RAP PUBLICATION 2012/07

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

Volume II

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Volume II

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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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 planning 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 activites 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

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

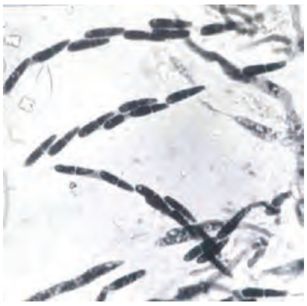
SOUTH AMERICAN LEF BLIGHT (SALB) OF RUBBER

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. ulei *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, pycnospores and ascospores. (Figures 1, 2 and 3).

Figure 1. Conidia

Figure 2. Pycnospores

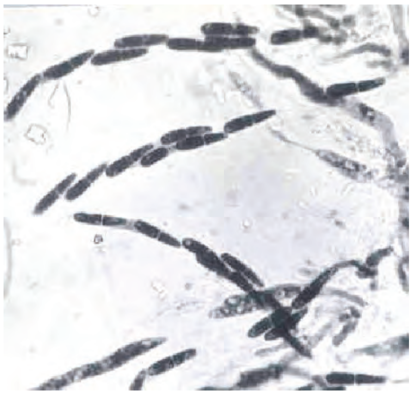


Figure 3. Ascospores

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.

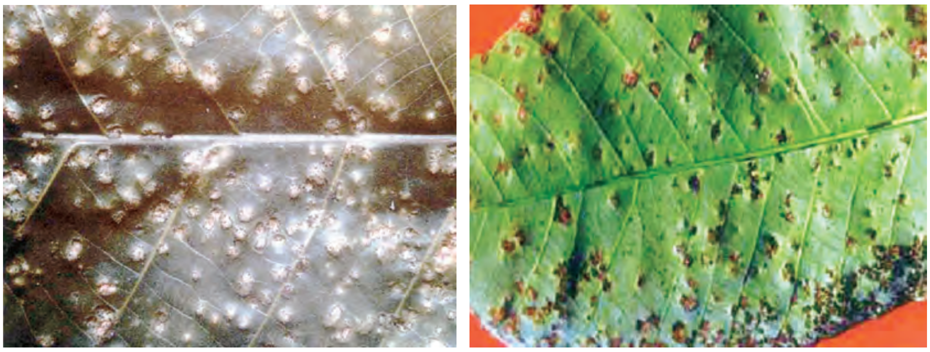


Figure 7.

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.

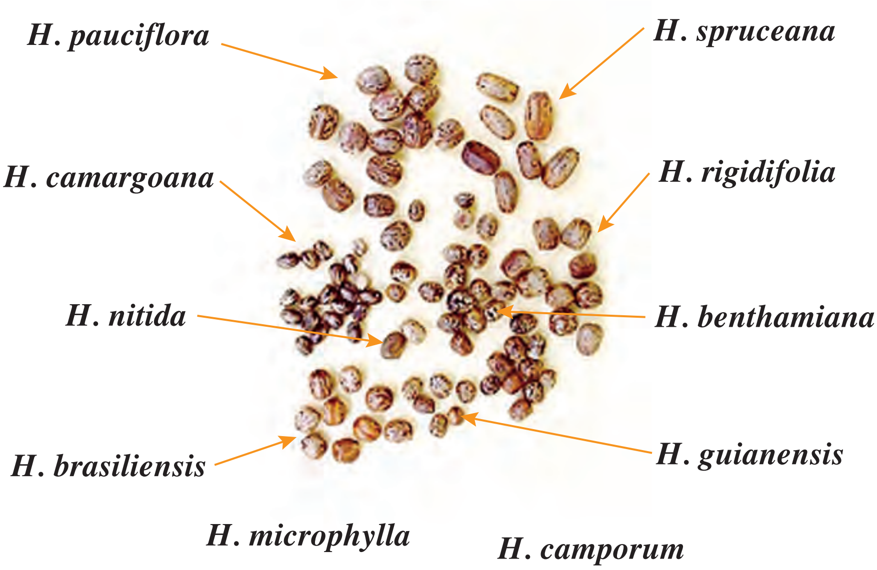

Budded stumps


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.

