaves or to the flowering parts of the tree will result in the non-functioning of these organs.

If the normal function of any part of a tree is disrupted so that the normal function of the whole tree is disturbed, the tree is then said to be diseased.

THE CAUSES OF FOREST TREE DISEASE

There are two broad groups of forest tree diseases:

1. Environmental diseases : those caused by non-living, or environmental factors.

2. Pathogenic diseases : those caused by living organisms.

The environmental factors affecting the tree are numerous and their effects variable. The factors causing disease are mainly related to the nutrition of the tree, to the climate and to the influence of the forest soil.

Pathogenic diseases can be caused by four types of organism. These are Bacteria, Viruses, parasites of the Mistletow type and Fungi. Of these, the fungi are by far the most important group.

However, not all forest diseases can be classified as being caused specifically by either a pathogen or an unfavourable environmental factor. Very often it is due to the combined effect of both that a forest tree becomes diseased. For instance :

(i) trees which are weakened by unfavourable environmental stresses are more susceptible to attack by a pathogen; and

(ii) trees which are under attack from a pathogen generally have less strength to resist the effects of a temporarily unfavourable environment.

THE DIAGNOSIS OF TREE DISEASES

It is not generally a simple matter to decide what factor has caused a tree to become diseased. When the forester comes across dead, or diseased and dying trees a standard approach to disease diagnosis should be taken.

There are four factors to be examined. These are :

1. The Reaction of the Tree. The diseased tree itself must be studied with a view to deciding what parts of the tree are affected and how they are affected. (For instance leaves are withered or roots are waterlogged.)

2. The Presence of Pathogens. A search must be made for signs of a pathogen. If there are no external signs (for instance a fungal fruiting body), the affected parts of the tree should be sent to a Pathology laboratory for analysis.

3. The Environment of a Tree. The surroundings of the tree should be studied from all aspects. If possible, the surroundings of diseased trees should be compared with those of otherwise similar undiseased trees.

4. The Past Environment of the Tree. Consideration must be given to possible occurrences in the past which may have been in some way responsible for the present diseased condition.

The occurrence of large numbers of diseased trees in the forest is a matter for grave concern and the forester must investigate, report and if possible take remedial action when this occurs.

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CHAPTER 3 - ENVIRONMENTAL DISEASES

Environmental diseases are those diseases caused by non-living or environmental factors. They can be discussed under three headings:

1. Diseases associated with the effect of Temperature.

2. Diseases associated with the effect of Water.

3. Diseases associated with the Level of Nutrients in the Soil.

THE EFFECT OF TEMPERATURE

The normal functioning of the tree can be adversely affected by both very low and very high temperatures. On the one hand, there is Frost Injury caused by temperatures below the freezing point of water (32 degrees Fahrenheit) and on the other there is Sun Scald (death of cambium) caused by very high sun temperatures on thin-barked trees.

Western Australian forest trees do not suffer from the effects of naturally occurring high temperatures, though damage of this nature can be done by the degree of heat generated in a fire. Frosts, on the other hand, occur annually in some parts of the forest region and this subject is now given further consideration.

The Occurrence of Frost. Frosts occur most frequently in the autumn and early winter months in Western Australia. They generally follow a cold, clear night and are most commonly found in valleys, depressions or gullies into which cold air can drain.

The Nature of Frost Damage. Frost damages the tree by freezing the water within the cells of the tree tissues. Normal cellular processes are disrupted and the tissues die. Young, delicate tissues are most susceptible to frost damage. On a mature tree, young tissues are found at the cambium and the growing tips; on a seedling the entire plant can be composed of frost-susceptible tissue.

Factors Affecting Frost Damage. The amount of damage caused by frost depends upon a number of factors. These are :

1. The species concerned. Some tree species are more frost-hardy than others and can resist the damaging effects of frost. Wandoo and Blackbutt, for instance, are highly resistant to frost injury. Jarrah is a species which is easily damaged and occasionally killed by heavy frost.

