

Protection against South American leaf blight of rubber in Asia and the Pacific region

Volume II



**Protection against
South American leaf blight of rubber
in Asia and the Pacific region**

Volume II

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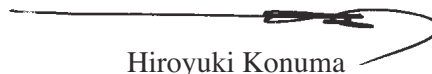
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FOREWORD

South American leaf blight (SALB) is a fungal disease of rubber trees and poses a major threat to the region. Prevention of the introduction of SALB is of major concern to member countries of the Asia and Pacific Plant Protection Commission (APPPC) and is one of the priority areas in the work plan of the APPPC. FAO has provided technical support to the initiatives of the APPPC over the past years with remarkable success.

The development of a training programme and publication of reference materials were identified for follow-up action by the APPPC working group on SALB. Accordingly, the APPPC organized a regional workshop for development of a training programme and production of reference materials for protection against SALB in 2011. The reference materials include promotional materials to raise awareness of the dangers posed by the introduction of SALB in the region. They include a pamphlet, a booklet, posters, banners and PowerPoint presentations for training sessions for various audiences including the general public, extension and quarantine officers, pathologists and technical officers. The workshop also prepared operational guidelines and training modules for prevention of the introduction of SALB in the region. The main objective of the operational guidelines is to facilitate establishment of an effective procedure for the importation of planting materials by reducing the potential risk of the entry and spread of SALB in Asia and the Pacific region. The operational guidelines will be used by National Plant Protection Organizations (plant quarantine officers, plant quarantine inspectors, plant pathologists and other related personnel) in APPPC rubber growing countries to deal effectively with the importation of rubber planting materials from SALB endemic countries.

It is expected that rubber producing countries in the region will be able to frequently use the reference materials contained in this publication to enhance the capacity and capability of each country's readiness in detecting, preventing and managing the introduction of SALB. Translation of this publication, or selected parts, is encouraged to maximize the potential benefits for countries in the region.



Hiroyuki Konuma
Assistant Director-General and
Regional Representative for Asia and the Pacific

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INTRODUCTION

South American leaf blight (SALB) is a fungal disease of rubber trees and poses a major threat to the region. Prevention of the introduction of SALB is of major concern to member countries of the Asia and Pacific Plant Protection Commission (APPPC) and is one of the priority areas in the work plan of the APPPC. FAO has provided technical support to the initiatives of the APPPC cover the past years with remarkable success. One such output was publication of the first volume in this series – RAP publication 2011/07: *Protection against South American leaf blight of rubber in Asia and the Pacific region*. The publication was prepared as a set of reference materials to improve phytosanitary measures and safeguard against the incursion of South American leaf blight of rubber into countries in the region and prepared the ground for further progress. It contained four reference books, as follows:

Book 1. Pest risk analysis for South American leaf blight (SALB) of rubber (*Hevea*)

Book 2. APPPC RSPM No. 7: Guidelines for the protection against South American leaf blight of rubber

Book 3. Work plan for the importation of budded stumps of budwood of *Hevea spp*

Book 4. Contingency plan for South American leaf blight (*Microcyclus ulei*)

As follow-up by the APPPC working group on SALB, a regional workshop was organized in 2011 for development of a training programme and production of reference materials for protection against SALB in the Asia-Pacific region, contained in this second volume. It includes reference materials, a training programme and operational guidelines, as follows:

Section 1. Reference materials

Section 1.1. Leaflet

A leaflet on SALB was prepared for the general public to increase awareness about the danger of the disease and the responsibilities of the public to protect their countries from incursion of the disease. It is a 1-page leaflet that contains pictures of SALB symptoms on young and mature leaves, shoot and rubber field infected and general information of SALB.

Section 1.2. Pamphlet

The pamphlet on SALB is targeted for extension and quarantine officers. The contents include introduction of the disease, pathogen, host range, symptoms and life cycle, distribution and spread, damage, management and the threat of SALB.

The pamphlet consists of information with design, detailed information and pictures on planting material.

Section 1.3. Booklet

A booklet on SALB was produced to be used as training material for pathologists and technical officers. The contents include detailed information on distribution, symptoms, the pathogen (*Microcyclus ulei*), disease spread and infection, economic importance, disease control, disease management, conclusions and references.

Section 1.4. PowerPoint presentations

Power point presentations. Seven topics were prepared as examples to be used for in-training materials for in-country trainings:

- i) Diseases of *Hevea* rubber
- ii) The distribution and importance of South American Leaf Blight (SALB)
- iii) South American Leaf Blight (SALB): The causal pathogen and the disease
- iv) The epidemiology and host parasite interaction of SALB

- v) Management of South American Leaf Blight (SALB)
- vi) Quarantine measures against South American Leaf Blight (SALB)

Section 1.5. Banner and poster

Banner and poster for general public awareness.

Section 1.6. Bibliography

Bibliography consisting of 336 abstracts from relevant materials relating to SALB.

Section 2. Training programme for protection against South American leaf blight of rubber in Asia and the Pacific region

The purpose of the training programme was to build capacity to ensure the availability of competent and knowledgeable personnel to implement the various phytosanitary measures in relation to SALB. The training programme consists of lectures, demonstrations and laboratory sessions. The programme is divided into four modules. Module 1 is on the biology of the host plant, the biology and economics of SALB and *M. ulei* and other diseases of the rubber plant. Module 2 covers information on SALB and quarantine measures to reduce the risks of the introduction of SALB. Module 3 covers measures to eradicate the outbreak of SALB. Participants of the training programme would include plant quarantine officers, plant pathologists, crop protection officers, extension officers, and quarantine officers at entry points, technical/diagnostic officers, laboratory technicians and officers from other relevant agencies.

Module 4 consists of the proposed programme for the workshop on SALB convened in Brazil. The objectives of the workshop were to provide hands-on training on the diagnostics of SALB so that the participants would be able to recognize and identify SALB symptoms and its pathogen. Upon their return, participants were expected to train other officers in their country and the region in a training of trainers programme. The training programme consists of lectures, laboratory sessions and field visits. It was proposed that NPPO of Brazil assist in the organization of the workshop including arranging for field visits to fruit farms.

Section 3. Operational guidelines for importation of *Hevea* plants for planting to protect against South American leaf blight

The purpose of the Operational Guidelines is to establish an effective quarantine procedure relating to the importation of planting materials. The main objective of the operational guidelines is to reduce the risk of entry and spread of SALB into the Asia and the Pacific region. These operational guidelines will be used by National Plant Protection Organizations (Plant Quarantine officers, Plant Quarantine inspectors, plant pathologists) and other related personnel in the APPPC rubber growing countries to deal with the importation of rubber planting materials from SALB endemic countries. The contents of the guidelines include the scope, references, glossary, definitions, flow chart of work plan, legal authority, management responsibility, resources, quarantine procedures, document management and record control and training.

It is expected that this publication will contribute to a more coordinated regional effort in preventing the incursion of SALB, that would be detrimental to the economies of many rubber growing countries in the region, through training approaches and public awareness movements in member countries.

It is recommended to create public awareness initiatives in member countries for the prevention of the introduction of SALB. The activities may include:

- Distribution of leaflets, posters and pamphlets on SALB
- Organization of public lectures/seminars
- Broadcast of relevant articles on SALB in appropriate media – newspapers, magazines, radio, television, websites
- Establish a National SALB committee to carry out activities including awareness/training programmes, surveillance, control measures and other related activities
- Distribute videos on SALB

The background of the page is a light green, semi-transparent image of bare tree branches, likely from a flowering tree like a cherry blossom, with many thin, dark lines crisscrossing the frame.

SECTION 1

REFERENCE MATERIALS

Section 1.1. Leaflet

SOUTH AMERICAN LEAF BLIGHT

.....A DEADLY DISEASE OF RUBBER!

Introduction

Natural rubber is a valuable raw material used in more than 400 000 products for transportation, health care, household items, toys, etc. The rubber industry is economically important in many countries in Asia and Africa as the industry provides valuable export earnings and employment. The Asian rubber growing countries produce more than 90 percent of the world's natural rubber. In most countries, rubber is cultivated mainly by millions of small farmers. The rubber tree is also an important source of renewable timber that also contributes to the environment. This important industry is under threat from a deadly disease known as South American leaf blight (SALB) which is hindering the development of natural rubber growing industry in its region of origin (South America). At present, the disease is confined to South and Central America.



South American leaf blight (SALB)

SALB is a leaf disease of rubber plant caused by a fungus called *Microcyclus ulei*. SALB can be recognized by its symptoms on young and mature leaves. The young leaves are deformed and numerous dark irregular lesions are present on the lower leaf surface. On mature leaves, prominent raised black bodies resembling warts occur on the upper leaf surface.

This disease will result in leaf defoliation, reduction in growth and yield and even death of infected plant. The fungus produced abundant spores on young and mature leaves. The spores which remained alive for sometimes are responsible for spreading the disease. The disease can be spread through movement of infected materials and contamination of travelers and their belongings.

Our responsibility to prevent the spread of SALB

We can prevent the spread of this disease by taking appropriate precautionary measures:

1. Travelers who visited a rubber farm in Central and South America should take precautions to rid themselves and their belongings of living spores (taking bath and washing used clothing in transit countries)
2. Travelers should not bring home any parts of the rubber plants especially green leaves
3. Rubber planters should be vigilant of SALB and should contact relevant authorities e.g. Department of Agriculture or Rubber Research Institutes if SALB is suspected

Section 1.2. Pamphlet

Design

SOUTH AMERICAN LEAF BLIGHT (SALB) OF RUBBER

1. INTRODUCTION

South American leaf blight (SALB) is the most serious disease of the rubber tree due to its devastating effects. Historically, SALB had destroyed several rubber plantations established in the 1930s in Central and South America. The Asian rubber growing countries that produce more than 90 percent of the world's natural rubber are very concern of the threat of SALB. This is because the climatic conditions in the major rubber producing countries are conducive to serious SALB infection.

2. THE PATHOGEN

South American leaf blight is caused by the fungus that is called *Microcyclus ulei*. It produces three types of spores i.e. conidia, pycnospores and ascospores.



3. HOST RANGE

M. ulei infects only *Hevea* species. There are 11 *Hevea* species but *M. ulei* infects only five species (*H. brasiliensis*, *H. spruceana*, *H. guianensis*, *H. benthamiana*, *H. camporum*).

4. SYMPTOMS

The fungus only infects young plant part



The first signs of infections are deformation of young leaflets; eventually severely infected leaflets shrivel and turn blackish.



The leaf tissues at the centre of the lesions become necrotic and turn papery white and later tear off leaving shot-holes in the leaf.



Severely infected leaflets defoliate, the petioles remain intact on the branches for sometimes, but they eventually drop-off.



Infection of the stem may cause tip die-back. The severely infected trees will have poor canopy with dead branches.

***M. ulmi** also infects leaf petioles, young stems, inflorescences, flowers and young fruit.*



DISEASE MANAGEMENT

Application of fungicides is a popular strategy to control SALB.

Many older fungicides (chlorothalonil, propineb, mancozeb, benomyl) and newer systemic fungicides (triadimephon, thiophanate methyl, prochloraz, propiconazole, triadimenol and azoxystrobin) are effective.

These fungicides are applied by aerial or ground mistblowing.



Persistent use of a systemic fungicide may induce fungicide resistant strain.

In the past, so called ‘resistant clones’ are severely infected when a new race of *M. ulei* occurs.

THREAT OF SALB TO ASIA AND THE PACIFIC REGION

Several diseases for example potato late blight, coffee rust and Dutch elm’s disease had crossed oceans and established themselves in new areas. The spread was attributed to either through wind-borne spores or importation of infected plant materials. Hence, SALB is a threat to Asia and the Pacific region due to increase of communication between SALB endemic countries and the rubber growing countries in the region. It is predicted that rubber in South East Asia will be destroyed within 5 to 7 years of SALB introduction due to the contiguous growing pattern, conducive environment and susceptible clones.

Information

SOUTH AMERICAN LEAF BLIGHT OF RUBBER

1. INTRODUCTION

South American leaf blight (SALB) is the most serious disease of the rubber tree due to its devastating effects. Historically, SALB had destroyed several rubber plantations established in the 1930s in Central and South America. Until today, it is the most important factor limiting a vibrant rubber planting industry in tropical Central and South America where the disease is endemic. The Asian rubber growing countries that produce more than 90 percent of the world's natural rubber are very concern of the threat of SALB. This is because the climatic conditions in the major rubber producing countries are conducive to serious SALB infection.