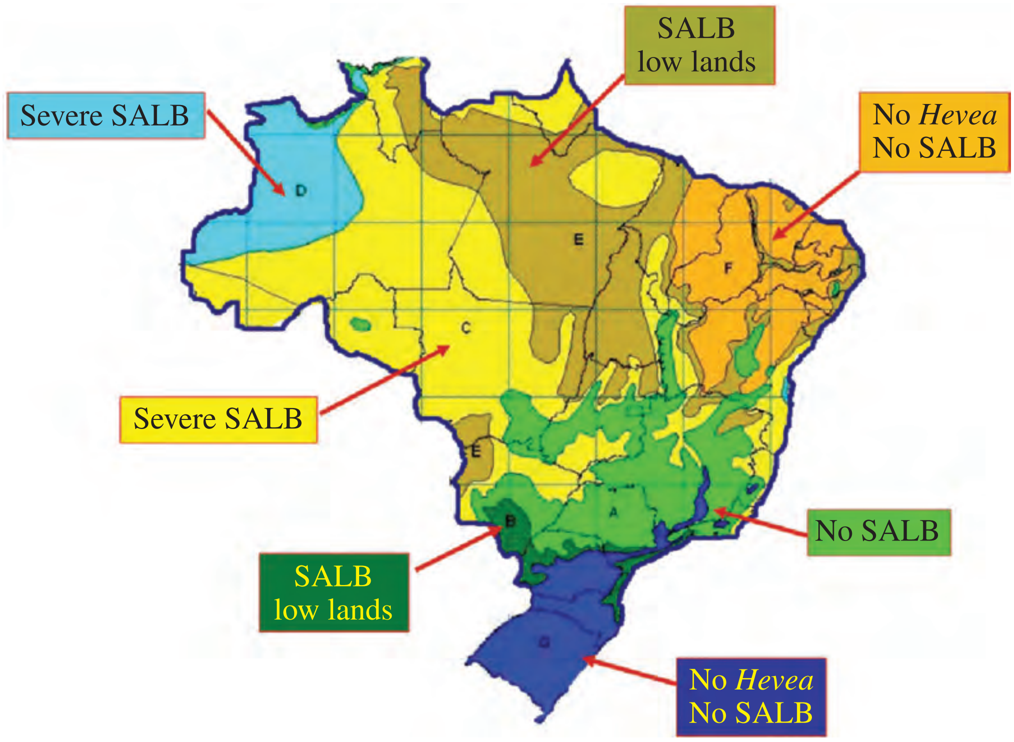
This publication briefly reviews the biology of SALB and its causal agent *M. ulei* (P. Henn.) v. Arx. The publication will be a useful guide to plant pathologists and plant quarantine officers who are dealing with SALB.

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.

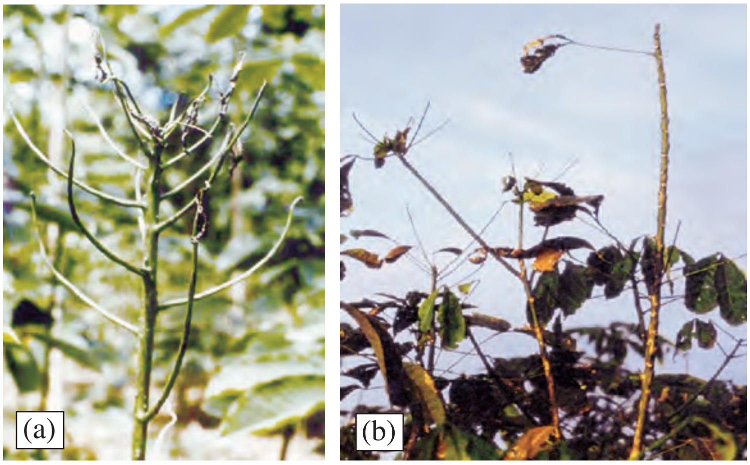
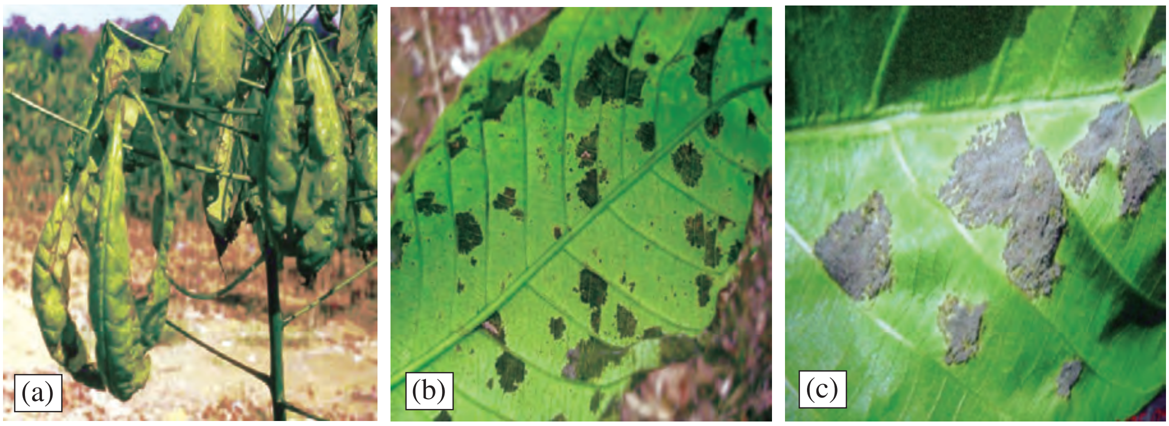