2. The duration of the frost. The longer trees are subjected to frost temperatures the greater will be the damage that is done.

3. The season of the year. The most serious frost damage is done in the growing seasons of the year when the trees are covered with young, succulent growing shoots.

4. The age of the tree crop. Frost damage is most severe on trees in the sapling or seedling stage.

Control of Frost Damage. Frost damage to the forest can be controlled by the application of sound silviculture. There are three principles to be considered.

THE EFFECT OF TEMPERATURE (continued)

1. For plantations : the planting of frost-resistant species in frosty sites.

2. For the natural forest : the use of a selection silvicultural system in bad frost sites to ensure that regeneration is protected by an overstorey.

3. For nurseries : the selection of the site is of paramount importance - all efforts must be made to situate the nursery on an area free from frost. If this is not possible, the use of movable screens or covers must be considered.

THE EFFECT OF WATER

Water can be associated with diseased forest in two ways:

(i) through the presence of an excess of water in the soil, causing waterlogging and

(ii) through a deficiency of water in the soil, causing drought.

WATERLOGGING. An excessive amount of water in the soil prevents an adequate supply of oxygen reaching the tree roots and results in death of the roots by "drowning".

In soils which have become waterlogged, most tree species will deteriorate and eventually die. Two species remarkably resistant to the effects of waterlogging are Eucalyptus rudis and Eucalyptus camaldulensis. Pinus pinaster and Jarrah are species which cannot tolerate saturated soil conditions.

Waterlogging may frequently develop on low lying areas cleared for plantation. When this occurs, the construction of artificial drains may be necessary to prevent winter deaths of young trees.

DROUGHT. Drought is caused by an inadequate supply of water to the tree roots and occurs when the forest soil becomes abnormally dry. This condition generally results from the combined effect of a series of dry winters and periods of hot, drying winds.

Drought can kill trees, but normally only results in a decreased rate of growth. The severity of injury depends upon the severity of the drought and on the age of the forest crop.

Young, shallow rooted trees are more susceptible to drought than are older ones with their roots deep in the soil.

The effect of slight droughting may sometimes be seen in young plantations on poor sites in late summer and autumn. It is characterised by a browning and wilting of the tops of the young pines.

Prevention of drought is obtained by silvicultural practices aimed at conserving available soil moisture for the crop trees of the forest. For instance:

(i) In the forest : thinning, maintenance of canopy ("soil shading") and scrub suppression.

(ii) In the plantation : thinning and weeding or cultivation of competing scrub.

THE EFFECT OF WATER (continued)

(iii) In the nursery : weeding, watering and shading of young plants.

THE EFFECT OF THE LEVEL OF NUTRIENTS IN THE SOIL

Diseases of forest trees can be either caused by a deficiency of a particular substance in the soil, or by an excess of a particular substance in the soil. These conditions result in respectively, a "nutrient-deficiency" disease or a "toxicity" (or poisoning) disease.

TOXIC DISEASES. Some soils can have a toxic, or poisonous, effect on trees planted in them. This is due to the presence in the soil, in excessive amounts, of some particular substance. A classic example is the effect of Salt : very few plant species can live in a soil which contains high levels of salt. Aluminium in a certain form is also toxic to plants if present in the soil at concentrations above a certain level.

In the forest regions of Western Australia, toxic diseases are not of any great importance.

Note: excessive applications of fertilizers (such as superphosphate) can result in the development of toxic diseases. Care must always be taken to avoid this when fertilizer dosages are made up. This is of particular importance in the nursery.

DEFICIENCY DISEASES. The growth and health of trees are affected if they are not supplied with adequate quantities of the major and minor ("trace") elements.

This fact has not always been known and the planting of pines on nutrient-deficient soils in the early part of this century resulted in some spectacular failures.

