

Project title: Detection and Documentation of Forest Diseases in Jigme Dorji National Park in Bhutan for Forest Conservation.

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This Presentation is For Fulfilling the Part of Project Objectives.

Forest Pathology- The Basic Concept



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Overview

Part A- General Information on Forest Pathology

1. Historical background and problem statement of forest disease
2. Plant diseases and Forest Pathology
3. Introduction to Types of Forest Diseases
4. Cause of Forest Diseases
5. Identification, Isolation and Pathogenicity of Pathogens
6. Basic Principal of Forest Diseases Control

Part B- Forest Diseases in Bhutan

1. *Abies densa* and *Pinus wallachina* die back
2. Flowering mistletoe - *Arceuthobium minutissimum*, and *Taxillus kaempferi* on *Pinus*
3. Bark beetle *Ips schmutzenhoferi* on *P. spinulosa* and *P. wallichiana* and *Ips longifolia* on *P. roxburghii* out break

Historical Background

Forest pathology, like Forestry, had its origin from Europe. Beginning is epitomized by **Robert Hartig** (1839-1901), a German forester.

He is recognized as the **father of forest pathology** for pioneering the field and contributing its first text in 1874. He investigated fungus hyphae in the decay wood.

Major outbreak of plant diseases around world Example.
Agriculture plants

1. Bengal Famine-1943

- ✓ The **Bengal famine** struck the Bengal Province of pre-partition British India (present-day West Bengal, Odisha, Bihar and Bangladesh) during World War II
- ✓ Approximately 3 million people died due to famine. By fungus
- ✓ *Helminthosporium oryzae*

2. Irish Potato Famine-1845-49

- Also called **Great Potato Famine** or **Great Irish Famine**.
- Causative agent *Phytophthora infestans*.

Example of Forest Diseases

1. Shisham mortality-2000

- ✓ *Dalbergia sissoo* (Shisham) is an important tree species for production of quality timber.
- ✓ The species is eclipsed with one of the most important disease called dieback wilt caused by *Fusarium solani*

***Fusarium solani* is soil born fungi, how did it transfer?**

2. Dutch elm disease (DED)-1910

- First appeared in the north-western Europe.
- A fungal disease spread by elm bark beetles
- Second outbreak in 1960s :
- It was considered some **60 million elm trees have been lost to the disease.**
 - a) *Ophiostoma ulmi* - caused the original epidemic
 - b) *O. novo* - a new highly aggressive pathogen that caused the second epidemic



3. Chestnut blight-1990s

- Caused by the fungus *Cryphonectria parasitica* and infects American chestnut trees (*Castanea dentata*) throughout the United States and Canada in early 1900s.
- The fungus arrived from Asia (imported from Japanese chestnut trees) in the late 19th century.
- By 1913, the disease had wiped out enough trees to warrant investigation by the USDA.
By 1940, over three and a half billion trees had been lost to the disease.



Most of countries have reported numbers of potential forest diseases.

So,

What about forest in Bhutan??????????

Are they free from diseases?????????



Lets find out in Part B

Problem Statement of Forest Pathology

- ✓ The contributions of forests to the well-being of humankind are extraordinarily.
- ✓ However, in order to manage our forests wisely for the benefit of current and future generations, it is vital to have a clear understanding on forest pathology.
- ✓ They reduce tree growth, cause mortality, reduce timber productivity, change wildlife habitat, and affect watershed quality.
- ✓ Along with fire and insects, diseases are the major disturbance agents for changing forest age, density, composition, and structure on a stand or landscape level.

- ✓ In terms of mortality and growth loss, the impacts of diseases and insects on forest are far greater than those of fire or any other disturbances (Agrios, 2006).
- ✓ Forest diseases account 40% of total growth impact as compared to 20% by forest insects, 12% by fire, 8% weather induced and 6% forest animals.
- ✓ The annual volume and monetary loss attributed to diseases is weakly known and tree diseases are often chronic and pervasive and may often go unnoticed (Gyem & Chhetri, (2011)).
- ✓ According to Boyce (1948) around 10 % of total loss of forest annually is due to diseases.

- ✓ Damage will undoubtedly increase over time due to increased introduction and evolution of invasive pathogens in concert with complex environmental disturbances, such as climate change.

Even then,

- ✓ Forest diseases seldom receive more than a brief mention and many themes and researches are restricted to animals' diseases (Tatter, 1981).
- ✓ For all of these reasons, the role of forest diseases deserves a greater attention in conservation biology efforts.
- ✓ so, its is major concern for maintaining the biodiversity and conservation efforts.

But..... what is plant diseases?

Definition

Horsfall and Cowling

"The term plant disease is properly applied to **any deviation from normal** growth or structure of plants that is sufficiently pronounced and permanent to produce visible symptoms or to impair quality and economic value."

Stakman and Harrar

"Any disturbance of a plant that interferes with its normal growth and development, economic value, or aesthetic quality; a **continuously, often progressively affected condition** in contrast to injury, which results from momentary damage."

Schumann

“Any disturbance brought about by a pathogen or a consistent environmental factor which **interferes with normal** manufacture, translocation, or utilization of nutrients of plants, or Failure to reach full genetic potential due to the activities of another organism or environmental factor.”

Agrios

“A malfunctioning of host cells and tissues that results from their continuous irritation by a pathogenic agent or environmental factor and leads to the development of symptoms. Disease is a condition involving abnormal changes in the form, physiology, integrity or behavior of a plant. Such changes may result in partial impairment or death of the plant or its parts.”