2. THE PATHOGEN

South American leaf blight is caused by the fungus that is called *Microcyclus ulei*. It produces three types of spores i.e. conidia, pycnosporos and ascospores. (Figures 1, 2 and 3).

Figure 1. Conidia



Figure 2. Pycnosporos



Figure 3. Ascospores



3. HOST RANGE

M. ulei infects only *Hevea* species. There are 11 *Hevea* species but *M. ulei* infects only five species (*H. brasiliensis*, *H. spruceana*, *H. guianensis*, *H. benthamiana*, *H. camporum*). It does not infect any other plant. On *Hevea* rubber, *M. ulei* infects the young aerial part of the plant. Infection is most common on young leaves; however leaf petioles, young stems, inflorescences, flowers and young fruit are also infected.

4. SYMPTOMS AND LIFE CYCLE

The fungus only infects young plant parts. Shortly after infection of young rubber leaflets, the first visible symptom is the distortion in shape of the leaflets. A few days later, irregular-shaped disease lesions developed on the undersurface of the young brown colored leaflets. Then, the lesions produce abundant conidia and appear dark to olive green in colour (Figure 4). Heavily infected susceptible leaflets shrivel, turn black and drop off. The petioles remain on the stem for several more days before they also drop off. The size of lesions and the amount of conidia produced are influenced by the age of leaflets, the susceptibility of the clones and the prevailing weather conditions. The characteristic lesions with abundant conidia are visible on young green leaves remaining on the plant (Figure 5). About two to three weeks after infection started, the leaf tissues on the upper surface of leaf immediately above the disease lesions on the lower leaf surface turn yellowish and later small round black raised structures are formed (Figure 6). Several weeks later, the round dark raised structures enlarge and form another dark colored raised bodies especially around the edges of the disease lesions (Figure 7). As the leaf ages, the leaf tissues at the centre of the lesions become necrotic and turn papery white and later tear off leaving shot-holes in the leaf. *M. ulei* also infects the inflorescence, petiole, stem and fruits (Figure 8). Infection of the stem may cause tip die-back (Figure 9). The severely infected trees will have poor canopy with dead branches (Figure 10).

Figure 4.



Figure 5.



Figure 6.

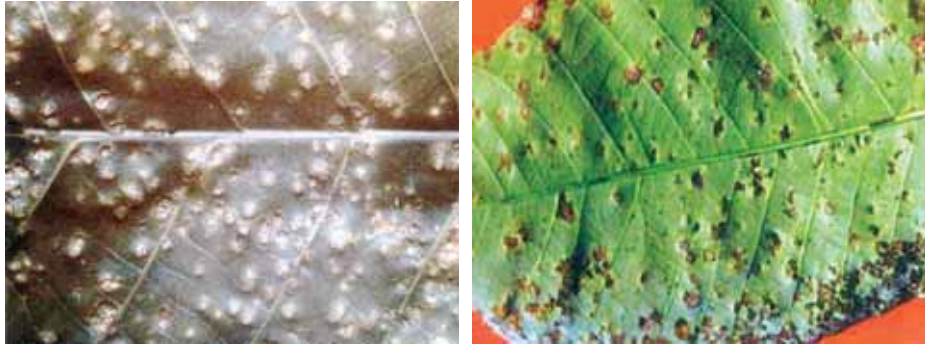


Figure 7.

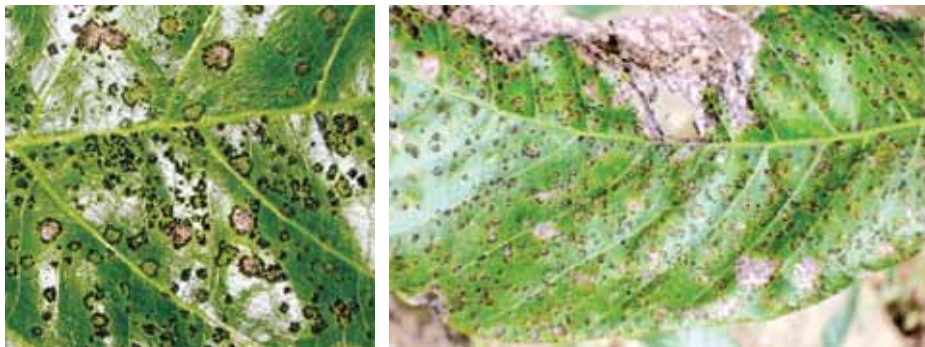


Figure 8.



Figure 9.



Figure 10.



5. DISTRIBUTION

In early 1900s, the disease was detected on wild rubber plants in the Amazon jungle. Later, SALB spread to newly established rubber plantings, notably at Fordlandia and Belterra in Brazil. Currently, SALB is confined to South and Central American countries i.e. Mexico, Guatemala, Panama, Honduras, Belize, Costa Rica, Nicaragua, Trinidad and Tobago, Haiti, Dominican Republic, Guyana, French Guiana, Surinam, Venezuela, Colombia, Peru, St Lucia, Ecuador, Bolivia, El Salvador, Paraguay and Brazil. SALB is serious in areas with high annual rainfall (about 2 500 mm) with long period of high humidity (>80 percent R.H.) with no distinct dry period for several months.

6. DAMAGE

The economic destruction of the disease has been shown during the early attempts to establish rubber plantations in Brazil in 1930s and 1940s. The Ford Motor Co. rubber plantation established at Fordlandia, Brazil in 1928 was abandoned in 1933. Similar fate happened to the plantation established at Belterra in 1934 that was abandoned in 1942. These plantations were destroyed by SALB within seven years. Until today, SALB is the cause hindering expansion of commercial rubber cultivation in the Americas.



Trees infected with SALB

The disease reduces the plant growth and lengthens the immaturity period. It also reduces latex yield. The yield loss couple with the extra management costs and agronomic inputs required reduces the economic viability of rubber cultivation. Prolonged infection of SALB may also kill rubber plants.

7. DISEASE MANAGEMENT

Application of fungicides is a popular strategy to control SALB. Many older fungicides (chlorothalonil, propineb, mancozeb, benomyl) and newer systemic fungicides (triadimephon, thiophanate methyl, prochloraz, propiconazole, triadimenol and azoxystrobin) are effective. These fungicides are applied by aerial or ground mistblowing. Persistent use of a systemic fungicide may induce fungicide resistant strain. The cost of treatment may be economically prohibitive especially when the price of rubber is low.

Planting of resistant clone is the most suitable strategy to manage SALB. Unfortunately, high yielding clones resistant to all races of *M. ulei* are very limited. In the past, so called 'resistant clones' are severely infected when a new race of *M. ulei* occurs.

8. THREAT OF SALB TO ASIA AND PACIFIC REGION

Several diseases for example potato late blight, coffee rust and Dutch elm's disease had crossed oceans and established themselves in new areas. The spread was attributed to either through windborne spores or importation of infected plant materials. Hence, SALB is a threat to Asia and the Pacific region due to increase of communication between SALB endemic countries and the rubber growing countries in the region. It is predicted that rubber in South East Asia will be destroyed within five to seven years of SALB introduction due to the contiguous growing pattern, conducive environment and susceptible clones.

Pamphlet (information on planting material)

PLANTING MATERIALS OF *HEVEA* SPP.



Budded stumps



Budwood



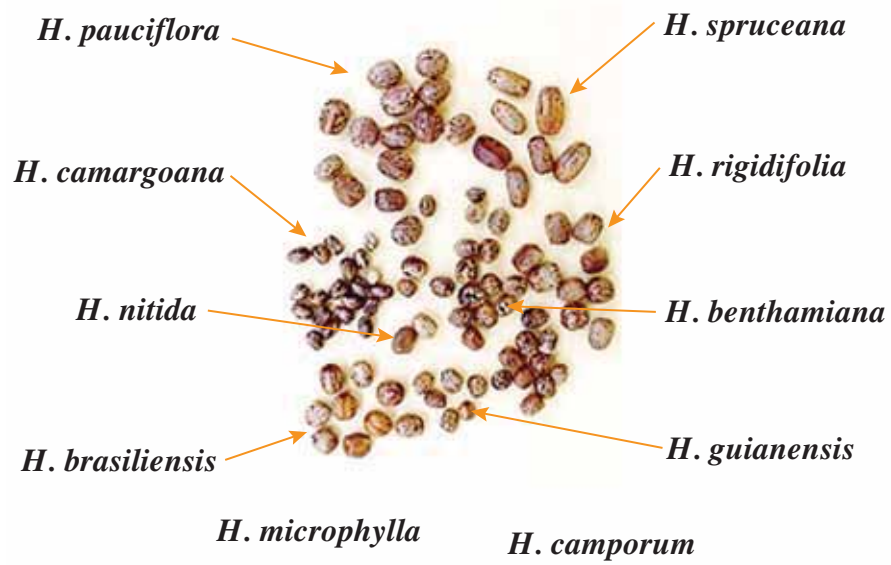
Crown budding



Advanced planting materials



Seed



Seeds of *Hevea* species

Section 1.3. Booklet

SOUTH AMERICAN LEAF BLIGHT (*Microcyclus ulei*) OF *HEVEA* RUBBER

Ismail Hashim

1. INTRODUCTION

South American leaf blight (SALB) is the most serious disease of the rubber tree due to its devastating effects. Historically, SALB had destroyed several rubber plantations established in the 1930s in Central and South America. Until today, it is the most important factor limiting a vibrant rubber planting industry in tropical Central and South America where the disease is endemic (Lieberei, 2007; Sambugaro, 2003). The Asian rubber growing countries that produce more than 90 percent of the world's natural rubber are very concerned of the threat of SALB (Rao, 1973a; Edathil, 1986; Jayasinghe, 1992; Soepadmo, 1975). This is because the climatic conditions in these major rubber producing countries are conducive to serious SALB infection (Chee, 1980b; Rao, 1973b; Silva, 2007). These countries are taking serious quarantine actions to reduce the chance of introduction of the disease (Aziz, 1976; Chee, 1985; Rao, 1973a). The Asia and Pacific Plant Protection Commission (APPPC) was established in 1956 based on APPPC agreement which includes measures to protect the region from SALB. These actions had been useful in preventing the entry of SALB into the Asian rubber growing countries (Thurston, 1973). In addition, efforts are being taken to increase knowledge of relevant pathologists and quarantine officers.

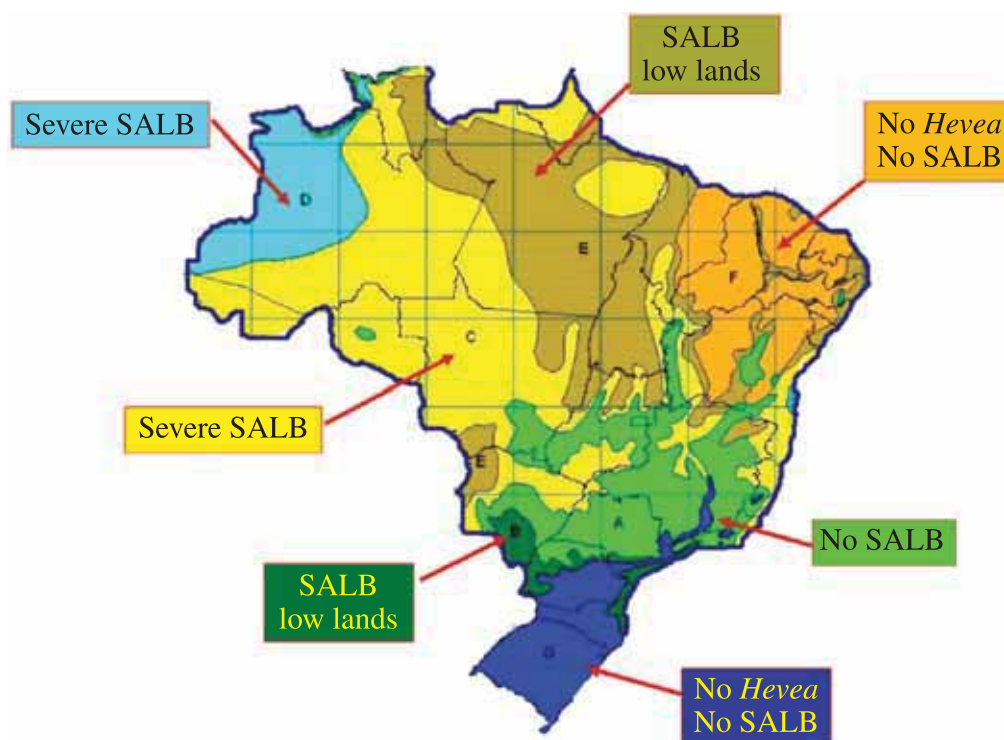
This publication briefly reviews the biology of SALB and its causal agent *M. ulei* (P. Henn.) v. Arx. The publication will be a useful guide to plant pathologists and plant quarantine officers who are dealing with SALB.