Major Elements. The major elements essential for healthy tree growth are calcium, magnesium, nitrogen, phosphorus, potassium, sulphur, and several others (see course on "Forest Botany").

Most Australian forest soils are deficient in phosphorus. The native forests are adapted to this condition and do not suffer from phosphate deficiency. However, with exotic pines planted on the same soils, the phosphate level of the soil must be increased if the pines are to make healthy growth. This can be done by the application of superphosphate fertilizer to the plantation soil.

Diseases due to deficiencies of the other major elements are not important in Western Australian forests.

Minor Elements. The minor, or trace elements essential for healthy forest tree growth are boron, copper, iron, manganese, molybdenum and zinc.

Of these, zinc is by far the most important in Western Australia, for many plantation soils are zinc-deficient.

Zinc-deficiency generally develops in very young plantations. For the first twelve months following planting, growth is healthy and vigorous. The first signs of the disorder appear after that and develop progressively.

THE EFFECT OF THE LEVEL OF NUTRIENTS IN THE SOIL (continued)

The symptons of zinc-deficiency in a young pine stand are:

1. Marked reduction in the amount of foliage on the trees.

2. Needles and side branches are very much shorter than normal.

3. The side branches are bare, except for a tuft of foliage around the terminal bud (a "rosetted" appearance).

4. The general appearance of the stand is chloritic. (yellowed foliage.)

Zinc-deficiency in young pine stands can be readily corrected. The methods used are:

(i) Spraying the foliage of the young pines with a zinc solution (zinc sulphate in water) at a rate of approximately 70 gallons per acre of a 2½% solution, or

(ii) Application of the zinc in the solid form (zinc oxide) either by itself or mixed with superphosphate.

Forest tree diseases due to the deficiencies of the other trace elements are not of importance in Western Australia, though trace element deficiencies in certain agricultural crops are widely recognised.

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CHAPTER 4 - PATHOGENIC DISEASES

Forest tree diseases caused by living organisms (pathogens) far outnumber those caused by the non-living environment. The major groups of causal organisms are the Bacteria, the Viruses, the Mistletoes and the Fungi.

Bacterial and Viral diseases are not of importance in Australian forests and will not be discussed in this course. The Mistletoe parasites are found throughout Australian forests and are particularly common on inland eucalypts. However, they are not important from an economic point of view (particularly in Western Australia) and will not be covered in this course.

However, forest diseases caused by Fungi are of vital importance. The vast majority of forest tree diseases, including decay of wood, are caused by fungi.

THE NATURE OF FUNGI

The fungi are lowly organisms, devoid of chlorophyll, which obtain their food from the dead or living matter of other organisms.

Structure. The fungus body can consist of either a single cell or of a mass of branching threads called hyphae. A mass of densely inter-woven hyphae is known as a mycelium. At certain times the mycelium masses into a fruiting body and the reproductive units of the fungi, the spores, are formed. Spores are generally produced in extremely high numbers : they are disseminated by wind, rain or mobile microorganisms such as insects. On germination, a spore gives rise to a new fungus body.

Function. Fungi live by penetrating with their hyphae the cells and cell walls of host material. The substances extracted therefrom are the nutrients upon which the fungus lives.

If the fungus can only survive on living host material, it is termed a parasitic fungus. If the fungus requires the host material to be dead, then it is termed a saprophytic fungus.

The effect of fungal attack on the host plant is two-fold :

(i) there is a decrease in the availability of food to the plant, and

(ii) where the fungus attacks the cell walls there is a breakdown in the physical structure of that part of the plant.

Conditions Favourable for the Development of Fungi. For the optimum development of fungi in any medium, be it soil, living plant or timber, the following conditions are necessary.

1. There must be suitable food material available. Cellulose is a suitable food material.

2. The moisture content of the medium must be above 20% and below saturation. The optimum moisture content is around 40%.

