FACTORS THAT GOVERN THE SPATIAL DISTRIBUTION OF THE ROOT ROT DISEASE AT SABAH TEA

SITI FARIHAH JUAINI

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I declared that this writing is the sole work of mine except for the quotation and summary which I have explained the source of each one of them.

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SITI FARIHAH JUAINI
HS 2002-3923

EXAMINERS ACKNOWLEDGMENT

Acknowledged by:

Signature

1. **SUPERVISOR**

   (DR. ANJA GASSNER) ____________

2. **EXAMINER 1**

   (DR. KAWI BIDIN) ____________

3. **EXAMINER 2**

   (PROF MADYA DR. MIROSLAV RADOJEVIC Radojevic Miroslav

4. **DEAN**

   (PROF. MADYA DR. AMRAN AHMED) ____________

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SITI FARIHAH JUAINI
HS 2002-3923

Abstract

Root rot disease of tea trees in Sabah Tea Plantation is caused by *Poria hypolateritia* (fungus). The study site is located 20km from Ranau. A total of 7 hectares were selected as study site. These consisted of Nalapak Field 2 as first site is 4 hectares and second field is Nalapak Organic 2, 3 hectares. Both of the fields are in sloping area. The main objective of this research is to investigate the spatial distribution of the Poria disease found at Sabah Tea. Thus, in order to reach this objective, three sub-objectives are carried out which are; 1) to asses the spatial variability of root rot disease in Sabah tea by means of variograph, 2) to create a digital elevation model (DEM) for the fields under investigation, 3) to assess the role of topography for the distribution of root disease in tea. In Nalapak Field 2, 74 data of dead and 21 data for removed trees were taken. When in Nalapak Organic 2, 221 data of disease trees were taken. The samples then were analyzed by using the kriging and DEM. Besides that, hotspot analysis was used to show the density estimation of disease trees in Sabah Tea Plantation. The distribution of the disease is spatial for both fields.

Abstrak

Penyakit akar pada pokok teh di Ladang Teh Sabah adalah disebabkan oleh *Poria hypolateritia* (fungus). Kawasan kajian terletak 20km dari Ranau. Sejumlah 7 hektar tanah ladang telah dipilih untuk dijadikan sebagai kawasan kajian. Ini termasuklah Nalapak Field 2 sebagai kawasan kajian pertama seluas 4 hektar, manakala Nalapak Organic 2 seluas 3 hektar sebagai kawasan kajian kedua. Kedua-dua kawasan adalah kawasan beralun. Tujuan utama kajian ini adalah untuk menyelidik taburan secara kelompok ke atas penyakit Poria yang terdapat di ladang teh di Sabah. Dengan demikian, untuk mencapai matlamat tersebut 3 sub-objektif perlu dicapai terlebih dahulu iaitu; 1) untuk menilai taburan penyakit akar pokok teh di ladang teh menggunakan variograph, 2) untuk membuat digital elevation model (DEM) ke atas kawasan kajian, 3) untuk menilai peranan topografi ke atas taburan penyakit akar pokok teh. Di Nalapak Field 2, sebanyak 74 data pokok mati dan 21 data pokok yang telah disingkirkan telah diambil. Manakala di Nalapak Organic 2, 221 data pokok berpenyakit telah diambil. Data-data ini telah dianalisis dengan menggunakan kriging dan DEM. Selain itu, analisis hotspot digunakan untuk menunjukkan anggaran kepadatan (densiti) penyakit akar pada pokok teh di Ladang Teh Sabah. Analisis ini digunakan di kedua-dua kawasan kajian. Taburan penyakit adalah secara 'spatial' di kedua-dua kawasan kajian.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Sabah Tea Palantation is the largest single commercial tea plantation in Sabah. It has a unique location at the foothills of the Mount Kinabalu. Optimal yield production at Sabah Tea is hampered by the presence of root diseases, the most common and the critical one being the red root rot. The terrain condition of Sabah Tea Plantation is filled with slopes, so the fungus can spread easily. In accordance to it, a research is carried out to determine how the slope terrain condition influences the spreading o disease in the roots of tea trees in Sabah Tea Plantation.

Sabah Tea Plantation at Nalapak, Ranau is facing the problem from the fungus *Poria hypolateritia* since the beginning of the plantation. The fungus attacks the root of the tea trees and it is called root disease. Red root rot disease is caused by the fungus *Poria hypolateritia* (Sivapalan *et al*, 1986). Red root rot disease is red in colored when the disease attacked the tea trees. Actually, four root diseases of tea common root diseases are known. These are Red Root disease, Black Root disease, Charcoal Root disease and Brown Root disease.