2. DISTRIBUTION OF SALB

The disease was first detected in the early 1900s on rubber plants from the Amazon jungle. The disease later spread from the Amazon forest to cultivated rubber in other areas within the Americas in tandem with the expansion of monoculture rubber cultivation in large holdings or plantations. It was detected in Guyana in 1910, Trinidad in 1916, Venezuela in 1944, Costa Rica in 1935 and Mexico in 1946. Hilton (1955) presented a detailed account on the early cultivation of rubber in Central and South America and the occurrence and destruction of SALB in these countries.

The SALB region is now confined to the American tropics from Mexico to the north and Brazil to the south. The disease is now present in Mexico, Guatemala, Panama, Honduras, Belize, Costa Rica, Nicaragua, Trinidad and Tobago, Haiti, Dominican Republic, Guyana, French Guiana, Surinam, Venezuela, Colombia, Peru, St Lucia, Ecuador, Bolivia, El Salvador, Paraguay and Brazil. (Commonwealth Mycological Institute, 1975; Compagnon, 1976; Hilton, 1955; Holliday, 1970b). In Mexico, SALB occurs at Vera Cruz, Oaxaca and Chiappas regions about 400 km from Mexico City (Rivano, 2004). In Brazil, SALB is particularly serious in the hot and humid Amazon region and also in the states of Bahia and Espirito Santo (Bergamin Filho, 1984). SALB is less serious in the states of Sao Paulo and Mato Grosso as the climatic condition in these states is less favorable for SALB due to the longer dry period and lower rainfall (Campanharo *et al.*, 2011, Holliday, 1970b). SALB is serious in areas with high annual rainfall (about 2 500 mm) with long period of high humidity (>80 percent R.H.) with no distinct dry period for several months (Holliday, 1970b).

Map showing the distribution of SALB



3. SYMPTOMS OF SOUTH AMERICAN LEAF BLIGHT

3.1 Young leaves

Shortly after infection of young rubber leaflets, the first visible symptom is the distortion in shape of the leaflets (Figure 1). Two to 12-day-old leaves showed symptoms of SALB about 2-3 days after inoculation (Blazquez and Owen, 1957). Heavily infected susceptible leaflets shrivel, turn black and drop off (Figure 1b). The petioles remain on the stem for several more days before they also drop off (Figure 2). A few days after infection, irregular-shaped disease lesions develop on the undersurface of the young brown-colored leaflets. Then, the lesions produce abundant conidia and appear dark to olive green in colour (Figure 3). The size of lesions and the amount of conidia produced are influenced by the age of leaflets, the susceptibility of the clones and the prevailing weather conditions.

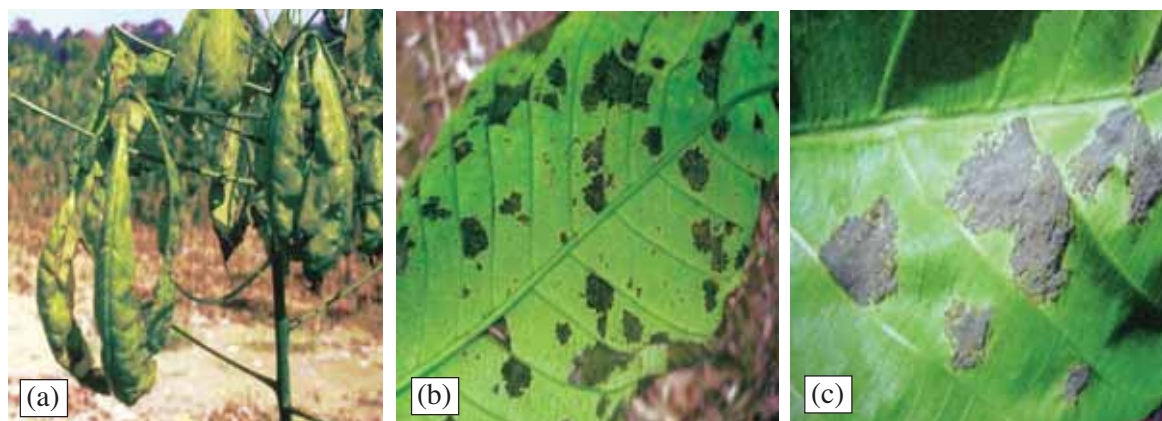
Figure 1. Symptoms on young leaves: (a) Deformation of young leaflets; (b) Severely infected leaflets that had shriveled and turned black.



Figure 2. Defoliation of leaves: (a) Petioles remain intact on the branches for sometimes; (b) Shoots without leaves.



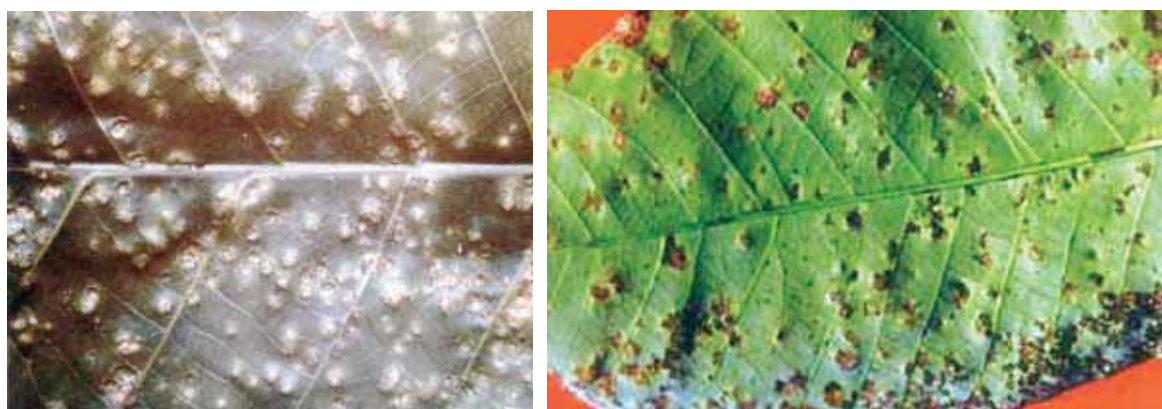
Figure 3. Symptoms on intact young leaves: (a) Distorted infected leaves; (b) and (c) Conidial lesions on the lower surface of the leaves.



3.2 Immature green leaves

About two to three weeks after infection started, the leaf tissues on the upper surface of leaf immediately above the disease lesions on the lower leaf surface turn yellowish and later small round black raised structures called the pycnidia are formed (Figure 4). The pycnidia are 120-160 μm in diameter and these fruiting bodies produce the pycnosporos.

Figure 4. The pycnidia on the upper and lower leaf surfaces



3.3 Mature green leaves

Several weeks later, the round dark raised structures enlarge and form another dark colored raised bodies called the perithecia especially around the edges of the disease lesions (Figure 5). The perithecia produce ascus that bears the ascospores. The number of perithecia varies with severity of infection and susceptibility of leaves. In certain cases, the whole upper surface of the lamina is covered with numerous perithecia (Figure 5b). As the leaf ages, the leaf tissues at the centre of the lesions die, turn papery white and later tear off leaving shot-holes in the leaf (Figure 6).

Figure 5. The perithecia on the upper surface of mature leaves

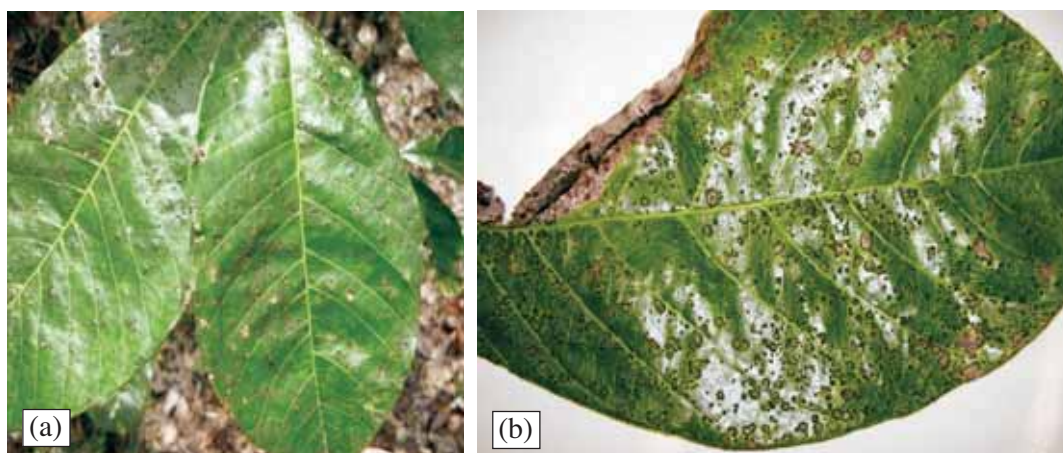


Figure 6. Symptoms on old leaves showing the shot holes formed following necrosis of tissues at the centre of the perithecia



3.4 Other plant parts

M. ulei also infects other parts of the plant and the symptoms on the inflorescence, petiole, stem and fruits are as shown in Figure 7. Infection of the stem may cause tip dieback (Figure 7b).

Figure 7. Infection on other parts of rubber plants



(a) Infection on lamina and midrib



(b) Infection on young shoot causing shoot dieback



(c) Infection on leaf petiole



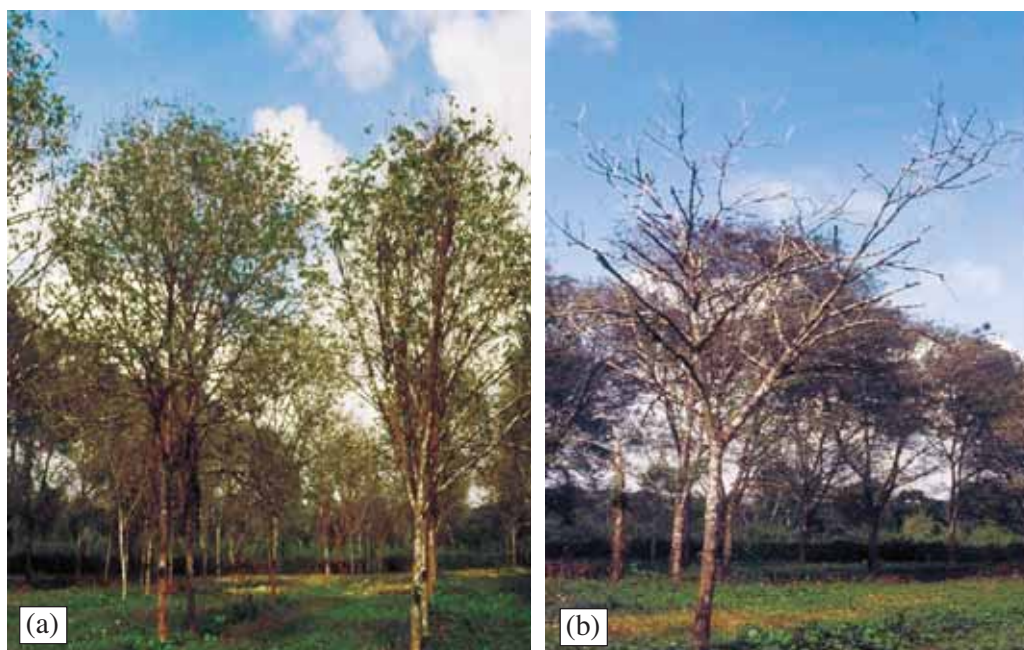
(d) Infection on inflorescence



(e) Infection of young pods

The canopy density of trees severely infected by SALB is poor and the tree has dead branches (Figure 8). Severely infected plants through time may also die.