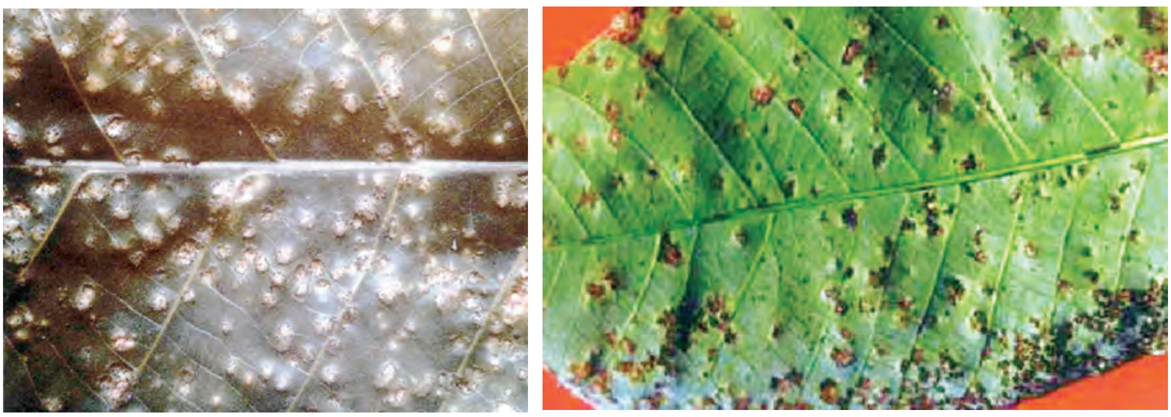
Figure 3. Symptoms on intact young leaves: (a) Distorted infected leaves; (b) and (c) Conidial lesions on the lower surface of the leaves.



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 pycnospores.

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

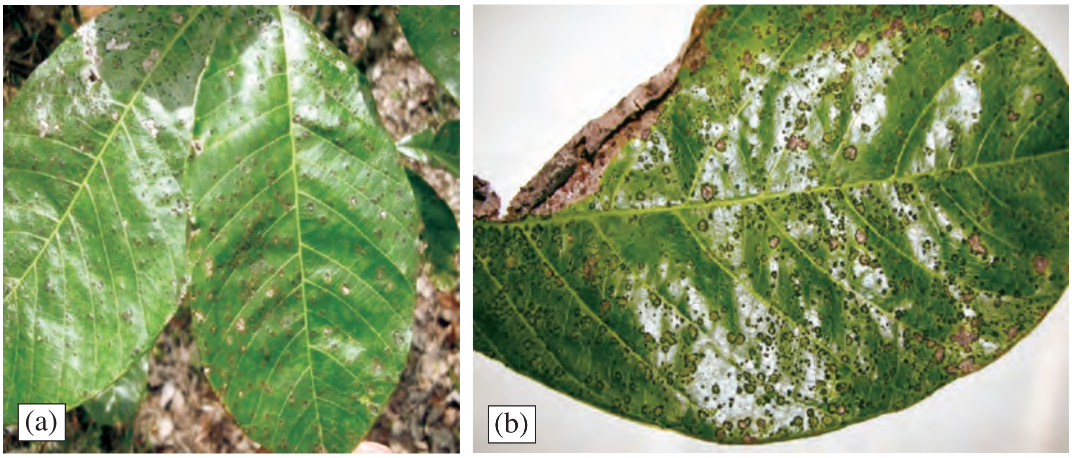


Figure 6. Symptoms on old leaves showing the shot holes formed following necrosis of tissues at the centre of the perithecia

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*)