3. There must be an adequate supply of air, for fungi require oxygen for respiration as do all living organisms.

4. The temperature must be favourable. Fungi will not develop at temperatures above the boiling point or below the freezing point of water. The optimum temperature range is between 70 and 90 degrees F.

THE NATURE OF FUNGI (continued)

The Beneficial Effect of Fungi in the Forest. Certain saprophytic fungi are of enormous benefit to the forest. These are the fungi which are responsible for the breakdown of the forest litter into soil humus. Without this activity there would be a very much slower return of nitrogen and plant minerals to the soil.

Another group of fungi play an important role in the forest. These are the Mycorrhizal Fungi. This type of fungi live "in partnership" with the roots of certain trees (mainly pines) as neither parasites nor saprophytes. They live in close association with the living roots and a mutually beneficial exchange takes place : the fungi supply the roots with nitrogen, potassium and phosphorus which they easily extract from the soil and the trees supply the fungi with the carbohydrates manufactured in their leaves.

Mycorrhizae are of such great importance in W.A. that pine seedlings in local nurseries will fail, if the nursery soils are not first innoculated with a mycorrhizal fungus.

The Major Fungal Diseases. The fungal diseases of importance to the forester are studied under the following headings:

1. Diseases of forest tree seed.

2. Diseases of the nursery.

3. Diseases of mature forest trees.

A fourth group, Decay of Wood, is discussed separately in Chapter 5.

DISEASES OF FOREST TREE SEED

Fungal spores may lodge on, and germinate into, the seeds of forest trees. When this occurs, the infected seed does not develop successfully.

Little can be done to prevent this occurring in the field, but the fact should be considered when forest tree seed is stored for any length of time as it is in a seed store. Here the following precautions should be taken:

(i) Store seed at low temperatures and humidities (conditions unfavourable for fungi).

(ii) Before storing, dust seeds with fungicide powder or immerse seeds in a fungicidal solution.

DISEASES OF THE NURSERY

Particular importance must be attached to pathology in the forest nursery, for the young trees growing under densely crowded conditions therein are highly susceptible to fungal disease.

The two major nursery diseases are Damping-off and Root Rot.

DISEASES OF THE NURSERY (continued)

1. DAMPING-OFF. Damping-off is the most universal and the most destructive disease of nursery stock : it results in the rapid decay and ultimate death of young, succulent seedlings. The important damping-off fungi are Pythium and Phytophthora.

There are two types of damping-off disease :

(i) Pre-emergence Damping-off. The fungus attacks the germinating seed beneath the ground and kills the seedling before it emerges from the soil.

(ii) Post-emergence Damping-off. The succulent root tips of the newly germinated seedling are attacked and destroyed.

The development of damping-off diseases in the nursery is favoured by high humidities, over-watering, dense sowing and unfavourable soil acidity.

The disease may be controlled as follows :

(a) avoid heavy watering;

(b) correctly regulate the sowing density of seedlings;

(c) dust the seed with Thiram (a fungicide) before sowing;

(d) drench newly germinated seedlings with Cheshunt Mixture (a fungicidal solution);

(e) adjust soil acidity by cultural or chemical means.

2. ROOT ROT. The same fungi which cause damping-off in newly germinated seedlings can persist in the soil and cause the disease and death of older seedlings and of seedlings transplanted from nurseries to the field. The disease is then called Root Rot. In the nursery Root Rot can be controlled in the same way as damping-off; with transplanted stock it can be prevented by dipping the seedling roots in a fungicidal solution before planting out.

DISEASES OF THE MATURE FOREST TREE

Fungal diseases of the mature forest tree are of three types : Root diseases, Stem diseases and Foliage diseases.

ROOT DISEASES. Fungi which attack the root systems of trees are called Root Rotting Fungi. There are many different varieties of these fungi and they are capable of attacking a wide variety of tree species.

The effect of root rotting fungi is to disrupt the absorptive organs of the tree : supplies of water and minerals to the tree are therefore greatly reduced. This can ultimately cause the death of the tree.