**Figure 8. Severely infected trees: (a) Trees with poor canopy density;
(b) dead trees**



4. THE PATHOGEN (*Microcyclus ulei*)

The pathogen of South American leaf blight (SALB) is the obligate fungus *Microcyclus ulei* (P. Henn.) v. Arx. The fungus was previously known by other names such as *Dothidella ulei* P. Henn., *Melanopsammopsis ulei* (P. Henn.) Stahel, *Fusicladium macrosporum* Kuyper (refers to the conidial state of the fungus) and *Aposphaeria ulei* P. Henn. (refers to the pycnidial state of the fungus). It was shown that the various names actually refer to the same fungus. The identification and the related historical development on naming the fungus were extensively presented by Hilton (1955) and Holliday (1970a; 1970b).

4.1 Spores

M. ulei is in the group Ascomycetes and the fungus produces three types of spores in sequence viz. the conidia (Figure 9a), the pycnospores (Figure 9b) and the ascospores (Figure 9c). The conidia are produced abundantly during the asexual stage while the pycnospores and the ascospores are produced during the sexual stages of the fungus. The conidia are mainly two-celled with a broad proximal cell and a tapered distal cell. The unique character of the conidia is that they are twisted. Various sizes of the conidia had been reported (Table 1). The size of the conidia varied with location and season. The conidia, sometimes, have only one cell and the one-celled conidia are more common during dry weather conditions and in laboratory cultures.

The pycnospores are dumbbell shape and small (6-10 μm long and 2-5 μm in width). The ascospore is oblong shaped and is made up of two cells of unequal size. The size of the ascospores also varies (Table 1).

Figure 9. Spores of *M. ulei*



(a) Conidia with two cells



(b) Pycnospores

(c) Ascospores

Table 1. Spores of *M. ulei*

Spore	Description	Size (Reference)
Conidia	Mostly septate with two cells with broader proximal cell, dark grey to olive green in colour, twisted; sometimes unicellular.	<ul style="list-style-type: none"> • 12-30 × 5-8 μm (Langford, 1945) • 23-65 × 5-10 μm (Holliday, 1970b) • 23-65 × 5-10 μm for septate and 15-34 × 5-9 μm for aseptate conidia (Chee and Holliday, 1986)
Pycnospores	Dumbbell-shaped with the ends twice the width of the centre.	<ul style="list-style-type: none"> • 6-10 μm (Holliday, 1970b) • 6-10 μm (Chee and Holliday, 1986)
Ascospores	Septate with two cells of unequal size, ellipsoidal, hyaline	<ul style="list-style-type: none"> • 3-5 × 10-15 μm (Langford, 1945) • 2-5 × 12-20 μm (Holliday, 1970b) • 2-5 × 12-20 μm (Chee and Holliday, 1986)

4.2 Culture of *M. ulei*

Eventhough *M. ulei* was earlier termed as an obligate parasite, the fungus has been successfully isolated and cultured on artificial media. Various media had been developed that contained special additives such as leaf extracts, vitamins, coconut water, etc. (Blazquez and Owen, 1957; Chee, 1978b; Langdon, 1966; Langford, 1945; Mattos, 1999; Medeiros, 1977). The potato sucrose medium supports good growth of *M. ulei* (Chee, 1978b). The growth of the fungus is very slow and forms stroma either raised above the surface of the medium or flattened along the media surface (Figure 10). Conidia are produced on artificial

medium especially on special medium for spore production (Chee, 1978b, Junqueira *et al.*, 1984; 1987; Mattos, 1999). Exposure to intermittent light and dark periods effectively enhanced conidial production (Chee, 1978b).

Figure 10. Stroma of *M. ulei* in culture



4.3 Physiological races of *M. ulei*

Several physiological races of *M. ulei* exist and the occurrence of new races of *M. ulei* had caused breakdown of resistance of certain clones. Variability in the fungus was observed by several earlier scientists (Langdon, 1965; Langford, 1945). The existence of four races of *M. ulei* was established by Miller (1966). Miller also established a set of clones to differentiate Race 1, Race 2, Race 3 and Race 4 of the fungus. More races and other physiological strain of *M. ulei* were described. Chee *et al.* (1986) differentiated nine races of *M. ulei* from Bahia, Brazil using a set of differential clones. Later, Ismail and Almeida (1987) confirmed the existence of four races (Race 2, Race 3, Race 4, and Race 6) of *M. ulei* in Bahia. A more virulent strain of *M. ulei* was reported in Trinidad and Tobago (Chee, 1978; Liyanage and Chee, 1981). More variability in the population of *M. ulei* was indicated in Brazil (Furtado *et al.*, 1995; Junqueira *et al.*, 1986; Mattos *et al.*, 2007), French Guiana (Rivano, 1997) and Mexico (Cano, 1997). Three physiological groups of *M. ulei* were separated among the 16 isolates of *M. ulei* studied (Junqueira *et al.*, 1986). Rivano (1997) identified seven 'virulence factors' and differentiated 11 physiological races of *M. ulei* among the 16 isolates used. Gasparotto and Junqueira (1994) indicated the existence of ecophysiological variability among isolates of *M. ulei*. Until today, the number of physiological races of *M. ulei* is not certain. Mattos *et al.* (2007) identified 36 variations in infection types from isolates obtained in Bahia state using a set of differential clones. The number of strains of *M. ulei* may be as large as 50 (Pinheiro, 1995). However, there is no doubt that several races, more than four, of *M. ulei* exist nowadays.

4.4 Viability of spores

The viability period of the spores is influenced by weather conditions especially moisture and temperature. The spores in their fruiting bodies remain viable for longer period than detached spores. Several specific studies were conducted to determine the viability period of spores at different temperature and humidity. These studies indicate that the spores could survive for a reasonably long period (Table 2). Under moist conditions at 24 °C, the perithecia on green leaves were viable for 12 days and for nine days for those on fallen brown leaves (Chee, 1976d). Conidia placed on glass slides and maintained at 24 °C and at 65 to 95 percent relative humidity (RH) for three weeks still germinated (Chee, 1976d). The percentage germination of the conidia varied with the period of storage whereby 12 to 27 percent of the conidia germinated after one week and the percentage germination declines to three to six percent after three weeks of storage. Detached conidia remained viable for about nine days at 65 percent RH and for six days at 80 to 90 percent RH (Chee, 1976d).

Table 2. Viability of spores and perithecia of *M. ulei*

Spores	Storage condition	Viability period
Conidia (detached)	24 °C and 65-95 percent R.H.	3-4 weeks
Conidia (intact)	24 °C and 85 to 100 percent R.H.	2 weeks
	24 °C and under dessication	16 weeks
Ascospores	24 °C and 85 to 100 percent R.H.	9 days
Perithecia	24 °C and 65 percent R.H.	3 weeks
	24 °C and 100 R.H.	12 days

Chee, 1976d

It is interesting to note that the spores stored under cold and dry condition survived for a longer period. The conidia and ascospores obtained from leaves stored in a refrigerator for a reasonably long period still germinated. Spores on glass slides stored under desiccation for 16 weeks still germinated (Chee, 1976d). The ascospores kept under desiccation survived for 15 days (Chee, 1976d). In fact, spores stored under freezing temperature (-74 °C) still survived (Lebai-Juri, 1995). Under dry condition, the conidia shrivel (Figure 11) and become turgid under high moisture.

Figure 11. Shrunk desiccated conidia

In another study, the spores remained viable for a certain period when they are deposited on common materials (Zhang *et al.*, 1986). The conidia deposited on paper, glass, leather and cloth for a week still germinated with 5.8-31.5 percent germination (Table 3). Some of the conidia deposited in soil for 10 days still germinated.

Table 3. Viability of conidia of *Microcyclus ulei* stored on selected material for seven days

Materials	Germination (percent)
Cloth	31.6
Plastic	29.3
Leather	26.5
Glass	26.0
Metal	6.3
Paper	5.8
Rubber leaf	21.0

Zhang *et al.* (1986)

5. DISEASE SPREAD AND INFECTION

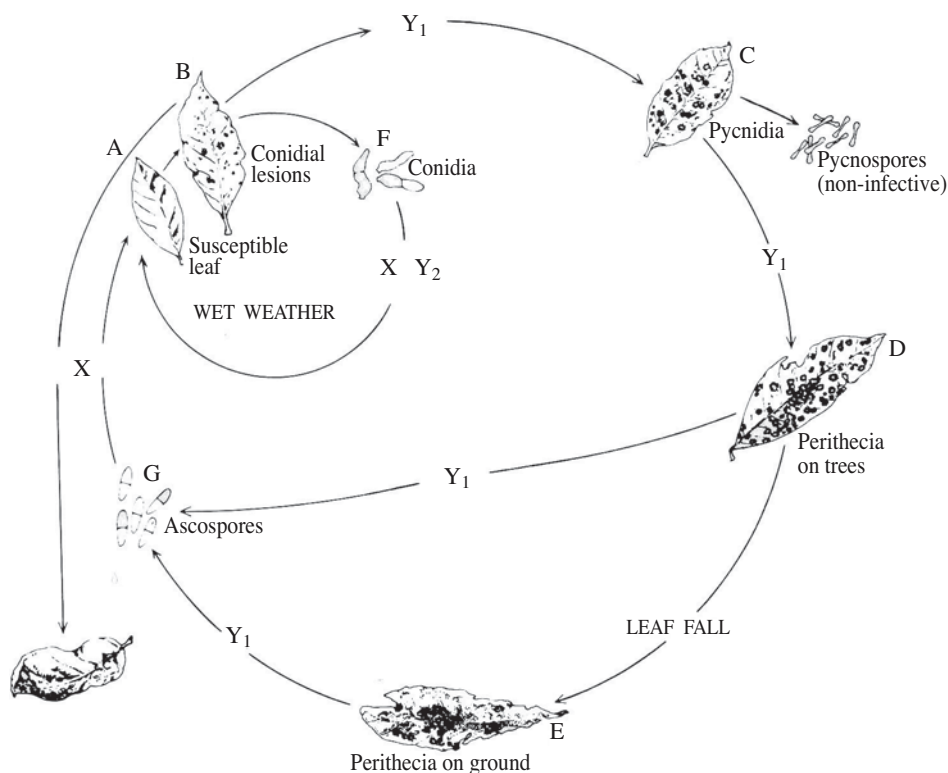
5.1 Disease dispersal

The spread of SALB is attributed to wind and rain splash (Holliday, 1970; Liyanage, 1981). Wind-borne spores had also been accredited to the spread of the disease from the natural habitat to the early cultivated rubber of Brazil (Hilton, 1955). Insects and other animals may also spread the disease locally (Chee, 1980a).

5.2 Spore germination

The conidia obtained from disease lesions germinate readily under moist condition. In distilled water, conidia germinated within one hour and most of the conidia germinated within three hours (Holliday, 1970). The distal cell germinated first and followed later by the proximal cell. Similarly, the ascospores germinated within two to six hours (Chee, 1976). On detached leaves, the conidia germinated three hours after inoculation (Blazquez and Owen 1963; Ismail *et al.*, 1978; Kajornchaiyakul *et al.*, 1984). Spore germination is influenced by weather conditions. The optimum temperature for germination of conidia and ascospores is 24 °C (Chee, 1976). However, conidia and ascospores germinated between 14-36 °C and 14-29 °C respectively.

Disease cycle of SALB (from Chee & Holliday 1986)



5.3 Epidemiology

Epidemiology studies indicate that spore production, spore liberation and infection vary with weather conditions (Chee, 1976c; Gasparotto *et al.*, 1989; 1991; Holliday, 1969; Rocha and Filho, 1978). The optimum temperature for spore production is 24 °C and high humidity favours sporulation. Maximum infection occurred at 24 °C and less at 18 °C. Infection was high at 100 percent RH as compared to 65 percent RH (Chee, 1976c).

There is diurnal periodicity in liberation of conidia. The number of conidia liberated was low at night and the number started to rise in the early morning and reached a peak at midday and declined thereafter. In Trinidad and Tobago, the peak was at about 10.00 hours (Chee, 1976c; Holliday, 1969) while in Brazil, the peak was at noon (Rocha and Filho, 1978). Conidia liberation is influenced by rainfall as the amount of conidia released increased after a rain (Chee, 1976c; Holliday, 1968). In the case of the ascospore, on a dry day, ascospore release is higher at night reaching a peak at 06.00 hours. On a wet day, ascospores are also liberated especially after rain.