Poria disease occurs in tea plantations which were originally jungle area. After clearing the jungle trees, the disease develops on left over tree stumps. The patches where diseased bushes have been removed are the places where the disease originally occurred (personal communication: Warren, 2004). In the original jungle the fungus existed as a weak parasite that has to struggle for life. When the jungle was cleared, the fungus survived as a saprophyte on the roots which served as food bases. From these, the fungus also could send out hyphae through the soil to affect other woody debris or living trees.

By changing its host from jungle trees to tea trees, the fungus could improve its living condition as tea roots are softer than jungle roots and thus easy for the fungus to penetrate. Thus, the fungus became independent of the original food base and changed to a parasitic mode of life. Today, the fungus appears to spread from tea trees to tea trees, using the infected root of one tree as a food base to attack the next tree (personal communication: Warren, 2004).

Although the red root rot disease is recognized to be the most destructive disease of tea particularly in Asia (Arulpragasam, 1992) no sustainable control of the disease has been achieved so far. Managing plant pest in a cost effective, environmentally acceptable and sustainable manner requires interventions when and where the probability of encountering the pest is high. One of the manners is by fumigation of infected areas with methyl bromide. Although, it is very effective, it is not applicable within an organic farming system. Besides that, by doing the uprooting or dig up and cleaning up of infected tea trees with one or two rows of surrounding apparently healthy trees is an alternative strategy to avoid the spreading of the disease. This strategy practiced at Sabah Tea Plantation is more environmental sound. Subsequent planting of Guatemala grass (*Tripsacum laxum*) infected areas interrupts the life cycle of *Poria* and after six to nine month the area can be replanted with tea.

1.2 OBJECTIVES

The main objective of this project is to investigate the spatial distribution of the *Poria* disease found at Sabah Tea. Thus, in order to reach this objective, three sub-objectives are carried out:

- To assess the spatial variability of root rot disease in Sabah tea by means of variography.
- To create a digital elevation model (DEM) for the fields under investigation.
- To assess the role of topography for the proliferation of root disease in tea.

CHAPTER 2

LITERATURE REVIEW

2.1 FUNGI

Fungi are small, generally microscopic, eukaryotic, spore bearing organisms that lack chlorophyll and have cell walls that contain chitin and glucons (Agrios, 1997; Parker, 2000). Fungi are saprophytic, symbiotic or parasitic eukaryote (Dommergues and Krupa, 1981; Manners, 1982). Saprophytic fungi live on dead organic matter which they decompose. The kingdom of fungi includes four phyla: Chytridiomycota, Zygomycota, Ascomycota and Basidiomycota (Alexopoulos *et al,* 1986). Basidiomycetes are the third most diverse phylum of fungi (phylum basidiomycote), including not only the mushrooms but also many important plant pathogens among the groups (Raven and Johnson, 1995). In the basidia, the spores from the meiosis are elevated, otherwise; the details of the life cycle are generally similar.

2.2 What is *Poria*?

Poria is one of the species in *Aphyllophorales* group of Basidiomycota. A general feature for these fungi is that they have a filamentous vegetative body called mycelium (Agrios, 1997). The special features of *Aphyllophorales* is, the basidia is build without cross walls and produces only hymenia-forming hyphae and lining the surface of small pores and tubes. In some fungi the mycelium consists of many cells and others have cross walls (septa). In this order, many species produce conspicuous basidiocorps that can be seen even from a distance (Alexopoulos *et al*, 1996). Besides that, the fungi have a tissue directly supporting the hymenia. Meanwhile, the hymenium is exposed while the spores are still immature, but not to angioscorps basidiocorps that produced by gasteroid form in which the fertile layer is enclosed by the basidiocorps until the spores are matured.

Many *Aphyllophorales* species decay, like *Poria*, wood of trees that already is dead but some of the species are specialized to enter woods in living trees and to make their way to the heartwood (Fisher & Binkley, 1999). The process of wood decay by microorganisms is depending on the decay organism, the plant species and the microhabitat within the substrate. Decay fungi will remove the cell wall components – lignin, hemicellulose and cellulose. Besides that, the chemistry of lignin and cellulose degradation is complex (Alexopoulos *et al*, 1996).

2.3 Root rot disease

Poria disease is an infectious disease. It means that is caused by agents that are capable of being transmitted from a diseased plant to a healthy plant and of causing disease in latter when the environment is favorable (Kenaga, 1974). Fungi are one of the infectious disease agents besides bacteria, viruses, nematodes and parasitic plants. A specialized environment is often necessary to 'condition' the plant, causing it to become susceptible to the agent (Kenaga, 1974). So, the fungus *Poria* need a suitable condition to get the food and to survive which means to spread the disease.