Disease = Abnormality

Forest Pathology

- The word pathology means “discourse on sickness or disease”.
- Forest pathology is the study of forest diseases
- It is both a science and art within the professions of forestry and plant pathology.
- As a science it is one of many crop-oriented divisions of plant pathology that are collectively dedicated to understanding the nature of diseases in plants.
- As an art, it is a discipline in forestry serving the public interest by applying scientific principles to the prevention and control of tree diseases

Factors/Causes for Plants Diseases

- ✓ A living plant is called the host when it harbours a parasite.
- ✓ Parasite is termed pathogen when the latter is able to cause disease in host.
- ✓ Biotic factors are living factors, characterized by:
 - Scattered patterns
 - Spread or movement over time; progressive
- ✓ Abiotic causes are non-living factors
 - Generally are distributed uniformly across a plant or field and are repeated.
 - Don't spread or move with time; non progressive

Biotic Factors (Pathogens/ living organisms)

- Viruses
- Mycoplasma
- Bacteria
- Fungi -Fungi cause over 70% of the common plant diseases
- Insects -vector and pathogen
- Nematodes

Abiotic Factors (non- living environmental factors)

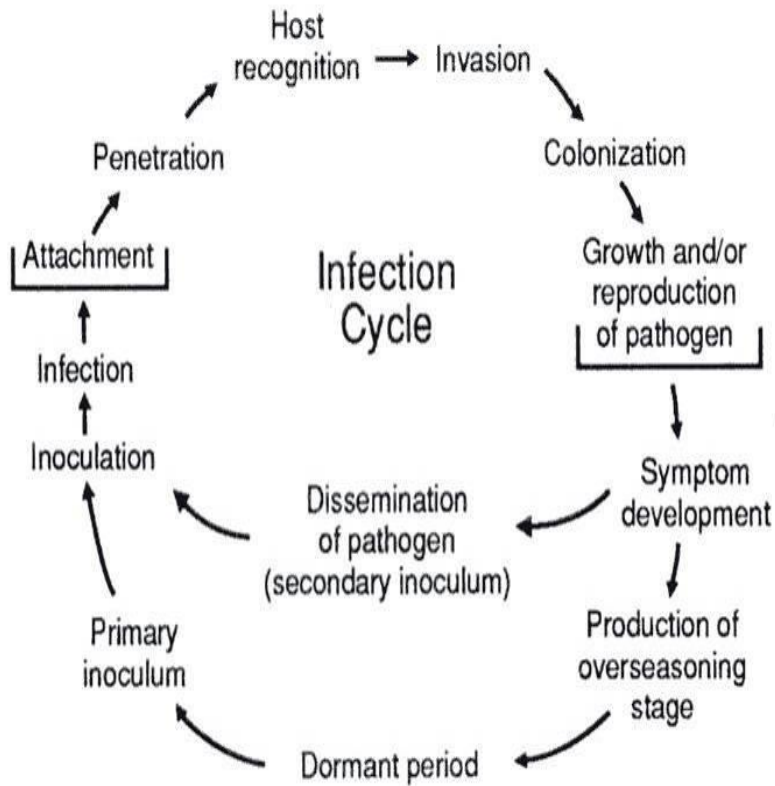
- Various mineral deficiencies and excesses and unfavourable environmental conditions
- Temperature
- Water
- Frost/ hail
- Toxic substances

Disease Triangle Concept



Disease is the result of an interaction between a host, a potential pathogen, and the environment. If any one of these factors is missing then disease will not occur.

Disease Cycle



Plant Disease Development

Disease Epidemics:

Monocyclic: completes 1 disease cycle in a year

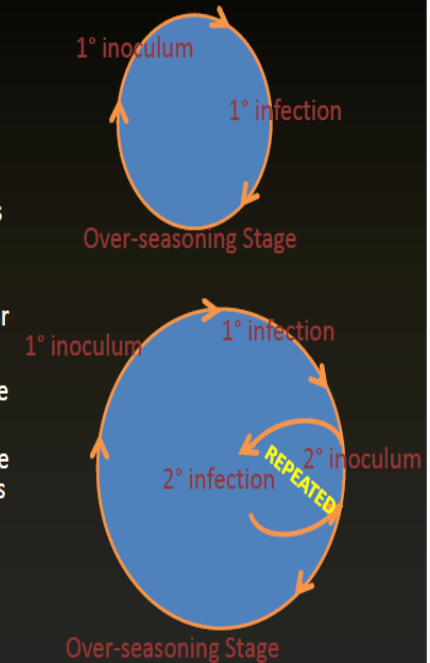
- 1° inoculum is only inoculum for entire year
- Disease increases year to year as inoculum builds

Polycyclic: 2 or more disease cycles in a year

- most pathogens
- disseminated by air, and airborne vectors
- create explosive epidemics – Late Blight, Powdery Mildew, and Rusts

Polyetic – requiring two or more years to complete lifecycle (considered monocyclic)

- typical of many vascular wilt pathogens – Dutch Elm Disease



Diagnosis of tree diseases- Symptomatology, signs, methods of identification of diseases

Diagnosis of tree Problems

Several steps must be taken in order to effectively diagnose tree problems.

The following are general guidelines:

1. Properly identify the tree. It is important to know exactly what species you are looking at.
2. It is also vital to know what the leaves, bark, trunk, and roots should look like under “normal” conditions.
3. Check for host specificity.

4. Carefully examine the types of symptoms and the part of the plant impacted.

a) Typical symptoms include: underdevelopment of tissues or organs (stunting and malformed leaves); overdevelopment of tissues or organs (galls, brooms, and stress cones); necrosis (death) of plant parts (wilting, dieback, and leaf spots); and alteration of normal appearance (chlorosis).

b) Examine how the symptoms are distributed. If the entire tree is infected, there is likely something wrong with the roots or stem, or there may be an environmental cause. Single or randomly scattered affected branches are often associated with insects or diseases.

c) Biotic agents tend to affect one species, are clumpy in distribution, show progressive symptoms, and usually impact specific plant parts. Abiotic agents tend to affect many species relatively uniformly

5. Determine the history of the tree and the site. Has the rootsystem been disturbed? Have chemicals been used? Has there been any harvesting? Other site factors, such as changing water relations, extreme temperatures, or wind, fire etc.