A local example of a root rotting fungus is Phytophthora cinnamomi, the fungus associated with die-back of Jarrah and certain other Jarrah forest species. This fungus has also been found attacking Pinus radiata in New South Wales and New Zealand and may be associated with pine die-back in some local plantations.

The development of a root rotting disease to epidemic proportions (i.e. the "group dying" of trees) is usually associated with some change in the local forest environment. A general weakening of root systems due to say, drought or waterlogging, makes them far less able to resist the attack of a root pathogen.

DISEASES OF THE MATURE FOREST TREE (continued)

Other Root Pathogens. An important root pathogen is Armillaria mellea, a fungus capable of attacking the roots of nearly all forest trees. Armillaria will occasionally cause the death of a young tree already weakened by an unfavourable environment. The fungus is found in local pine plantations, and occurs commonly on Marri, but is not considered a dangerous pathogen in Western Australian forests.

Another root pathogen of great importance in other countries is Fomes annosis. This fungus causes considerable damage in both natural and planted forests.

FOLIAGE DISEASES. Foliage diseases are those which cause malfunction in the crown of a tree. There are two kinds of foliage disease:

(i) Defoliation caused by rotting of leaf petioles.

(ii) Leaf Spotting, the formation of dead areas in the leaf, resulting in decreased leaf efficiency.

A foliage disease occasionally found in pines is the "Needle Cast" disease caused by the fungus Diplodia. This disease results in the stunting of new growth and the browning of needles, and severe attacks lead to crown die back. It is normally found on young pines or on pines weakened by drought or water logging. Both Pinus radiata and Pinus pinaster are known to be susceptible to this pathogen, but to date no serious outbreaks have been recorded in W.A. plantations.

Foliage diseases are not of economic importance in local hardwood forests. This form of disease is generally associated with loss of increment rather than death in forest trees.

STEM DISEASES. Apart from the fungi associated with decay of standing timber (see next section) many fungi can be responsible for diseases in the sapwood and cambium of tree stems. These diseases result in malformations on the stem such as galls, swellings or cankers. These malformations have the following effects:

1. Disruption of the activities of the sapwood (the transport of water, minerals and food) and

2. Disfigurement of the timber cut from the tree stem.

Stem diseases are not serious in local forests. Marri and Red Flowering Gum often carry cankers formed by the fungus Sporotrichum destructor (a fungus which attacks young trees or the limbs of older trees) but this disease does not usually bring about the death of the tree.

The classic example in forest pathology of a serious stem disease was the "Chestnut Blight" (caused by the fungus Endothia parasitica) which wiped out the valuable chestnut forests of North America in the early years of this century.

THE PINE DISEASE ASSOCIATED WITH THE SIREX WASP

Mention must be made in these notes of a very serious disease of pines associated with a wood wasp, Sirex noctilio, which was introduced to Australasia from Europe about seventy years ago. This disease has for many years caused great losses in New Zealand and Tasmanian plantations and has recently been reported in Victoria. The major species attacked is Pinus radiata, although Pinus pinaster is also known to be susceptible.

THE PINE DISEASE ASSOCIATED WITH THE SIREX WASP (continued)

The Disease. The female wasp lays her eggs in a tunnel she drills in the wood of the living tree bole. Together with the eggs she also deposits the spores of an efficient wood-rotting fungus. The fungus (whose name has not yet been positively decided upon) develops rapidly in the tree. Its primary function, it is believed, is to "soften-up" the wood for the newly hatched Sirex larvae ("grubs", or immature wasps), and while doing so it generally kills the tree. Within 12 months, the Sirex larvae develop into adult wasps; they fly to new trees, carrying fungal spores with them, and new tunnels are bored and eggs laid. The process is continuous, and in a short time, many trees can be infested and killed.

Two factors lead to the Sirex disease developing to epidemic proportions :

(i) a high population of the wasps, and

(ii) the presence of unthrifty trees in the plantation.