5.4 Disease infection

The conidia and the ascospores are responsible for infection. The pycnosporangia had not caused infection following artificial inoculation though the pycnosporangia germinated *in vitro* (Holliday, 1970). The histology of disease infection has been studied (Blazquez and Owen, 1963; Ismail *et al.*, 1978) and summarized by Lieberei (2007). Following germination, the hyphae may penetrate directly through the cuticle into the epidermal layer or the hyphae may first form appressoria from which the hyphae penetrate into the epidermal layer. The reaction of the host to infection is influenced by the degree of resistance of the leaves. In susceptible leaves, the fungus spreads intercellularly in the leaf. However, in certain highly resistant or immune clones, disease spread was inhibited by hypersensitive host cell collapse accompanied by discoloration due to accumulation of phenolic compounds (Berger, 1992; Figari, 1965; Giesemann, *et al.*, 1986; Martains, *et al.*, 1970 and Pita *et al.*, 1992).

6. ECONOMIC IMPORTANCE AND DISEASE CONTROL

6.1 Economic importance

SALB is the most serious disease of the rubber plant. Its economic destruction has been shown during the early attempts to establish rubber plantations in Brazil in 1930s and 1940s (Table 4). Ford Motor Co. started to establish a large plantation at Fordlandia in 1928 in Brazil. The planting materials were seeds obtained from the regions around Tapajos, Solimoes and Machado Rivers (Goncalves *et al.*, 1983). Soon after the establishment of the plantation, the rubber plants were seriously infected by SALB. Then, the company abandoned this plantation in 1933 and subsequently established another plantation at Belterra in 1934 and by 1942, about 6 570 hectares had been planted using local as well as oriental materials. This plantation was also seriously infected by SALB. The severe infection by SALB forced Ford Motor Co. to abandon these two plantations. It is interesting to note that these plantations were destroyed and abandoned about seven years after their establishment. Several other international companies attempted to establish rubber plantations. Goodyear Company established a plantation in Panama and also in Brazil at Belem, Para and Una, Bahia. Firestone Company established its rubber plantations in Bahia and eventually this plantation was sold to Michelin Company and nowadays Michelin is the only international

Table 4. Historical destruction of rubber cultivation by SALB

Country	Fate of earlier plantations
Brazil	<ul style="list-style-type: none"> Ford Motor Co. established a plantation of 3 200 ha at Fordlandia in 1928 and the plantation was abandoned in 1933. Another plantation of 6 478 ha was established by Ford Motor Co. at Belterra in 1936 and was abandoned in 1943. In 1972 a special rubber planting programme called PROBOR was established and the programme was supposed to continue until 1994. However, the programme was prematurely terminated in 1986 as by then 100 000 ha out of 150 000 ha established were seriously affected by SALB.
Surinam	A plantation was established in 1911 and was abandoned in 1918.
Panama	Goodyear Plantation established an estate in 1935 and the plantation was abandoned in 1941.

Lieberer, 2007

company operating a large rubber plantation in Brazil specifically in Bahia and Mato Grosso states. Thus, SALB is still the limiting factor to natural rubber cultivation in Central and South America. Rubber cultivation in Brazil expanded especially under a special programme called PROBOR. From 1967 to 1986, about 150 000 ha of rubber were cultivated. Unfortunately, it was reported that in 1986, about 100 000 ha was infected by SALB and the project was prematurely terminated.

Several renowned plant pathologists predicted that SALB would be devastating in South East Asia. The weather condition in South East Asia is similar to those found in the SALB endemic areas in Brazil (Chee, 1980; Silva, 2007). Moreover, the rubber clones planted in Asia are susceptible to SALB. An outbreak of SALB would destroy the rubber growing industry in South East Asia within a short period. Richard Evans Shultes, a well known rubber botanist, predicted that within five years, the rubber industry in South East Asia would be compromised (Davis, 1997).

SALB is most damaging when it infects the young leaves and shoots developing during the annual leaf change season. Severely infected leaves fall-off and the repeated cycle of infection and defoliation resulted with trees with poor canopy throughout the year. The growth of young rubber plant is reduced and the immature period of the plants is increased. In Asia, it is common that the newly plants will mature within six years or earlier. In the SALB endemic countries, the immaturity period may be extended even to 13 years. Prolonged infection of SALB may kill younger rubber plants. The latex yield of SALB infected trees is also reduced. The yield loss couples with the extra management costs and extra agronomic inputs required especially on pest and disease control reduce the economic viability of rubber cultivation in SALB endemic countries until today.

6.2 Quarantine measures

Several diseases for example potato late blight, coffee rust and Dutch elm's disease, had crossed oceans and established themselves in new areas. The spread was attributed either to wind-borne spores or importation of infected plant materials. Hence, SALB is always a threat to the rubber cultivation in Asia or Africa in view of the expansion of rubber cultivation in many South American countries and the increase in communication between SALB endemic countries with the Asian and African rubber growing countries. The threat of SALB to the Asian rubber growing countries was realized since 1950s (Altson, 1955; Hilton, 1955; Rao, 1973) and prompted the introduction of special quarantine measures. The establishment of the Asia and Pacific Plant Protection Agreement had been launched in 1955 as an effective means to reduce the risks of introduction of SALB into Asia (Lieberei, 2007; Thurston, 1973). Apart from other general actions, the agreement clearly stipulated measures to deal with SALB especially to regulate the importation of rubber planting materials.

The Association of Natural Rubber Producing Countries (ANRPC) once established the ANRPC Technical Committee on SALB and an ANRPC Agreement on SALB was established with the main objective to secure common and effective actions to deal with SALB. Unfortunately, the committee and the agreement were abolished. The major contribution of the Committee then was introducing measures to increase the preparedness of the member countries to deal with SALB. Most member countries established SALB Country Committees and also the SALB Contingency Plan that includes measures to eradicate the disease in the event of an outbreak. ANRPC also introduced training programme to increase the knowledge of plant quarantine and research personnel on SALB. With the co-operation of the International Rubber Research and Development Board (IRRDB), special training programme and SALB workshops were held in Brazil and also in some member countries. The IRRDB SALB Fellowship programme enables plant quarantine officers or plant pathologist to work on SALB for a period in Brazil. This strategy ensures that each member country has a personnel well verse with SALB. In addition, certain measures had been implemented then to tackle the possible entry of spores of *M. ulei* that lodge on bodies and clothing of persons visiting a rubber area infected with SALB. Thus it was recommended that these travelers break their return journey in temperate North America or Europe. This is to enable them to rid their bodies and used clothing from viable spores. Detergents, UV irradiation and moist heat killed spores of *M. ulei* (Chee, 1985; Lebai Juri *et al.*, 1997; Zhang *et al.*, 1986). Gamma irradiation was shown to kill the spores

(Lebai Juri *et al.*, 1997). Previously, there were direct flights between SALB endemic countries to Thailand and Malaysia. These two countries implemented special measures to deal with these travelers and their personal belongings.

Table 5. Effects of UV light and other quarantine treatments on survival of *M. ulei* conidia

Treatment	Spore survival
UV irradiation	Some conidia (5-10 percent) germinated after 15 min exposure (Zhang and Chee, 1986), however 45 min and 60 min exposure (Lebai Juri <i>et al.</i> , 1997) caused total kill
X-ray irradiation	Killed the conidia (Lebai Juri <i>et al.</i> , 1997).
Commercial disinfectant, detergent, formalin liquid and gas or moist heat	Killed the conidia (Lebai Juri <i>et al.</i> , 1997; Zhang and Chee, 1986).

7. DISEASE MANAGEMENT

7.1 Chemical control

Earlier, application of fungicides is the most popular strategy to manage SALB. Therefore, it is not surprising that a great deal of research attention was given to chemical control. Many fungicides are effective against *M. ulei*. The older fungicides such as chlorothalonil, propineb, mancozeb and benomyl and the newer systemic fungicides (triadimefon, thiophanate methyl, prochloraz, propiconazole, and triadimenol, triforine, azoxystrobin?) were effective against *M. ulei* (Chee, 1978a; 1980; 1985; Chee and Holliday, 1986; Rocha *et al.*, 1975; Santos and Pereira, 1985; 1986a; 1986b). Reports of wide-scale applications of fungicides applied by fogging (Lim, 1982; Rocha *et al.*, 1973) or aerial spraying (Alencar *et al.*, 1975; Bezeera *et al.*, 1980; Mainstone *et al.*, 1977; Rocha *et al.*, 1975; Rogers and Peterson, 1976) had produced variable results. There is no shortage of effective fungicides, however the cost effectiveness of chemical treatment is not encouraging especially during low rubber price.

Being a deciduous plant, *H. brasiliensis* changes its leaves once a year. The annual leaf change or wintering process from shedding of mature leaves and sprouting of new leaves may take several weeks depending on weather conditions. Normally, the process is longer during wet seasons as the leaf shedding is not uniform among trees. The young leaves emerging after the annual leaf change (wintering) season should be sprayed weekly until most of the leaves are green and thus resistant to *M. ulei* infection. Many spray rounds are required thus affecting the economics of disease control.

In the nurseries, the fungicides are normally applied using portable mistblowers. The height of mature rubber is often above 20 meters and is a limiting factor to chemical treatment. Thus, larger or tractor mounted mistblowing machines are required. Fogging machines had also been used to control SALB (Lim, 1982; Rocha *et al.*, 1973), however the effectiveness of fogging had been questioned (Albuquerque *et al.*, 1987). Airplanes and helicopters had been used to treat large areas of mature rubber (Alencar *et al.*, 1975; Mainstone *et al.*, 1977; Rocha and Vasconcelos, 1975; Rogers and Peterson, 1976). Weekly aerial spraying of mancozeb for six rounds was effective to control SALB (Rogers and Peterson, 1976). The effectiveness of fungicide treatment was also improved by using suitable spray oils (Pereira *et al.*, 1980; Rao *et al.*, 1980). Controlling SALB with fungicides had improved latex yield (Alencar *et al.*, 1975; Chee, 1980).

Earlier, benomyl, a systemic fungicide was widely used to manage SALB. Unfortunately, benomyl resistant strains of *M. ulei* had developed in Bahia, Brazil where the chemical had been used (Ismail, 1988). Thus, measures should be taken to ensure that *M. ulei* does not develop resistance to a particular fungicide. The response of *M. ulei* to fungicides also varied with races of *M. ulei* (Zhang and Chee, 1986). They indicated that races 6 and Race 8 were less sensitive to benomyl and thiophanate methyl as compared to the sensitivity of Race 4 and Race 7.

Figure 12. Spraying of fungicides using a tractor-mounted mistblower



7.2 Biological control

The potential of biological control of SALB had been investigated. The fungus *Hansfordia pulvinata* (later known as *Dicyma pulvinata*) on SALB has the most potential. *D. pulvinata* forms white mycelial colonies on *M. ulei* lesions and parasitize the pathogen (Mello, 2004). Several trials reported that *D. pulvinata* was effective in controlling *M. ulei* (Delmadi *et al.*, 2009; Junqueira and Gasparotto, 1991; Junqueira, *et al.*, 1991; Mello, 2004; Mello *et al.*, 226; 2007). However, Junqueira and Gasparotto (1991) observed that *D. pulvinata* controlled SALB in a rubber area planted with many rubber clones but the fungus was not effective in an area planted with only one rubber clone as a single rubber clone could not maintain an effective population of *D. pulvinata*. Genetic studies indicated that *D. pulvinata* isolated from *M. ulei* was similar from all rubber regions (Tavares *et al.*, 2003). So far, biological control with *D. pulvinata* has not been adopted to control SALB. The effectiveness of mycorrhiza was also investigated but it did not significantly affect disease severity though VA-mycorrhiza infected rubber plants were more resistant to SALB (Feldman *et al.*, 1989; 1995).