By knowing and understanding the behaviour of a disease the grower can predict and control the disease. People expect the plant own ills to be cured but actually they cannot be cured. Five distinct phases can help the development of a disease (Parker, 2000). The first phase is inoculation. This process is the introduction of the pathogen to the host plant tissue. Many factors can help the distribution of the pathogen. The second phase is the incubation process a period development when the pathogen changes to a form that can penetrate or infect the new host plant. Thirdly, the process getting inside the plant is called penetration. When the pathogen interrupts the plant tissue and builds a parasitic relationship between itself and the host, infection has occurred. A disease exists when the host plant responds to the presence of the pathogen. The host can show the symptoms of the disease such as chlorosis or necrosis and so on.

2.3.1 The factors of the spatial distribution of the root rot disease at Sabah Tea

Forest pathology inherently involves a landscape perspective, because tree pathogens propagate according to heterogeneous spatial patterns of flow and isolation (Holdenrieder *et al*, 2004). Because of the tree pathogens such as bacteria and fungus, the landscape ecologist and the forest pathologist have to find a way to avoid the fungus become more spread out. The fungus distributes the disease and attacks the tea root in imperceptibly. After survival, the pathogen has to transfer from the source of its survival to the active cultivated host plant. It is important to spread of plant disease and to continue the life-cycle and evolution of pathogen. All infectious diseases are transmissible which they are carried by various methods from the diseased plant to the healthy plant. In general, diseases are dispersed by movement of seed or the seed-borne pathogens, soil-borne pathogens through the movement of soil and through root contacts and wind-borne for those surviving on wild host in active stage (Singh, 1975).

However, a combination of mechanisms aided by external physical and biological forces are operate in disperse the pathogens. For example, the movement of propagules through the wind is common in even soil and seed-borne pathogens. The same pathogens may be carried by soil and its transport may be aided by water.

The factors of the spatial distribution of the disease are divided by two categories: direct (active dispersal) and indirect (passive dispersal) (Singh, 1975).

- **Direct (active dispersal)**

Dispersal of bacteria, fungus, viruses, nematodes and other insects is accomplished through the agency of soil, seed and plant organs during normal agronomic operations. In this type of dispersal, there is no major role of external agencies like wind and water. In this part, just soil-borne will be discussed.

Pathogens may survive through soil especially for soil-borne facultative saprophyte (*Poria*). The dispersal of pathogens may be by movement in the soil or it growth in soil under suitable condition or may be by movement of the soil containing the pathogens. Only fungi can grow to new sites from the sites of survival or activity in soil. But, in absence of the host, the soil environment is highly inimical to active survival.

Dispersal in the soil can be divided to three stages:

i. Contamination of soil: the soil receives the pathogen by contaminated soil or plant debris (Stevens, 1974; Singh, 1975).

ii. Growth and spread of the pathogen in the soil: once the pathogen has reached the soil it can grow and spread depending on several factors. One of the factors is specific characters of pathogen. The pathogen has to have the adaptability to soil environment including the survival ability. Survival ability means the pathogen has compete to each other to live in soil. Thus, specialized facultative parasites, unspecialized facultative parasites and obligate parasites can be pathogen in soil according to the basis of the competitive survival ability (Garrett, 1970; Tarr, 1972; Singh, 1975; Manners, 1982). The unspecialized facultative parasites can pass their life in soil. Specialized facultative parasites or saprophyte can pass their life n soil in absence of the host depends on the residue of their host plant. Obligate parasites such as nematodes need the active host for activity of this category (Kenaga, 1974).

iii. Persistence of the pathogen: the pathogen has to have survival ability to live with others.

The three stages above help a pathogen to enter the soil and grow or spread in the soil. However, the pathogen also can spread out by the soil. The dispersal by soil occurs during the cultural operation in a field. The movement of soil from one point to another within the field through agricultural implements, workers feet, and erosion and plantation equipments. This type of dispersal is highly erratic.

Decomposed plant and animal material add the makeup of soil and healthy soil is critical to the success of agricultural. Soils are different as they form from different parent materials in different environment. Five factors control soil formation which is parent material, time, climate, vegetation and topography (Parker, 2000).

Parent material refers to the rock in which the soil formed. The soil is formed by weathering. Weathering is the change from original material to new material through the action of natural forces. It may be physical weathering which are by water, wind, plant roots, ice or gravity or by the chemical weathering by reactions with other substances in the suitable condition environment (Castriganò *et al*, 2000). For example, rain is slightly acid and these acids can dissolve soil minerals. Besides that, weathering is a slow process that can be cause of the time loss to form the soil. More rainfall means more water passing through the soil and more weathering. Vegetation, it will affect the amount of organic matter added to the soil. The last factor is topography. This factor is very important for the soil because it affects the amount of water passing through the soil. Topography means the slope and the position of the land (Parker, 2000).