6. Look for signs of biotic agents such as fungal fruiting bodies parasitic plants, larvae, or adult insects.

a) Identify agents. Laboratory studies may be necessary in some circumstances

Symptoms

Symptoms are the expressions of the diseases process in the plant. When plant becomes infected, it takes time known as incubation period, for symptoms to develop.

Disease symptoms manifested by any plants parts may be classified into three types namely, **necrotic, atrophic and hypertrophic** (Boyee, 1961).

1. Necrotic symptoms

a) Wilt-Pathological wilt should be distinguished from physiological wilt which is generally a normal phenomenon. death of affected tissues.

b) Canker -Localized lesion on woody stems formed as a result of killing of bark tissue or cambium generally formed as a resulting in an open wounded exposing the wood from beneath are termed canker.

c) Decay-Decay refers to the breaking down of the tissue.

Atrophic or hypo-trophic symptoms

These symptoms appear when there is a slowing down in the development of the plant or plant parts, resulting from subnormal cell division (Hypoplasia) or from cell degeneration. The common symptoms in such cases are known as dwarfing.

Hypertrophic symptoms

Hypertrophy indicates overgrowth due to abnormal increases in the number of cells. The symptoms are distinguished by the size, form and appearance into galls and burls.

Signs- Physical presence of pathogens

a) Fruiting bodies-The diseases may manifest either as vegetative or reproductive structure of the organism causing the disease.

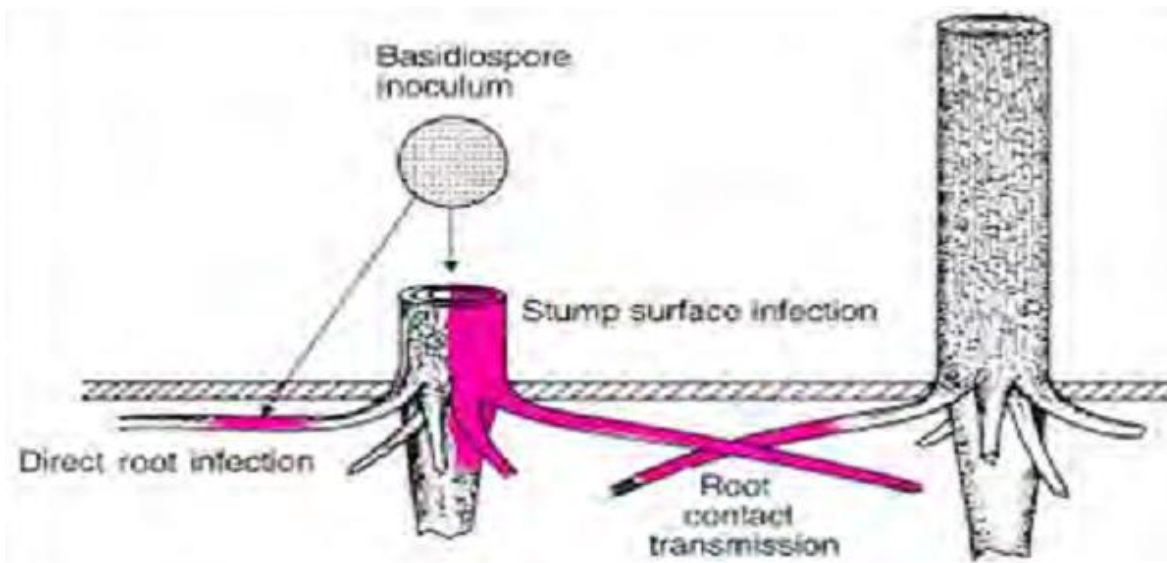
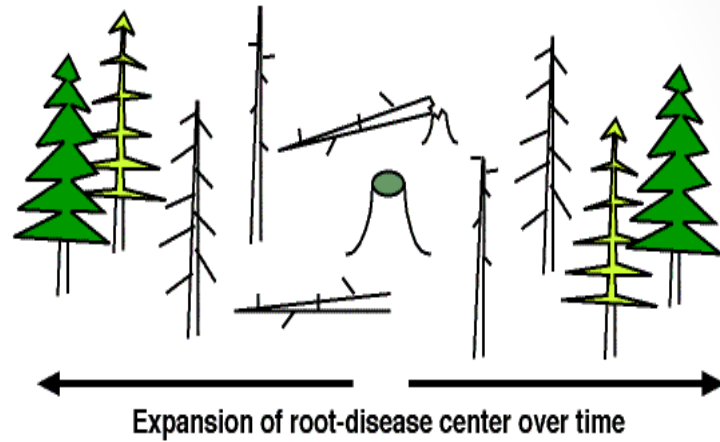
b) Epicormic branching -When tree grow under adverse condition branches usually of limited growth may develop in cluster in the main stem due to the activity of dormant or adventitious buds.

c) Exudation- Exudation may be the result of abnormal physiological process in plant

Root diseases

- ✓ Rooting system which account for about a third of the tree remains underground and hence diseases affecting the plants may continue to be unnoticed till the diseases manifest to the aerial parts.
- ✓ It is difficult for accurate diagnosis of the root diseases because symptoms on the aerial parts often resemble to the other diseases such as wilt and diebacks. Symptoms include wilting, loss of foliage or small, stunted foliage, and shoot and tip dieback.
- ✓ Root and butt rot is the one of most common forms of tree disease affecting the hardwoods. Many fungi like *Heterobasium annosum*, *Armillaria mellea*, *Ganoderma lucidum* and *Phaeolus schweinitzii* are capable of causing root and butt rots of trees. Root rots are more common on older trees or trees which have sustained root or basal injury