7.3 Resistant clones

When the earlier plantations at Fordlandia and Belterra were ravaged by SALB, there were some plants that were not infected by the disease. This indicates the existence of resistance to *M. ulei* in *Hevea* species. Thereafter, planting of resistant clone was adopted as a strategy to manage SALB and resistant clones were selected or bred. Earlier, the Ford Motor Co. started the breeding programme by crossing some of the resistant progenies found at Fordlandia and Belterra plantations with high yielding oriental clones (e.g. PB 86 and Tjir 1). The progenies of Ford breeding and selection programme are the F, FA, FB and FX clones. Then since 1945, *Hevea* breeding was carried out by the Instituto Agronomico do Norte which produced the IAN clones. Some 'resistant clones' in the IAN, F and FX series were planted commercially. Unfortunately, the resistance of these clones broke down with time when Race 2 and other new races of *M. ulei* emerged. A notable example is the breakdown of supposedly resistant clone IAN 717 and other clones that derived their resistance from F 4542, a *H. benthamiana* clone when Race 2 of *M. ulei* emerged (Langdon, 1965). Another clone FX 3864 was considered tolerant to SALB and this clone was widely planted in Bahia, Brazil. However, FX 3864 is now severely infected by SALB there. Therefore, in view of the perennial nature of rubber plant and the fast speed of disease spread, breeding for SALB resistant clones should take into account the existence of numerous physiological races of *M. ulei*.

Numerous attempts were made to breed clones resistant to SALB in Central and South America (Goncalves, 1968; Goncalves *et al.*, 1983; Pinheiro and Libonati, 1971). Breeding for SALB resistance was also carried out in other continents. Bos and McIndoe, (1965) documented the early Firestone Plantation Co. breeding programme conducted in Africa. Similar attempts were made in Malaysia

(Brookson, 1956; Subramaniam, 1970; Ong, 1980), Sri Lanka (Fernando and Liyanage, 1975; Jayasekara and Fernando, 1977; Wijewantha *et al.*, 1965), Indonesia (Wirjomidjojo, 1962) and France (Garcia, 2004). In Malaysia, several introduced clones (such as FX 25), and selections from Madre de Dios and Rio Negro were used as the source of SALB resistance (Ong, 1980; Ong and Tan, 1987; Subramaniam, 1970).

The histological development of the fungus in resistant and susceptible leaves was studied in detail (Blazquez and Owen, 1963; Ismail Hashim, 1978; Ismail Hashim *et al.*, 1978; Lieberei, 2007). These studies indicate that the fungus could penetrate susceptible and resistant leaves. However, the subsequent spread of mycelia was inhibited in resistant leaves. The inhibition could be attributed to occurrence of hypersensitive host cell collapse which occurred soon after inoculation of very resistant or immune clones (Blazquez and Owen, 1963; Ismail Hashim, 1978; Ismail Hashim *et al.*, 1978). Hypersensitive host cell collapse is associated with vertical resistance.

Since the fungus could penetrate into leaves of all clones, it was suggested that biochemical reactions is more important in the mechanism of resistance of *Hevea* to SALB after studying changes in phenol content and activities of selected enzymes (Ismail Hashim (1978; 1979); Ismail Hashim *et al.*, 1978a; 1978b; 1980). A yellow fluorescent substance was observed following infection of resistant leaves (Blazquez and Owen, 1957; Figari, 1965; Ismail Hashim, *et al.*, 1978a). This substance was identified as a glucoside of kaempferol (Martins, *et al.*, 1970). Another phenolic compound scopoletin was also observed following infection of resistant leaves (Garcia *et al.*, 1995a; 1995b; 1999; Giesemann, 1980). Scopoletin is a phytoalexin and the rapidity and amount of its occurrence was associated with resistance (Giesemann *et al.*, 1980).

Many *Hevea* clones exhibit vertical resistance to SALB characterized by hypersensitive reaction following infection and breaking down of resistance to new races of *M. ulei*. Since rubber is a perennial crop, vertical resistance is not of benefit in the long run. Therefore, breeding for clones with horizontal resistance has been suggested (Simmonds, 1990). Lesion size, latent period and spore production are useful parameters to identify clones with horizontal resistance (Garcia *et al.*, 1999; 2004; Ismail and Pereira, 1986; 1989; Junqueira *et al.*, 1990; LeGuen *et al.*, 1995; 2008). Clones with horizontal resistance exhibited smaller or less number of lesions, produce less number of spores and the spore generation period is short. Recently, Michelin jointly with CIRAD had produced or identified 13 clones that exhibited some degree of horizontal resistance to SALB (Garcia, 2004). Breeding clones with horizontal resistance to SALB has been adopted as an important strategy to manage SALB.

The art of *Hevea* breeding is now being assisted with new developments in molecular techniques. Recent research throws more light on the genetics of resistance of *Hevea* to *M. ulei* (LeGuen *et al.*, 2000, 2003; 2004; 2011; Lespinasse *et al.*, 2000a; 2000b). Lespinasse *et al.* (2000a) had identified the QTLs involved with resistance to SALB. They had also created a linkage map of *Hevea*. Le Guen *et al.*, (2011) indicated that horizontal resistance is conferred by a qualitative gene and a major quantitative resistance factor.

7.4 Polyploidy

The chromosome number of the diploid (2n) *Hevea* spp. is 36. Polyploid rubber plants had been produced by treatments with chemical mutagens or X-ray irradiation. The susceptibility of these polyploid rubber plants to *M. ulei* had been evaluated and some polyploid plants were more resistant than the diploid plants (Junqueira, *et al.*, 1993).

7.5 Crown budding

Crown budding is the technique of bud grafting a specific rubber clone or progeny (crown clone) onto a trunk of another clone (trunk clone) which had itself been budded onto a seedling (root stock) to produce a 'three-part tree'. This technique is being utilized for managing SALB whereby clones resistant to SALB is used as crown clones to be budded onto high yielding trunk clone. Selected "resistant clones" such as FX 3899, FX 3810 and FX 3925 had been budded onto high yielding oriental clones (Chee and Wastie,

1980; Moraes and Moraes, 2008). Later, other clones (IAN 6158) or *Hevea* species such as *H. pauciflora* and *H. rigidifolia* had been used as crown (Furtado *et al.*, 2004; Lima *et al.*, 1992; Mattos, 2004; Moraes and Moraes, 2008). Though the technology of crown budding is technically feasible to overcome SALB, the current limiting factor is the unavailability of suitable resistant crown. Another disadvantage is that certain crown-scion combinations are incompatible and result in uneven growth of the trunk parts.

Picture of crown budding



7.6 Disease escaped areas

The severity of SALB is influenced by the amount and duration of rainfall. Holliday (1970) observed that the incidence of SALB was low in areas with annual rainfall of 130-150 cm (7-8 cm/month) with long dry season of at least four consecutive months. These relatively dry areas are termed as SALB 'escaped areas'. The 'escaped areas' in Brazil had been identified and mapped out (Almeida *et al.*, 1987; Camargo, 1963; Camargo *et al.*, 1967; 1975; Silva, 2007). The major 'escaped areas' are in Sao Paulo and Mato Grosso states. Cultivation of rubber in the 'escaped areas' has been a successful strategy to overcome the ravages of SALB (Pinheiro, 1995; Rivano, 2004). In the 'escaped areas' of Sao Paulo and Mato Grosso, SALB susceptible oriental clones such as RRIM 600, GT 1 and PB 260 had been successfully planted and produce good yield (Furtado, *et al.*, 2004; Pinheiro, 1995).

8. CONCLUSIONS

SALB is a very serious disease of *Hevea* rubber that is the main hindrance to a viable commercial cultivation of rubber in Central and South America. Despite the existence of many fungicides, chemical control does not offer a cost effective solution of the disease. The only practical method is to plant resistant clones. Unfortunately, high yielding clones that are resistant to SALB are very limited. SALB is always a threat to the rubber industry in the major rubber producing countries in Asia and Africa. Effective quarantine measures should be taken to prevent the introduction and spread of SALB into Asia and the Pacific region.

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Section 1.4. PowerPoint presentations

Diseases of Rubber an overview

DISEASES OF *HEVEA* RUBBER

DISEASES OF *HEVEA* RUBBER

- Leaf diseases;
- Stem diseases;
- Panel disease;
- Root diseases.

LEAF DISEASES OF RUBBER

- Colletotrichum secondary leaf fall;
- Oidium secondary leaf fall;
- Phytophthora abnormal leaf fall;
- Corynespora leaf fall;
- Fusicoccum leaf disease;
- Bird's eye spot;
- Cylindrocladium leaf disease.

LEAF DISEASES

- Colletotrichum secondary leaf fall;
- Oidium secondary leaf fall;
- Phytophthora abnormal leaf fall;
- Corynespora leaf fall.



Distribution of Rubber Diseases in Malaysia

- Associated with rainfall pattern



MAJOR LEAF DISEASES

DISEASES	COUNTRIES
Colletotrichum leaf fall	Brazil, Cameroon, China, Gabon, Guyane, India, Indonesia, Malaysia, Vietnam
Corynespora leaf fall	Cameroon, India, Indonesia, Malaysia, Sri Lanka
Oidium leaf fall	China, India, Indonesia, Malaysia, Vietnam
Phytophthora leaf fall	Brazil, India

Colletotrichum secondary leaf fall

- Fungus – *Colletotrichum gloeosporioides*;
- Occur in Brazil, Cameroon, China, Gabon, India, Indonesia, Malaysia, Vietnam;
- Causes leaf fall and shoot dieback;
- Important in nurseries, young and mature rubber;
- Reduces plant growth and yield;
- Common during annual wintering;
- Needs rainfall.



IMPACT OF DISEASES

- To the tree:
 - Damage and defoliate leaves;
 - Cause shoot and stem dieback;
 - Damage the tapping panel and affect bark renewal;
 - Kill branches and trees.
- Economics:
 - Lengthen the immaturity period (>13 years for SALB);
 - Reduce latex yield (30 to 70% reduction);
 - Increase cost of production;
 - Affect the environment.

Oidium secondary leaf fall

- Fungus – *Oidium heveae* (powdery mildew);
- China, India, Indonesia, Malaysia, Vietnam;
- Important on young and mature rubber;
- Cause leaf defoliation and reduces latex yield;
- Light rain with cool misty nights.



Phytophthora abnormal leaf fall

- Fungus *Phytophthora palmivora* or *P. botryosa*;
- Brazil, India, (Thailand, Malaysia, Vietnam);
- Prolong heavy rainfall;
- Infects young and mature leaves, petioles, shoots, fruits;
- Causes leaf fall and shoot dieback .



Corynespora leaf fall

- Fungus *Corynespora cassicola*;
- Two races identified;
- Cameroon, India, Indonesia, Malaysia, Sri Lanka, Vietnam;
- Symptoms – spots or characteristic railway track symptoms;
- Infects young and old leaves.



Corynespora leaf fall

- Causes leaf fall, shoot dieback;
- Increase immaturity period, reduces yield;
- Kills plants.



Fusicocum leaf disease

- *Fusicocum* sp.;
- Occurs only in Malaysia;
- First detected in 1988 in a FELDA holding;
- Spread to other areas;
- Common on immature rubber;
- Causes leaf fall.



OCCURRENCE AND SEVERITY OF CORYNESPORA LEAF FALL

Country	Year	Severity	Clones affected
Indonesia	1980	Severe	RRIC 103, PPN 2058, PPN 2447, Gt 1, KRS 21, RRIM 725, RRIM 600, Fx 25, IAN 873
India	1960	Severe	RRII 105, Gt 1, RRIM 600, Tjr 1, RRII 118
Vietnam	1999	Severe	LH88/372, RRIC 103, RRIC 104
Malaysia	1960	Severe	RRIM 725, RRIM 600, IAN 873, RRIC 103
Sri Lanka	1987	Severe	RRIC 110, RRII 105, RRIM 600, Gt 1
Thailand	1985	Severe	RRIC 103, KRS 21, Songkla 36, RRIT 251, PR 255
Cote d'Ivoire	—	—	RRIC 103, RRIC 110, PB 260, PB 28/59

Management of leaf diseases

- Enviromax planting;
- Planting of resistant clones;
- Cultural practices:
 - Artificial defoliation to avoid secondary leaf fall and Corynespora leaf fall;
 - Increase nitrogen manuring for Oidium secondary leaf fall.
- Chemical control.

CHEMICAL CONTROL OF LEAF DISEASES

DISEASES	CONTROL METHODS
Oidium leaf fall	Sulphur dusting, tridemorph spray, artificial defoliation
Colletotrichum leaf fall	Spray with Daconil, propineb-effective for nurseries and immature rubber
Phytophthora leaf fall	Copper oxychloride – aerial spray, fogging

Methods of applying fungicides

- Dusting;
- Ground spraying;
- Aerial spraying;
- Fogging.