Trees weakened by drought or by root-rotting fungi such as Phytophthora or Armillaria, are very susceptible to the Sirex fungi; these are quickly killed and allow the rapid development of the wasp population.

Means of Control. The Sirex problem is extremely serious and a great deal of work is being done on the problem in the eastern States. The major methods of control used at present are the location and burning of all infested trees and the application of silvicultural practices which aim at the removal of all unhealthy, susceptible trees from the forest. Other means of control under investigation are :

1. The introduction of insects ("natural predators") which will destroy the Sirex wasp.

2. The release of massive numbers of sterilised male Sirex wasps (this results in the production of unfertilized eggs and thus a slowing down of the wasp "population explosion").

3. The breeding of varieties of Pinus radiata which are resistant to the Sirex fungus.

Sirex in W.A. The Sirex wasp has not yet been located in W.A. but there is always a possibility that it could be accidently introduced. Consequently a high degree of vigilance must be maintained by local foresters to ensure that a potential outbreak is quickly located and controlled. The following procedure should be adopted in all plantations.

1. All dying or dead trees must be reported and investigated.

2. Any tunnels found in the boles of trees must be thoroughly investigated by a competent pathologist.

3. All foresters must be able to positively identify the male and female Sirex wasp and be alert for its presence in the forest.

References. Some useful publications on the subject of the Sirex problem are :

1. "Report on the Sirex Fungus Conference" Waite Agricultural Institute (1963).

2. "Sirex noctilio and the Physiology of Pinus Radiata" by M. P. Coutts (1965).

3. Proceedings of the Sirex Conference. Canberra (1965).

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CHAPTER 5 - THE DECAY OF WOOD

The decay of wood is one of the most important economic aspects of forest pathology, for decay causes greater losses to forestry than all other forest diseases put together. Standing trees, felled logs and converted wood products can all be affected.

A recent survey indicated the extent of this problem in estimating that 14% of the volume of all standing trees is decayed.

Decayed wood has no value.

THE PROCESS OF DECAY IN THE TREE

Decay, or rot is caused by fungi.

Spores of wood-rotting fungi enter the tree and, if conditions are suitable, germinate there to produce masses of hyphae which ramify through the wood. The hyphae feed on the substances composing the cell walls of the wood. This results in the collapse of the cellular structure of the wood and the condition known as "decay".

For the decay fungi to develop, certain conditions must be met:

(i) there must be at least 20% of moisture in the wood, but the wood cannot be saturated;

(ii) the temperature must be favourable and

(iii) air must be present.

The heartwood of the tree is therefore the part of the tree most susceptible to decay.

After decay has become established, the fungi produce fruiting bodies on the outside of the tree. These produce enormous quantities of spores which are capable of infecting other healthy trees on which they may lodge. By this means, decay is spread through the forest.

Wood rotting fungi can enter the growing tree at the following points:

1. Through branch stubs and pruning scars.
2. Through dead limbs in the crown.
3. Through wounds on the bole.
4. Through holes in the tree caused by wood-boring insects.
5. Through dead roots.

TYPES OF DECAY

There are two sorts of fungi which decay wood:

(i) the primary attacking fungi and

(ii) the secondary attacking fungi.

TYPES OF DECAY (continued)

Primary Attacking Fungi : these are parasitic fungi which are only capable of attacking the wood of living trees. They cannot survive in converted timber.

Secondary Attacking Fungi : these are saprophytic fungi which are specifically adapted to living on dead wood, such as fallen logs and sawn timber. They do not decay the living tree.

Most wood-rotting fungi are either primary or secondary fungi. An exception is Polyporous australiensis which attacks Karri, Marri and Tuart. This species can act as both a primary and secondary attacking fungus.

The Primary Rots are divided into two broad groups, depending on their effect on the wood :

1. Cubical Rots - so-called because the decayed wood breaks into cube-like formations; and

2. Straw Rots - so-called because the decayed wood resembles straw.

Cubical Rot is the most common form of primary rot found in Western Australian forests although straw rot is often found in Wandoo.