Root disease pathogen (*Ganoderma lucidum*) and its expansion



Canker diseases

- ✓ Cankers are localized damage to the stem, branches and cambium caused by a number of factors, including abiotic causes such as frost damage, sunscald, and wounding and by biotic agents such as fungi and bacteria (Boyce, 1948).
- ✓ Many fungi that cause cankers normally inhabit the surface of the tree, gain entrance through natural or man-made wounds, and only cause disease when the tree is under stress (Elliott, 2010)
- ✓ Cankers cause deformation of stem growth, leading to loss of wood value and creation of infection court for wood-decay fungi; and mortality.
- ✓ eg. ***Cytospora* Canker** , **back canker-*Ceratocystis populicola***



Black cankers in heavily-affected aspen stand with diamond shaped canker (Sinclair & Lyon, 2005)

Wilt diseases

- ✓ In a healthy tree, water in the soil enters roots and is transported through vessels or tracheids in the xylem to leaves.
- ✓ Wilt diseases disrupt this flow of water in the xylem, thus causing leaves to wilt.
- ✓ These diseases result from pathogen activity in the vessels or tracheids.
- ✓ Wilt pathogens are parasites that can move through the vascular tissue of trees.
- ✓ The pathogens can include fungi, nematodes, bacteria, or other micro-organisms (Tatter, 1981)
- ✓ Pathogens may directly block water flow or cause air bubbles by damaging cell walls in the vessels or tracheids that disrupt water transport. Some wilt pathogens produce toxins that damage host cells or produce enzymes or other chemicals that disrupt flow



***Verticillium* wilt disease**

Heart rot

- ✓ Heart rot is a fungal disease that causes the decay of wood at the center of the trunk and branches
- ✓ It is main disease that cause destruction to merchantable timber however, decay does not set in till the heartwood is formed and it take about 15 to 30 years depending to the species of the plants (Negi, 1996)
- ✓ Fungi are responsible for heart rot in standing trees which belong to Hymenomycetes genera and polyporaceae family. Four species are dominating which include *Hericium erinaceus*, *Pleurotus sapidus*, *Polyporus fissilis*, and *Laetiporus sulphureus*



Heart rot of *Abies densa*

Nursery diseases

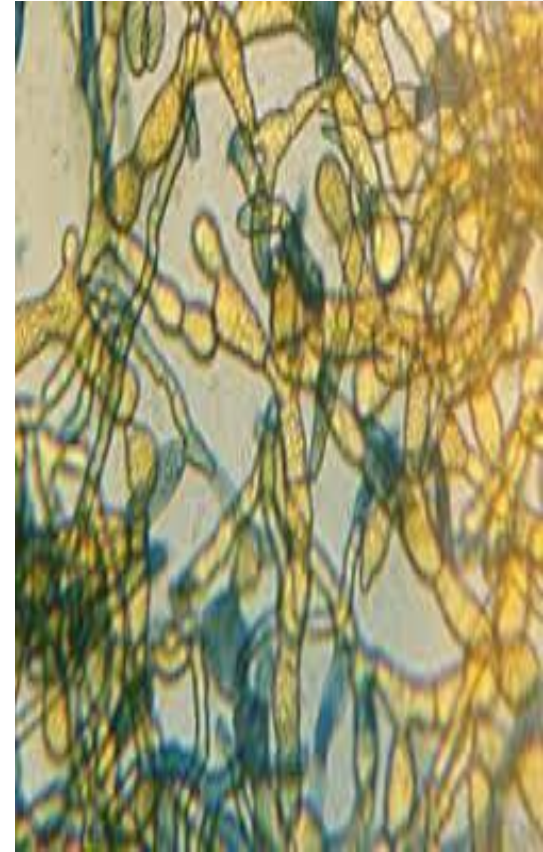
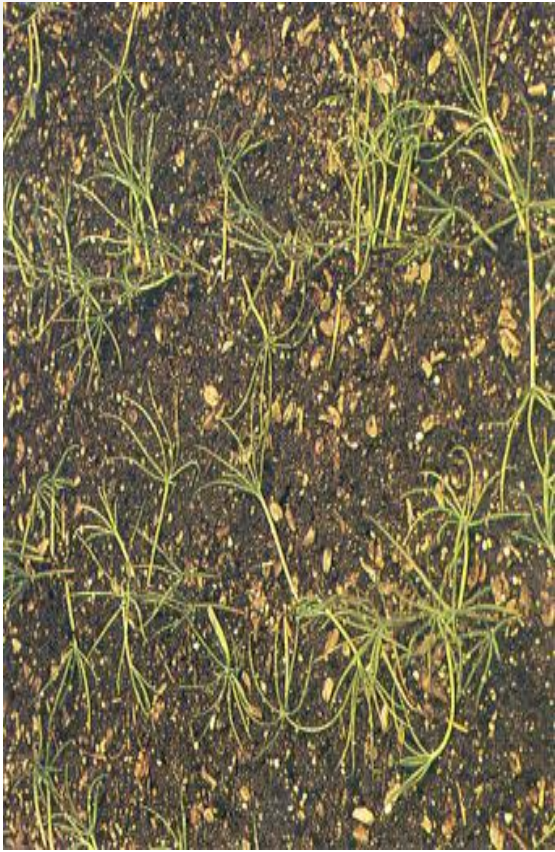
- ❖ Young seedling offer less resistant to diseases than older plants due to soft tissue and difficulty in acclimatization to environments (Negi, 1996).
- ❖ Environmental conditions like inappropriate temperature, water, nutrition and toxin chemicals within nurseries also helps in the proliferation of disease-causing pathogens such as *Rhizoctonia solani*, *Fusurim spp*, *Phytophtbora spp*. etc.