STEM DISEASES

- Pink disease – most important stem disease
- Ustilina stem rot – minor importance
- Bark necrosis – minor importance

Pink disease

- *Corticium salmonicolor*;
- India, Indonesia, Malaysia, Vietnam;
- Infects young rubber at the fork;
- Pink colour mycelium and latex;
- Kills branches and prolong immaturity period;
- Occurs during wet season.



Control of pink disease

- Spraying of Bordeaux mixture for trees not in tapping (weekly);
- Painting with fungicides (tridemorph, thiram, chlorothalonil);
- Spraying with thiram or chlorothalonil;
- Rainfast formulations had been developed;
- Most effective on less severe disease;
- Motorised sprayers for big areas;
- Resistant clones.



CHEMICAL CONTROL OF PANEL DISEASES

<u>DISEASES</u>	<u>CONTROL METHODS</u>
Pink disease	Bordeaux mixture spray, tridemorph painting
Black stripe	Ridomil spray,
Mouldy rot	Benomyl spray

PANEL DISEASES

- **Black stripe – most important**
- **Mouldy rot – localised**
- **Panel necrosis – rare**

Black stripe

- *Phytophthora palmivora*;
- Brazil, Cameroon, China, Cote d'Ivoire, India, Indonesia, Malaysia, Thailand, Vietnam;
- Dark depressions with dark streaks on wood;
- Long heavy rainfall;
- Spreads by rain splash and tapping knives;
- Damage bark and wood;
- Interferes with bark renewal and develop bulges that interfere future tapping;
- Control by applying fungicides (ridomil+mancozeb).



Mouldy rot

- Fungus *Ceratocystis fimbriata*;
- Brazil, Indonesia, Thailand;
- White moulds above the tapping cut;
- Damages bark and wood and affects bark renewal;
- Common in high moisture and weedy conditions especially on panels reaching the ground;
- Control with fungicides (benomyl).



Chemical control of panel diseases

- Spraying of fungicides using hand held sprayers;
- Painting with brush.



Hevea Root Diseases

- White root disease – most important;
- Red root disease – less important;
- Brown root disease – less important;
- Armillaria root rot – important in Africa;
- Purple root disease – Only in China.

Distribution and severity of root diseases of *Hevea* (1994)

Country	<i>Ganoderma</i>	<i>Rigidoporus</i>
Thailand	4	5
Sri Lanka	1	6
Malaysia	4	5
Indonesia	4	6
India	1	1
French Guiana	1	1
China	5	2
Brazil	3	3

1-Disease absent; 2-Disease occurs sporadically, localized, minor disease of no economic significance; 4-Disease occurs sporadically, moderately severe in certain localities, chemical control is required; 5-Severe occurrence of the disease can be localized or widespread, chemical control is necessary; 6-Very severe occurrences, large to widespread, cause severe economic loss.

White root disease

- Fungus *Rigidoporus lignosus*;
- Cameroon, Cote d'Ivoire, Indonesia, Malaysia, Sri Lanka, Thailand;
- Most important on young rubber (5 years);
- Symptoms on leaves – discolored;
- White mycelium on roots;
- Most serious (30 to 50%) incidence);
- Spreads by root contact;
- Fast growth of mycelium.



Red root disease

- *Ganoderma philippii*;
- China, Malaysia, Brazil;
- Fungus growth slower and disease more prominent on older rubber;
- Similar foliage symptoms;
- Roots covered with a layer of sand/soil;
- Red coloration on roots.



Brown root disease

- *Phellinus noxius*;
- Cote d'Ivoire, India, Malaysia;
- Less common;
- Can cause stem rot;
- Similar foliage symptoms;
- A layer of soil/sand with brown spots;
- Honeycomb structures on wood surface and inside wood.



ROOT DISEASE CONTROL

- **Pre-planting**
 - Correct land clearing procedures;
- **During planting**
 - Application of sulphur (150 to 200 g/plant);
 - Planting of creeping legume cover plants;
- **Immature rubber;**
 - Chemical control
- **Mature rubber**
 - Isolation trenches

CHEMICAL CONTROL OF ROOT DISEASES

- **Identifying infected trees:**
 - Quarterly foliage inspection for symptoms of root disease (discoloration) followed by collar inspection of infected and neighboring trees;
 - Foliage inspection is expensive and laborious;
 - Requires expertise.
- **Applying of fungicides:**
 - By painting;
 - By drenching.

Painting with fungicides

- Not being carried out due to high cost and lack of labour;
- PCNB for white root disease and tridemorph for white and brown root disease;
- Commercial product is unavailable.



Drenching of fungicides

- Most commonly used method;
- More effective on young and less severe disease;
- Normally not effective on trees with foliage symptoms;
- Carry out collar inspection to detect disease;
- Dig furrow and pour fungicides (1 or 2 l/tree);
- Repeat after 6 months;
- Effective fungicides – triadimefon, propiconazole, hexaconazole etc.



NURSERY DISEASES

- Bird's eye spot (*Drechslera hevea*);
- Dieback (*Colletotrichum*, *Phytophthora*);
- Control with fungicides.



EXOTIC PESTS AND DISEASES OF RUBBER

- **South American leaf blight;**
- **Black crust;**
- **Target spot;**
- **Mosca de renda;**
- **Mosca branca (white moth).**

South American leaf blight

- *Microcyclus ulei*;
- South and Central America;
- Most serious disease of rubber;
- Most Asian and African clones are susceptible;
- Suitable climate in Asia and Africa.



Black crust and target leaf spot

- Target leaf spot
- Black crust (*Catacauma huberi*)



Thank you



SALB – Distribution and importance

The distribution and Importance of South American leaf blight (SALB)

South American leaf blight (SALB)

- The most serious disease of rubber
- Destructive, spreads rapidly, difficult and expensive to control
- Infects only rubber plants (*H. brasiliensis*, *H. benthamiana*, *H. guianensis*, *H. spruceana*, *H. camporum*)

Past Destruction By SALB

SURINAM	1911 – 40,000 Tree Planted 1918 – Plantation Destroyed
PANAMA	1935 – Good year plantation starter 1941 – Plantation destroyed
BRASIL	1927 – 3,200 ha planted at Fordlandia 1993 – Plantation abandoned 1936 – 6,478 ha planted at Belterra 1943 – Plantation abandoned 1967 to 1986 – 150,000 ha planted under (PROBOR) 1986 – PROBOR Terminated, 100,000 ha infected with SALB

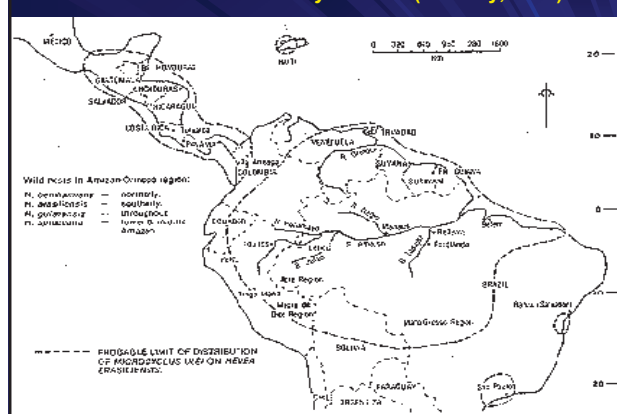
COSTA RICA

- Goodyear Speedway estate was planted in 1935 and was severely infected by SALB in 1941;
- History indicated that SALB caused a serious problem within 6-7 years of establishment of a plantation.

DISTRIBUTION OF SALB

- Confined to the American tropics and Caribbean islands from Mexico to Brazil
- Present in Brazil, Bolivia, Colombia, Peru, Venezuela, Guyana, Surinam, French Guiana, Trinidad & Tobago, Haiti, Panama, Costa Rica, Nicaragua, Salvador, Honduras, Guatemala, Belize and Mexico
- Asia and Africa are free of SALB

The distribution of *Microcyclus ulei* (Holliday, 1970)



IMPACTS OF SALB ON THE TREE

- Repeated leaf defoliation
- Shoot dieback
- Trees with poor canopy
- Weedy conditions

ECONOMIC IMPORTANCE OF SALB

- Reduces tree growth
- Prolongs the immaturity period
- Reduces latex productivity by as much as 70%
 - Productivity of RRIM 600 in Brazil – 11.2 g/t/t and 15.9 g/t/t
 - Productivity of RRIM 600 in Malaysia – more than 60 g/t/t
- Kills the rubber plants and reduce density of stand
- Increases cost of rubber production – extra weeding and disease control

Shoot dieback and dead branches



ENVIRONMENTAL EFFECT OF SALB

Contamination of the environment and farmers by pesticides used for controlling SALB and also the weeds.

THE THREAT OF SALB TO ASIA AND AFRICA

SALB: HOW SEVERE IT WILL BE IF INTRODUCED INTO SOUTH EAST ASIA

- “It is an open secret in the industry that SALB should it crosses the Pacific could wipe out the supply of natural rubber ” – Peter Wade in Fortune.
- “SALB would run through the Asian rubber plantations within five years” – Richard Evan Shultes.
- “It moves like a blow torch through the plantings” – Ernie Emle.

SUITABILITY OF SALB IN ASIA

- Suitable climatic conditions
- Abundant susceptible clones
- Contiguous rubber plantings
- Rubber plant is mainly planted in smallholdings

Effect OF Rainfall On Severity On SALB

- High Severity
 - Annual rainfall >250 cm, well distributed with no long dry season
- Intermediate Severity
 - Annual rainfall >200–<250 cm, well distributed with no long dry season
- Low Severity
 - Annual rainfall, variable with at least four months dry period with <7 cm rain per month

EFFECT OF CLIMATE ON SALB

- Temperature: *Conidia* germinate between 8-36 °C (maximum 24 °C)
- Humidity: Months with 18+ days with RH exceeding 95% for 10.00 hours – severe SALB

SIMILARITY OF CLIMATE IN MALAYSIA WITH CLIMATE IN SALB REGION

Months	Bahia, Brazil	Trinidad	Malaysia (N.S)
January	22	7	14
February	18	12	21
March	22	17	17
April	26	4	23
May	26	3	25
June	27	14	29
July	24	16	30
August	21	21	30
September	18	23	29
October	22	25	30
November	20	25	29
December	20	17	30

POSSIBLE METHODS OF INTRODUCTION OF SALB

- Infected *Hevea* Plants
- Spores Contaminating travelers, their belongings and imported commodities.

**The spores of
Microcyclus ulei remain
viable for a reasonably
long period**

VIABILITY OF SPORES

- LANGFORD (1945)
 - High germination of conidia and ascospores kept for 3 days at 80 °F and 70% R.H. and some still germinated after 7 days
 - Conidia sprayed onto young leaves, then kept dry for 7 days still infect when re-moist
- HOLLIDAY (1970)
 - Ten percent of conidia kept at room condition for 18 days germinated

VIABILITY OF SPORES OF *M. ULEI*

SPORES	CONDITIONS	VIABILITY
Conidia (detached)	24 °C, 65-85% RH	3-4 weeks
	24 °C, 85-100% RH	2 weeks
	24 °C, desiccation	16 weeks
Conidia (intact)		
Ascospores	24 °C, 85-100% RH	9 days
	31 °C, 0-100% RH	3 days
Perithecia	24 °C, 65% RH	3 weeks
	24 °C, 100% RH	12 days

Survival Of Conidia Of *M. ulei* After 7 Days On Different Materials

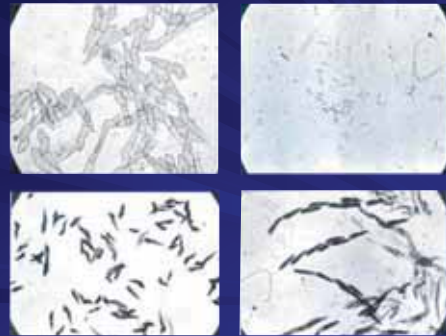
Material	Germination (%)
Infected Leaves	53.3
Cloth	31.6
Polyethylene	29.3
Leather	26.5
Glass	26.0
Hevea Leaves	21.0
Metal	6.3
Paper	5.8
Dry Soil	50.0
Moist Soil	10.0

THANK YOU

SALB – Epidemiology

THE EPIDEMIOLOGY AND HOST PARASITE INTERACTION OF SALB

SPORES OF *M. ulei*



DISEASE INFECTION

Conidia and ascospores are responsible for infection.