THE WOOD DECAYING FUNGI OF W.A.

The principle decay-causing fungi in Western Australia are:

1. Polyporous portentosus (also known as P.eucalyptorum). This is the commonest and most important of the primary fungi in the Jarrah forest. Long term attack by this fungus generally results in a column of rot in the centre of the bole of the tree. The fungus will attack most eucalypt species.

2. Polyporous pelles. This primary fungus causes the brown cubical pocket rot found in Jarrah trees throughout the Jarrah forest.

3. Polyporous australiensis. This is the commonest and most important rot found in the Karri forest. The fungus also attacks Marri and Tuart. The rot produced is light brown and cubical. P. australiensis is both a primary and secondary rotting fungus.

4. Stemphylium Species. A secondary rot which is extremely common in old timber which has been in contact with the ground (e.g. Jarrah fence posts).

5. Trametes Species. A secondary rot which is severe on Karri timber.

There are several other less important wood rotting fungi in Western Australia. They are described in "Forestry in W.A.", Chapter IV, and "Forest Mycology in W.A." by A. R. Kelly, Forest Notes, V3, No.1, 1965.

DETECTION OF DECAY IN STANDING TREES

For the purpose of assessment, treemarking and certain other forest activities, it is often necessary to know whether or not decay is present in the standing tree.

Since the decay is inside the tree and often some height from the ground, this is frequently extremely difficult to judge. Use must then be made of any external symptons which may provide a clue to the internal condition of the tree. These clues are:

1. The presence of fruiting bodies on the bole of the tree.
2. The presence of dead branch stubs or large dead limbs in the crown.
3. Excessive resin flow from below the branches.
4. The presence of insect holes and old scars on the bole.
5. The presence of pockets of rot extending out to the surface of the tree bole.
6. The presence of abnormal swellings on the bole.

Although these signs may indicate that decay is present, they do not indicate the extent of the decay. Sounding with an axe is sometimes a useful aid in judging the amount of decay in a tree.

THE PREVENTION OF DECAY

The prevention of decay in sawn timber and other wood products is of such vital importance to the Timber Industry that it has grown into a field of study of its own : Timber Preservation. The many techniques which have been developed in that field are described elsewhere. (See "Wood Preservation" by Hunt and Garratt, 1938; or "Australian Timber Handbook" by Wallis, (1963) Chapter XIV).

The prevention of decay in the forest is a much more complex and difficult problem than is the prevention of decay in forest products and few successful practical means have been achieved. Current practices aim at preventing the spread of decay rather than the occurrence of decay in the forest.

There are two means by which this can be done:

1. By the prevention of tree wounding. This reduces the number of points at which fungal spores can enter healthy trees. Sources of tree wounds such as fire scars, logging injuries and other man-made injuries can be guarded against by foresters who understand the importance of doing so.
2. By the removal of decayed trees. This reduces the source of decay infection in the forest.

These means, together with application of the more general principles outlined in the following chapter, provide the means of combatting decay in the forest.

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CHAPTER 6 - THE PRINCIPLES OF FOREST DISEASE CONTROL

Previously in this course, methods of controlling Environmental and Nursery diseases were described. In both cases, direct steps to prevent or eradicate disease can be taken.

Controlling fungal diseases in the forest is a different matter. Finance is not generally available to consider the treatment of individual trees or large scale control operations (such as aerial spraying with fungicides).

Disease control in the forest is based on prevention rather than eradication. There are two means available :

1. the application of good silvicultural practices, and

2. the maintenance of strict quarantine.

CONTROL BY SILVICULTURAL PRACTICE

Every operation in the forest influences the forest environment and can cause conditions which are either favourable or unfavourable for forest pathogens. The application of forest practices which lead to conditions which are unfavourable for the development of pathogens is one of the surest means of preventing the out-break of forest diseases.