Damping Off

It is term applied to any diseases that results in the rapid decay of young succulent seedlings or other shoot diseases or fungus invasion leading to early decay and death of seedlings whose stem are still soft and succulent (Boyce, 1948).

Two types:

1. Pre-emergence damping-off- before emergence from ground.
2. Post-damping off-after emergence from ground - "Soil-infection type" or "top-infection type".



Pinus radiata seedlings suffering from post damping off caused by *Phytophthora sp*

Leaf Diseases

- Leaf diseases or “foliar” diseases of the plants are caused by number of fungi (few bacteria and viruses) which are extremely sensitive to environmental conditions (Merrill,2013).
- Higher leaves disease incidence can be expected during spring and early summer due to cool and wet prolonged periods of time.
- Leaves in lower crowns and on north sides of trees are affected more because they remain wet longer in the morning (following dew) and after rainy periods (Petritz, 2011).

1. Blotches, Blight or Anthracnose -These diseases begin as spots, but spread down the leaf veins, into the leaf's stalk (or, petiole), and into the plant's woody tissue.

2. Leaf-blister or Curls - Leaf spot or blotch that is swollen or raised, so the area appears blister-like on the upper surface of the leaf.

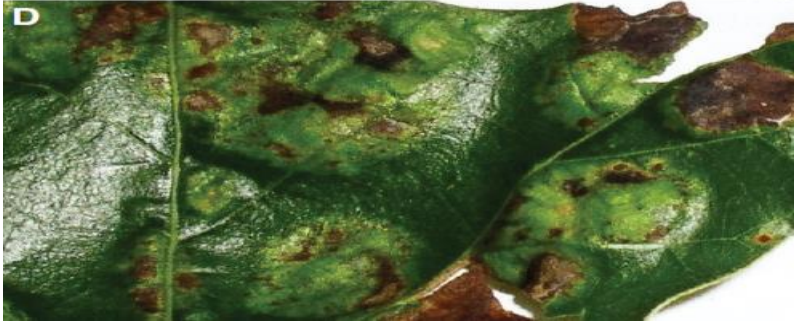
3. Scabs and Spots or Shot-hole—Loss of dead areas inside of spots that result in a series of holes in the leaf.

4. Leaf blotch—Dead area on the leaf that often diffuses into healthy tissues

5. Needle cast - Needles are often lost, or cast, prematurely.

However, there are some needle casts (for instance, on larch) where the needles are kept longer than normal.

- Needle casts have only one infection period per year.



Identification of Fungi

Two approach:

1. Morphological features of fungi for identification

- a) Hair- Velutinate, tomentose, hispid, strigose, scrupose, villose
- b) Attachment to host - Broadly attached, resupinate, effuso-reflexed.
- c) Shape of fruiting body- Triquetrous, unguulate, applanate, imbricate
- d) Pore Shape and Nos – round to angular, hexagonal, etc.
- e) Fruiting body Size-Thickness, Breadth , Length
- f) Context- thickness and colour
- g) Hyphae- colour, aseptate or septate
- h) Sterile organ-Setae , cystidia, hyphal peg

2. Fungal culture identification and authentication

After culture-Follow the identification key such as indian polyporance by B. K. Bakshi, Illustrated genera of imperfecti fungi by Burnett and Hunter, etc

Isolation of Fungi or Culture of Pathogens

Fungal culture is fundamental to the identification of many fungi.

Isolation of Fungi involves following steps:

1. Sterilization of Glassware's-soaking overnight in chromic acid and then repeatedly rinsed in running water and finished with a distilled water rinse. Another method includes -Dry Heat Sterilization in which dry heat is used for glass and other materials- 160°C- 1 hour

2. Preparation of Culture Media:

Potato dextrose agar (PDA): The composition of this media is as follows:

Potatoes	200g	}	In 1 litre of distilled water
Dextros	20g		
e Agar	20g		

3. Autoclaving: -a temperature of 121°C and a pressure of 15PSI (poundsper square inch) for a time of around 20 min.

Antibacterial Supplements: 1. Rose Bengal-Used at about 50 p.p.m. and can be added before autoclaving.2. Streptomycin sulphate: Use at about 200 p.p.m. Added to media after autoclaving.

4. Laminar flow cabinets-

Air is drawn through a HEPA (high efficiency particulate arrestance) filter and blown in a very smooth, laminar flow towards the user. Laminar flow cabinets have a UV-C germicidal lamp to sterilize the interior and contents when not in use.

5. Pouring media plates: Pour 20-25 ml of medium into the plate in lukewarm state

6. Inoculation of sample: For inoculation a minimum of forceps, alcohol, needle, blade, spirit lamp, matchbox, parafilm, marker, and cotton is required

7. Dilution plating: - for pure culture

8. Growth: The growth requirements for fungi may vary from strain to strain. Generally fungi are grown in the laboratory between the temperatures of 20 and 25°C.

Then make slide and observed the culture.

Proof of Pathogenicity

- ✓ Proof of the pathogenicity of specific biotic agents has generally been accomplished of the following set of procedures originally proposed by Robert Koch (1843-1901).

The modified procedures are as follows:

- ✓ There must be constant association of the suspected causal agent and the disease.
- ✓ The suspected causal agent must be isolated and grown in a pure culture.
- ✓ When inoculated into healthy plants, the agent that has been isolated must induce the disease.
- ✓ Re-isolation from the disease-induced plants must yield the same causal agent.
- ✓ Certain modifications of the procedures are necessary for specific types of disease agents that cannot be cultured- viruses, nematodes, mycoplasmas and some fungi.