DISEASE SPREAD

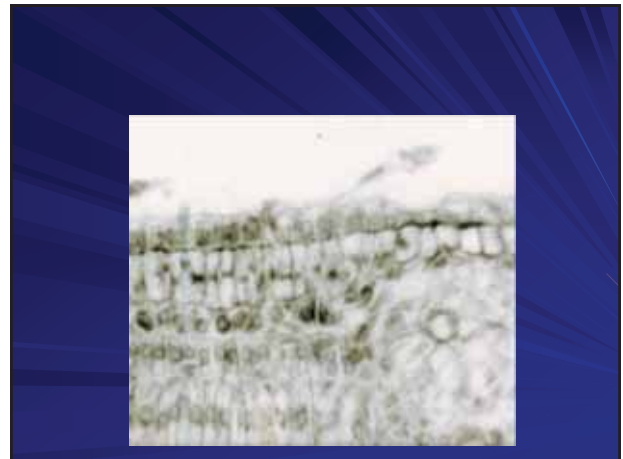
- Wind and rain splash;
- Insects and other animals;
- The ascospores initiate new disease cycle and the conidia are responsible for local spread of the disease.

GERMINATION

Conidia Infecting *Hevea* leaf



Infection by conidia



SPORE GERMINATION

- Distal end of the conidia germinated first followed by the proximal cell;



GERMINATION OF CONIDIA

- The conidia germinate within two hours;
- Hyphae penetrate directly or by forming appressoria;
- Formation of appressoria is influenced by resistance of leaves;
- Fungus spread intercellularly.

SPORE GERMINATION

Conidia germinate between 8-36 °C (maximum 24 °C);

RATE OF CONIDIAL GERMINATION

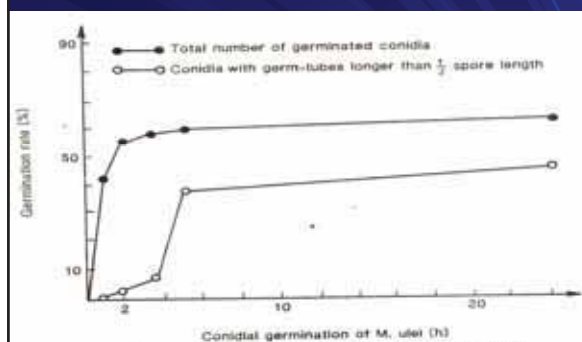
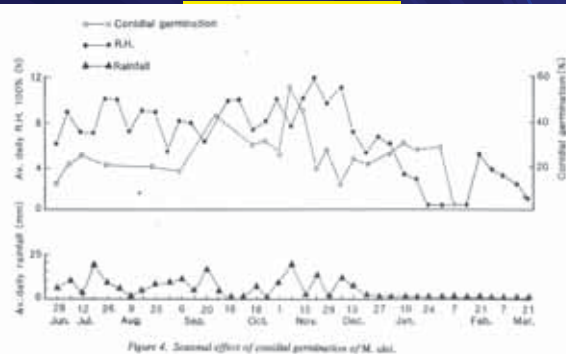


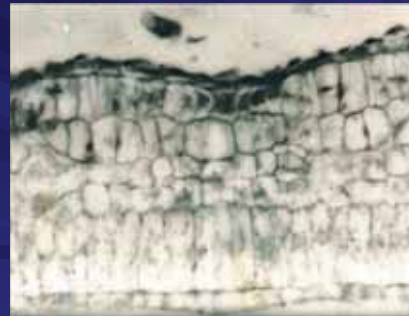
Figure 3. Rate of conidial germination of M. ulmi in relation to time.

SEASONAL EFFECT OF CONIDIAL GERMINATION



HOST REACTION AND DISEASE DEVELOPMENT

HOST CELL COLLAPSE



DISEASE DEVELOPMENT

- Lesion is visible by two days of infection;
- Host reaction is dependent on resistance of leaves;
- Host cell collapse may occur;
- Age of leaves and clonal resistance determine number and size of lesions.

INFLUENCE OF WEATHER ON DISEASE

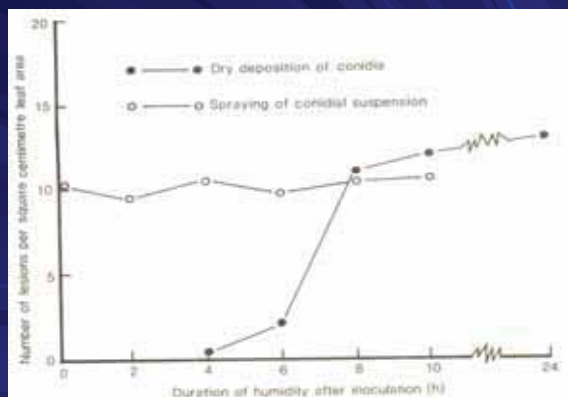
EFFECT OF RAINFALL ON SEVERITY

- **High Severity**
 - Annual rainfall >250 cm, well distributed with no long dry season
- **Intermediate Severity**
 - Annual rainfall >200–<250 cm, well distributed with no long dry season
- **Low Severity**
 - Annual rainfall, variable with at least four months dry period with <7 cm rain per month

EFFECT OF HUMIDITY ON SALB

Months with 18+ days with RH exceeding 95% for 10.00 hours – severe SALB

EFFECT OF HUMIDITY ON INFECTION



SPORE PRODUCTION

- Spore production vary with weather conditions;
- Optimum temperature for spore production is 24 °C;
- High humidity favors spore production.

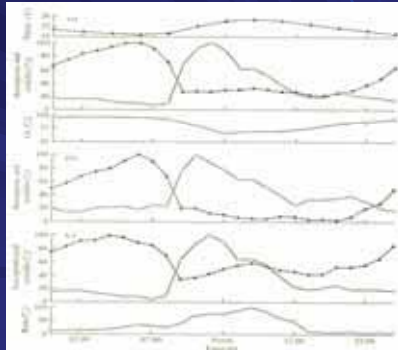
SPORE LIBERATION

SPORE LIBERATION

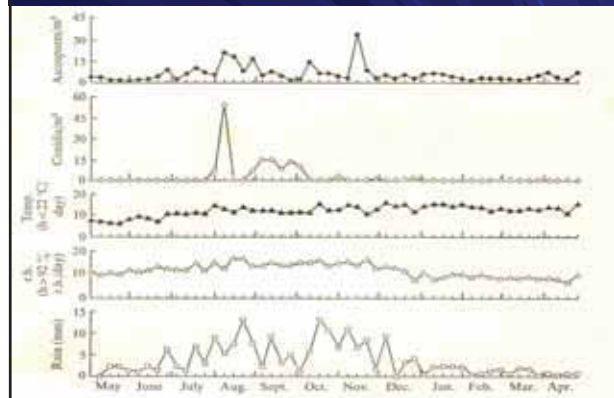
- Spore liberation varies with weather conditions;
- Diurnal periodicity in liberation of spores;
- Conidia liberation:
 - Low at night and rises in the morning;
 - Peak at mid day (10 a.m. to 12 p.m.) and declines there after.
- Ascospore liberation:
 - Ascospore are released at night and peak at 6 a.m.
- Liberation of conidia and ascospores is high after a rainfall.

DIURNAL PERIODICITY OF SPORE RELEASE

Conidia
(empty dots);
Ascospores
(darkened)



Annual dispersal of spores



Viability of spores

- Viability of spores depend on weather condition especially moisture and temperature;
- Spores in fruiting bodies remain viable for longer periods than detached spores;
- Several studies were made on viability of spores.

VIABILITY OF SPORES

- LANGFORD (1945)
 - High germination of conidia and ascospores kept for 3 days at 27 °C and 70% R.H.
 - 80 °F and 70% R.H. – some still germinated after 7 days
 - Conidia sprayed onto young leaves, then kept dry for 7 days still infect when re-moist
- HOLLIDAY (1970)
 - Kept at room condition for 18 days – Ten percent of conidia germinated

Viability Of Spores Of *M. ulei*

Spores	Storage condition	Viability period
Conidia (detached)	24 °C, 65-95% R.H.	3-4 weeks
Conidia (intact)	24 °C, 85-100% R.H.	2 weeks
	24 °C, desiccation	16 weeks
Ascospores	24 °C, 85-100% R.H.	9 days
Perithecia	24 °C, 65% R.H.	3 weeks
	24 °C, 100% R.H.	12 days

VIABILITY

- Spores stored under cold and dry conditions survived longer;
- Conidia and ascospores obtained from leaves stored for long period in a refrigerator remain viable;
- Ascospores stored under desiccation survived for 15 days;
- Spores stored at -74 °C still survived.

SALB – Pathogen

South American leaf blight (SALB): the causal pathogen and the disease

NOMENCLATURE

Dothidella ulei (P. Henn.)
Apospheria ulei (P. Henn.)
Fusicladium macrosporium (Kuyper)
Passalora heveae (G. Masee)
Scolecotrichum ulei (Griffon and Maublanc)
Melanosammopsis ulei (Stahel)
Microcyclus ulei (P. Henn.) von Arx

NOMENCLATURE

- *Dothidella ulei*, *Apospheria ulei* and *Fusicladium macrosporium* are descriptions of the same fungus.
- *Microcyclus ulei* (P. Henn.) von Arx is the accepted name with synonyms *Dothidella ulei* (P. Henn.) and *Fusicladium macrosporium* (Kuyper)

THE PATHOGEN OF SALB

- *Microcyclus ulei* is a fungus
- An ascomycete with sexual and asexual stages
- Produces three types of spores
 - The conidia (asexual)
 - pycnidiospores
 - ascospores (sexual)

Microcyclus ulei – conidia



CONIDIA

- Either septate (two cells) or aseptate (one cell). Percentage of aseptate conidia increased in drier periods and more common from laboratory cultures.
- Septate conidia are obclavate with broad proximal cell with truncate distal end.
- Possess a characteristic twist.
- Hyaline when young and turn grayish with age.
- Size of septate conidia vary – 23-65 x 5-10 µm (Chee); 23-62 x 5-10 µm (Holliday); 12-30 x 5-8 µm (Langford).
- Size vary with locations and season.

Microcyclus ulei



Shrunken conidia

Microcyclus ulei – pycnospores



Pycnospores

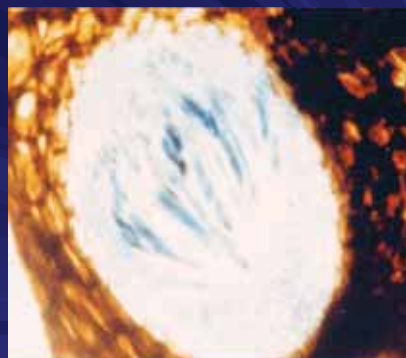
- Dumb bell shaped.
- One end larger (12-25 μm) than the other end (2-5 μm).
- 6-10 μm in length.
- Borne on hyphal elements.
- Germinate but do not cause infection.

Microcyclus ulei – ascospores

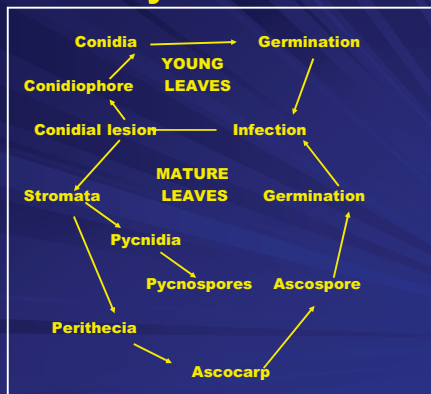


ASCOSPORES

- Septate with constriction at septum;
- Cells unequal in size;
- Various sizes reported –
12-20 x 2-5 μm (Chee);
10-15 x 3-5 μm (Holliday);
3-5 x 10-15 μm (Langford);
- Hyaline and ellipsoidal.



Life Cycle Of *M. ulei*



PLANT PARTS INFECTED

- Young plant parts – leaves, stems, petioles, inflorescence and fruits;
- Leaves at the copper brown stage are most susceptible;
- Leaves are more resistant as they age and old leaves are immune.

SYMPTOMS OF SALB

- The symptoms depend on the age of leaves at time of infection;
- The young copper brown leaflets shrivel, curl, turn blackish and drop-off leaving the petioles for several days on the stems;
- The fully expressed conidial lesions are seen on the lower surface of the green leaflets;
- The lesions are covered with powdery masses of conidia giving dark grey to olive green colour.



- Petioles remain on the stem for sometimes after the leaflets fall off