Pathogens may survive through the soil (Singh, 1975). *Poria* needs suitable soil moisture to survive and multiply. Commonly, high soil moisture levels will favor the development of diseases (Stevens, 1974). The dispersal of infectious plant disease might be from the movement of the pathogen in the soil, the growth in soil under suitable conditions or might be by movement of soil particle containing the pathogen. Among the various plant pathogens, only nematodes larvae are capable of actively move through soil pore spaces and reach the host to cause infection. Roots supply water and nutrients to the plant. They have a significant influence on soil development (Fisher & Binkley, 1999; Lancellota, 1993). The growth and distribution of roots are influenced by essentially the same environment factors that affect growth of the tree. All the factors including the chemical, physical and biological properties of the soil, light intensity, air temperature and wind also effect root growth (Fisher & Binkley, 1999). The soil factor is important to healthy tree growth. If the soil is having the fungi, the roots will absorb water that containing the fungi and tree will be infectious by *Poria*.

According to Warren (2004), the original tea in Sabah was planted on land that had been cleared from forest and burned, yielding soils rich in humus and nitrogen. The fungus *Poria* is kept in stumps. The soil at Sabah Tea Plantation is very suitable to the life cycle of *Poria* then the fungus spread out to get the food.

- **Indirect (passive dispersal)**

The passive dispersal of plant pathogens is accomplished through the agency of air, water, man, nematodes, farm and wild animals and birds. However, in this part, air, water, man and nematodes will be discussed (Singh, 1975).

Water

In addition to man, an other agent is water. Water provides for only short distance dispersal of plant pathogens. Water flow (rain water) from infectious plant to neighbouring plants may carry with it fungal propagules and attack to the healthy plants or the field. One of the method by which rain spreads plant pathogens is splash dispersal. Soil surface may splash the propagules in small droplets when rain drops falling with force and it enable the to land on healthy plant susceptible surfaces or the water droplets may be carried to long distance by air (Lancellota, 1993; Singh, 1975). Water has other roles to play in dissemination of spores of fungi. When spores are present in atmosphere rain water wets them and brings them down by trapping them. For growth and spore discharge of many fungi moisture is an essential pre-requisite. This helps liberation of spores into air currents which carry them to long distance (Singh, 1975). Otherwise, the terrain is often sloping, which aids surface drainage but may increase erosion. The dispersal of the pathogens may increase (Wrigley, 1988).

Wind

Unlike soil and water, air is not a habitat for any kind of pathogen. It acts only as a carrier of propagules of organisms. For dispersal by wind, the fungus must have certain characters adapted to conditions in the air. One of the characters is fungal spores must be able to cross the laminar airflow boundary near the surface of the host (Singh, 1975). Insects are one of the factors influenced by wind. Small insects are dependent on air currents to carry them to new sites because there are passive lies. In this situation, distribution patterns, wind-flow pattern is important (Byrne *et al*, 1995

Dispersal can be divided into three groups: spore removal, dispersal and deposition. Biology and physical process can influence the dispersal fungal spores. Biology process means how the spores are released and the main mode of dispersal which are wind or rain. Physical factors such as wind, rain and temperature can influence the manner of spore release and the mode of dispersal.

Wind plays an important role for root rotting disease. Spores can be removed from their host by being blown and by active release mechanism (Horsfall & Cowling, 1980). Active release mechanisms are many and diverse and have been described by Blakeman and Williamson, (1994). Active release means the host ejects spores into the air. Furthermore, to be removed by blown or shaken from their host, the mechanical forces acting on the spore must strong to hold spore to the surface (Campbell and Madden, 1990). Meanwhile, the strength of spore attachment or the wind speeds needed to remove spores can be relatively large. In sloping area, airflow sometimes become gusts and it is responsible for removing spores and other biological particles such as stumps.

Besides that, by wind influence, spore will be dispersing. The potential for dispersal by wind depends on speed and turbulence. The turbulent nature of wind causes spores to travel different distances and in different path, even if it is released from the same source under the same wind condition. Therefore, the concentration of spores in the air and the number of deposited are important for the wind factor. It can decrease downwind of the release point. Gradient of wind-dispersal particles can range in some distance depend on wind particles size of spores, position and size of source (Whitney, 1976). Winds disperse spores from the source and transport them

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