Basic principal of Forest diseases control

- The primary objective of forestry is to grow forest free of diseases and obtain a profitable harvest (Negi, 1996). Before disease outbreak occurred control measure should be taken for forests protection.
- The principle of forest disease control is broadly discussed under direct and indirect means

1. Direct control measure

- ✓ Specifically formulated to limit or even to eradicate a particular pathogen, including temporary or emergency treatments directly against newly introduced pathogens before they become firmly establish or against existing diseases that have reached, or threaten to reach, epidemic proportions under particularly favorable circumstances

2. Sanitation-Sanitation is process that reduces or eliminates the initial inoculum from which the disease develops

3. Eradication-Heteroecious parasite require two hosts to complete their life cycles. These diseases can, therefore be controlled by eradication of one of the hosts.

4. Isolation trench-Once the root disease establish in the forest it spread rapidly from the infection center to the nearby trees by roots contract or root graft.

5. Chemical control-Chemical controls are usually expensive and have side effects. Is not very fusible in forestry but nursery diseases controlled by the chemicals methods have shown good result.

Indirect Control Measures

Such measures rely on disease prevention rather than cure and are applied over a long period of time. These includes silviculture, management practices, choice of sapling, sites selection, biological control, etc.

Integrated Pest Management (IPM) is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks.

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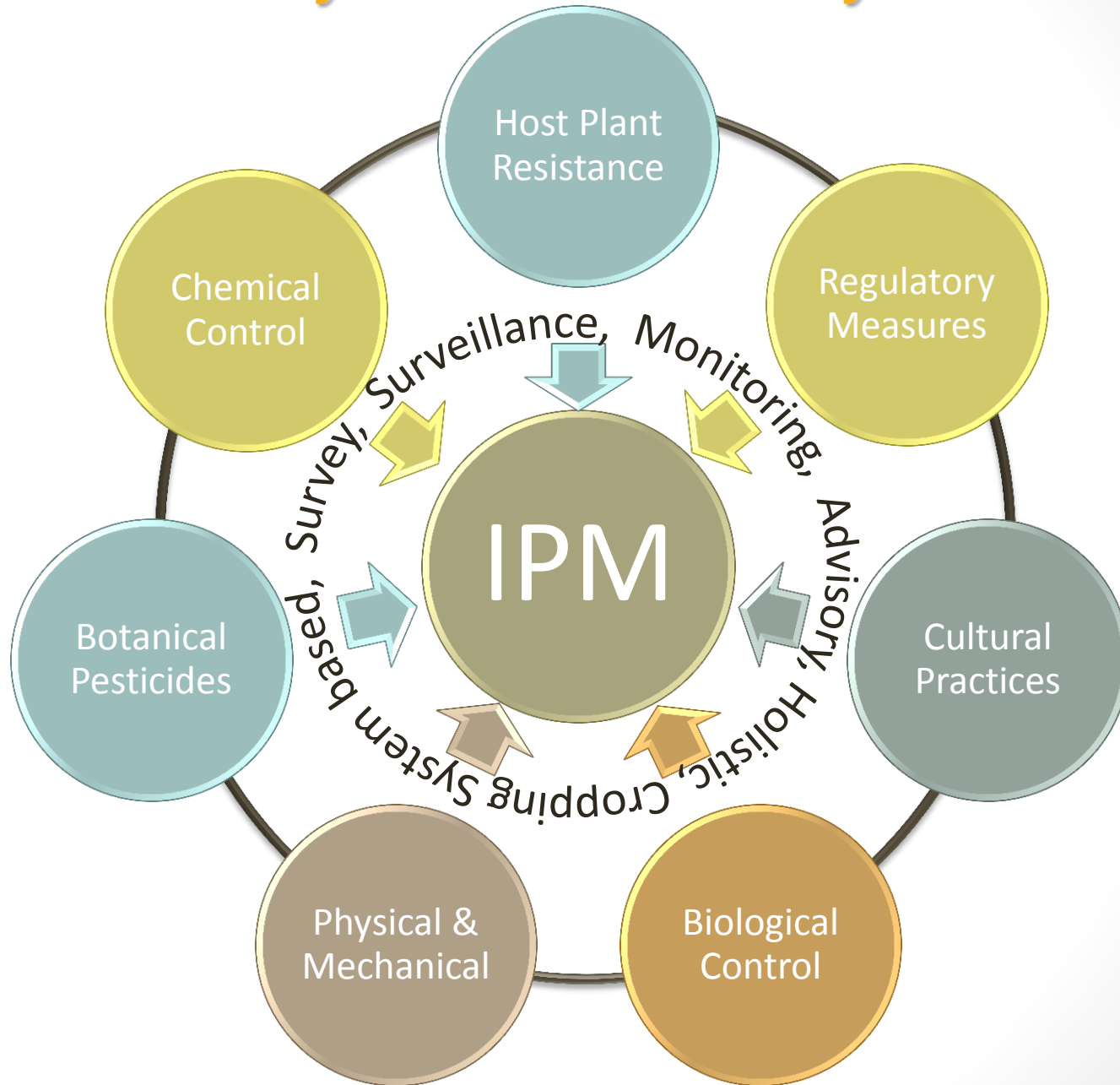
Aims of IPM

- Reduce the use of synthetic organic pesticides
- That are environmentally sound
- Minimal risk on human health
- Re-useable return on investment

Principles of IPM

- Identification of key pests and beneficial organisms
- Defining the management unit, the Agro-ecosystem
- Development of management strategy
- Establishment of Economic thresholds (loss & risks)
- Development of assessment techniques
- Evolving description of predictive pest models