Desirable silvicultural practices from the viewpoint of disease control are :

1. The regulation of forest composition. "Mixed" forest stands (those composed of more than one species) have a greater resistance to disease than have "pure" stands. In the pure stand every tree is available for attack by the pathogen. If pure stands are favoured over mixed stands (and they generally are, for several reasons) the danger of a disease epidemic must be accepted and where possible precautions against this occurring taken.

2. The maintenance of vigour. Strong, vigorous trees with a firm grip on the site have a much higher resistance to pathogens than have weak, unthrifty trees. The latter should be removed from the forest by a silvicultural practice such as thinning or improvement cutting.

3. The maintenance of health. Disease spreads through the infection of healthy trees by spores from diseased trees. This spread can be stopped by the removal of diseased trees from the forest. Cull Felling and Salvage Cutting provide the means by which this can be done. The removal of "high risk" trees (old weak members of the stand susceptible to disease attack) is equally important in stopping the spread of disease.

4. The protection of trees. The majority of fungal pathogens enter a tree through wounds on the bole, limbs or roots. The prevention of these wounds will lower the incidence of disease in the forest.

5. Regulation of the Water Table. Silvicultural practices resulting in a marked increase or decrease in the height of the soil water table must be avoided, as this will lead to a weakening of the trees and an increased susceptibility to disease.

6. Tree improvement. The breeding of trees which are resistant to disease is one of the most recent and perhaps most effective means of disease control. This method is mainly applicable in plantation forestry

CONTROL BY SILVICULTURAL PRACTICE (continued)

6. Tree improvement (continued)

or elsewhere where establishment is by artificial means. (For a detailed discussion of the subject of tree improvement, see the course on "Silviculture", Chapter 7).

CONTROL BY QUARANTINE

The worst diseases in the history of forest pathology have been caused by pathogens introduced either from other countries or from other distinct localities.

Quarantine provides the means of controlling the movement of forest pathogens and therefore of safe-guarding the forest against introduced diseases.

There are two types of quarantine which can be applied : national quarantine and local quarantine.

1. National Quarantine is the prevention of the introduction of forest diseases from other countries. To be effective this type of quarantine must be based on the strict policing of firm regulations.

2. Local Quarantine is the prevention of the movement of a disease from a locality where the disease occurs to a locality where it does not.

Local quarantine must be the concern of every forester. To shift diseased plants or soil from diseased areas into an area of healthy forest is bad local quarantine and must always be avoided.

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APPENDIX : SUGGESTED FURTHER READING

1. "Forest Pathology" by J.S.Boyce (1948).
2. "Pathology of Trees and Shrubs" by G.R.Peace (1962).
3. "Pathology in Forest Practice" by D.V.Baxter (1943).
4. "Forestry in W.A." Forests Department Bulletin No.63, Chapt.IV.
5. "Forest Mycology in W.A." by A.R.Kelly, Article in Forest Notes Vol.3, No.1, 1965.
6. "The Australian Timber Handbook" by N.K.Wallis (1963) Chapt.XIV.
7. "Wood Preservation" by Hunt and Garratt (1938).
8. "Timber and Some of its Diseases" by H.Marshal Ward (1909).
9. "Notes on Western Australian Fungi (with particular reference to the Jarrah forest)" by T.E.H.Aplin (1951).
10. "Forest Insects" by Doane, van Dyke, Chamberlin and Burke (1936).
11. "Forest Entomology" by S.A.Graham (1952).
12. "The Life of the White Ant" by M.Maeterlinck (1927).
13. "Forest Insects of Australia" by W.W.Froggatt (1923).
14. "The Sirex Wood Wasps and their Importance in Forestry" by R.N. Chrystal.
15. "Australian Termites" by Ratcliffe, Gay and Greaves (1952).
16. "The Insect Book" by W.W.Froggatt (1933).

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