IPM System and its Sub-system



Part B-Forest Diseases in Bhutan



- Bhutan have been identified as a global biodiversity hotspot and counted among the 234 globally outstanding eco-regions of the world by WWF.
- Forest has become an important theme for poverty reduction and Bhutan Government has estimated that forestry sector provides ecosystem services of \$14 Billion and sequestration 6.3 million tons of carbon dioxide annually.
- Its rich forest is in unique position, as forest conservation are primary based on Traditional Social Restriction System, Buddhist principles, Gross National Happiness (GNH) vision and less than 9% is under scientific management with huge gaps in Forest Pathology.
- Forest diseases have received a little concerned despite destroying a large area of forest due to huge lacuna of knowledge base and Forest Pathologist.
- Bhutan forest diseases is reported from 1980s but still getting reference is not a easy
- Some of major forest disease in Bhutan reported so far are;

1. Sikkim fir- *Abies densa*-Dunshing in Bhutan

- *Abies densa* occurs in Bhutan between about 3000 and 4000 m asl, is intermixed in the lower parts with spruce (*Picea spinuosa*), some larch (*Larix griffithiana*) in the higher ranges and in the understory with juniper (*Juniper recureva*) but also from single- tree species stand over large area
- The most important forest health problem of *Abies densa* is a syndrome known as fir decline or dieback.
- In the 1980s numerous stands over an extensive area in Western Bhutan were affected and at many sites a large area of trees were killed (Donaubauer, 1993).
- These dramatic fir decline was attributed to prolonged drought and frost as main inciting factors and various biotic agents (stem and root rot fungi) as predisposing and contributing factors (Kirisitis *et al.*, 2007).



Dieback of *Abies densa*

2. Blue Pine - *Pinus wallichiana*

- ❖ In Bhutan, it occurs in temperate conifer forests at elevations between 2100 and 3100 m asl (Grierson & Long, 1983).
- ❖ Blue pine is the preferred and most valuable softwood in this Himalayan country, being used for an array of purposes (Rosset, 1993).

***Pinus wallichiana* in Bhutan is affected by two main diseases:**

1. Two parasitic flowering plants, Himalayan dwarf mistletoe, *Arceuthobium minutissimum*, and the leafy mistletoe, *Taxillus kaempferi* (Donaubauer, 1993).
2. Die- back in plantation areas in Bhutan

General information on *Arceuthobium minutissimum* and *Taxillus kaempferi* in Bhutan

- ❖ *Arceuthobium minutissimum* is widespread and very damaging to blue pine forests in the Paro, Ha and Thimphu districts in Western Bhutan (Kirisitis et al., 2007).
- ❖ As is true for all dwarf mistletoes, *Arceuthobium minutissimum* is a holoparasite and infections are severe nutrition's deterrent to *P. wallichiana*.
- ❖ Pathogenic effects of this parasitic on the host include deformations, stunted growth, dwarfing, systemic witch brooms, strong reduction of diameter and height growth, impaired wood quality, reduced cone production and mortality.
- ❖ Because of its severe impact on the host tree, *A. minutissimum* is the most important pathogen of *P. wallichiana* in Bhutan

- ❖ Even where insect pests and microbial pathogens are considered, it is most probably still the most important biotic damaging factor on this conifer species in Bhutan.
- ❖ *A. minutissimum* occurred on 58%, *T. kaempferi* on 52% and both mistletoes on 30% of the of *Pinus wallichiana* in Bhutan.
- ❖ *Taxillus kaempferi* is a parasitic plant species in the genus *Taxillus* found in China ,Bhutan and Japan

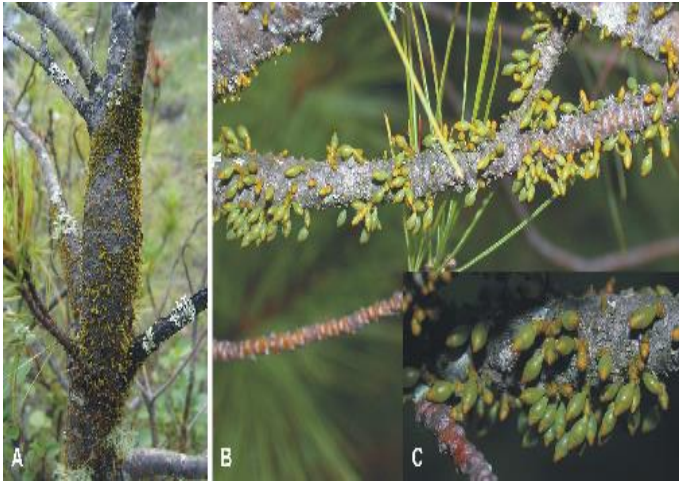


Image of *Arceuthobium minutissimum*



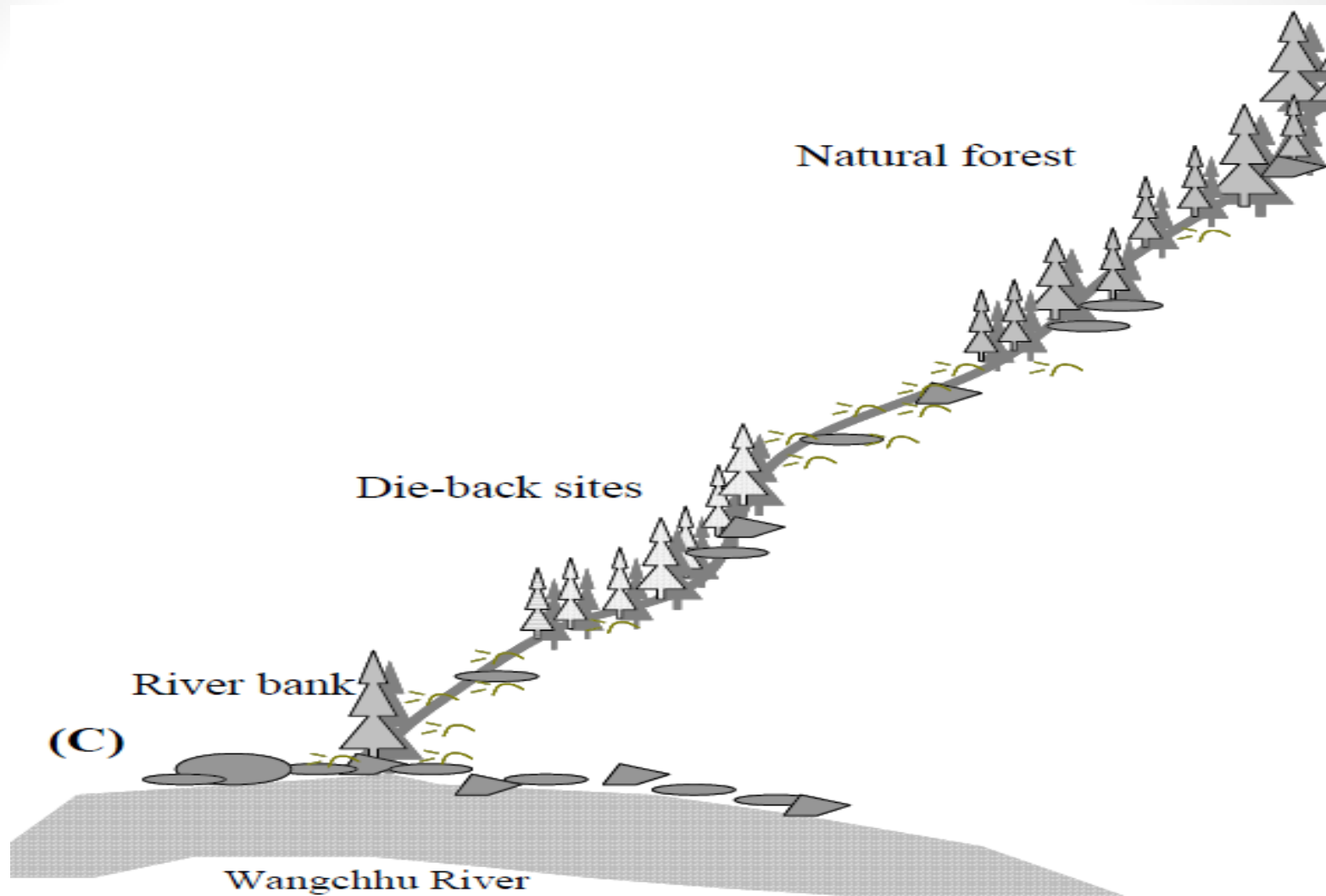
Taxillus kaempferi

Control to Mistletoe

- In heavily diseased area where most trees are infected, clear felling is the only option followed by regenerating the area.
- In case of limited infection selection felling is advisable (Bakshi, 1976).
- Pruning of infected branches and removing of tree also reduce infections.
- To check the spread of diseases, protection zone of about 20 m wide cleared area is necessary or other species are planted to keep area within effective range of seed dispersal.

Die-back of *Pinus wallichiana* plantation areas in Bhutan

- Dry barren slopes along the Pachhu-Wangchhu valley of Bhutan covering an area of 497.0ha were planted in the mid-1980s by the Department of the Forest with a total cost of Nu. 17.234 million over a period of 10 years (RNR,2009).
- The main objective of this activity was to bring back the degraded barren land into a productive forest and to reduce the soil erosion.
- Since then, periodic die-backs were observed five times in nearly one and a half decade in the plantation area particularly during the early spring months of 1994, 1999, 2001, 2003 and 2008.



Sketch of study site and die back (Yusipang Annul Report, 2009).

- ✓ Accordingly, the pine die-back problem was investigated by the visiting scientists from Japan, Europe and South Africa and found out no indication of biotic factors (disease, pest including nematodes or any outbreaks).
- ✓ Similarly, the entomological and pathological investigation conducted by Research Centre Yusipang also ruled out the biotic factors for Pachhu-Wangchhu Plantation pine die-back (RNR, 2009).
- ✓ According to studies, the die-back sites received relatively low precipitation with higher temperature contributing to the prolonged drought period.
- ✓ Several climate indices revealed that the die-back sites suffer severe water stress.

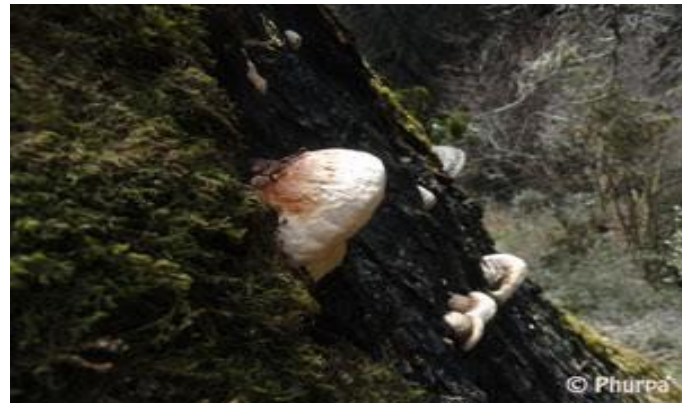
However, actual cause of dieback is not clearly known

Conclusion

- ✓ Forest diseases research is in infancy and there is a huge lacuna of knowledge base in forest pathology discipline .
- ✓ It is henceforth, imperative to enrich the current knowledge on forest diseases in this Himalayan country.
- ✓ If forest diseases is overlooked Bhutan will face difficulty in maintain 60% forest of in perpetuity as pledge by Constitution and carbon neutral commitment to UN.
- ✓ **So, what you do as forestry student?**

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Lets Protect Forest Against Diseases

Thanks. Wish you all best of luck in all endeavours