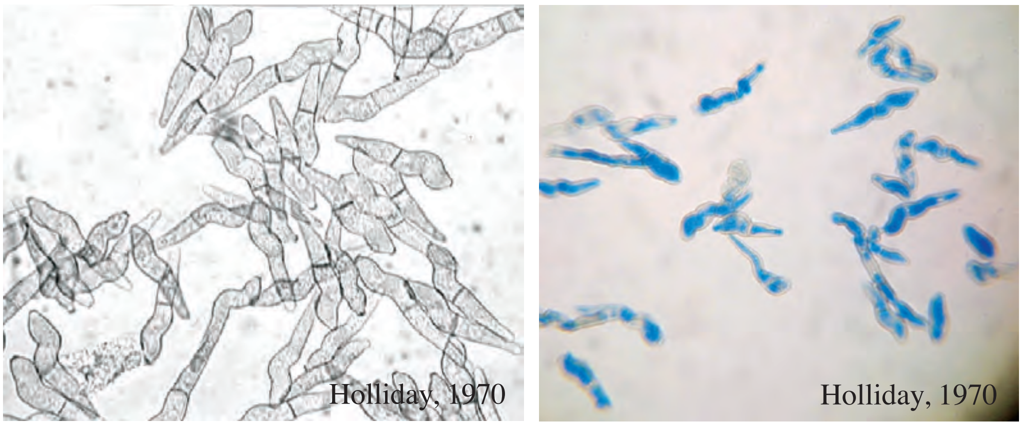
The pathogen of South American leaf blight (SALB) is the obligate fungus *Microcyclus ulei* (P. Henn.) v. Arx. The fungus was previously known by other names such as *Dothidella ulei* P. Henn., *Melanopsammopsis ulei* (P. Henn.) Stahel, *Fusicladium macrosporum* Kuyper (refers to the conidial state of 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.

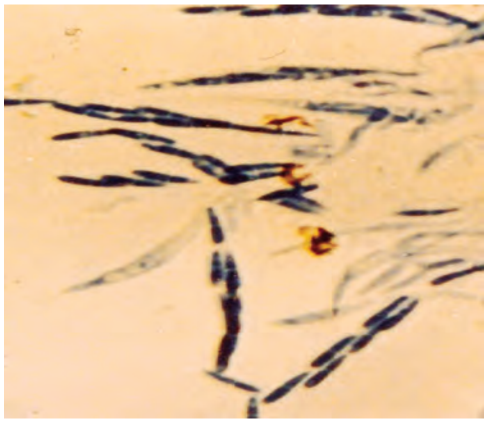
The pycnospores are dumbbell shape and small (6-10 μm long and 2-5 μm in width). The ascospore is oblong shaped and is made up of two cells of unequal size. The size of the ascospores also varies (Table 1).

Figure 9. Spores of *M. ulei*



(a) Conidia with two cells

(b) Pycnospores



(c) Ascospores

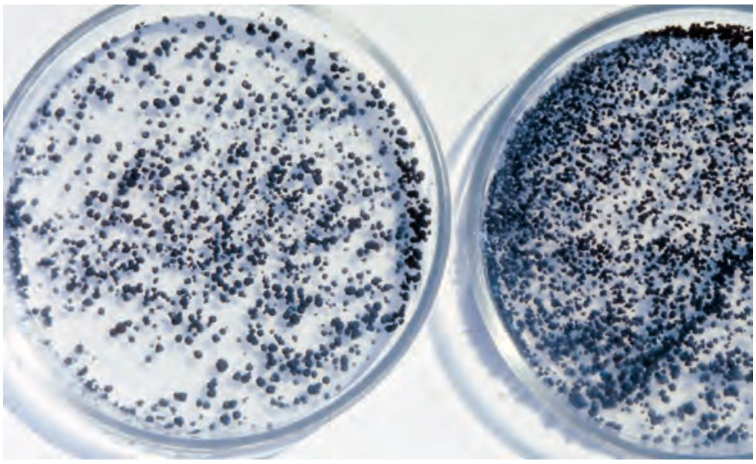
Table 1. Spores of *M. ulei*

Spore	Description	Size (Reference)
Conidia	Mostly septate with two cells with broader proximal cell, dark grey to olive green in colour, twisted; sometimes unicellular.	• 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.	• 6-10 μm (Holliday, 1970b) • 6-10 μm (Chee and Holliday, 1986)
Ascospores	Septate with two cells of unequal size, ellipsoidal, hyaline	• 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 ºC, 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 ºC 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 ºC and 65-95 percent R.H.	3-4 weeks
Conidia (intact)	24 ºC and 85 to 100 percent R.H.	2 weeks
	24 ºC and under dessication	16 weeks
Ascospores	24 ºC and 85 to 100 percent R.H.	9 days
Perithecia	24 ºC and 65 percent R.H.	3 weeks
	24 ºC 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 ºC) still survived (Lebai-Juri, 1995). Under dry condition, the conidia shrivel (Figure 11) and become turgid under high moisture.

Figure 11. Shrunken desiccated conidia

Holliday, 1970

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 dyas

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

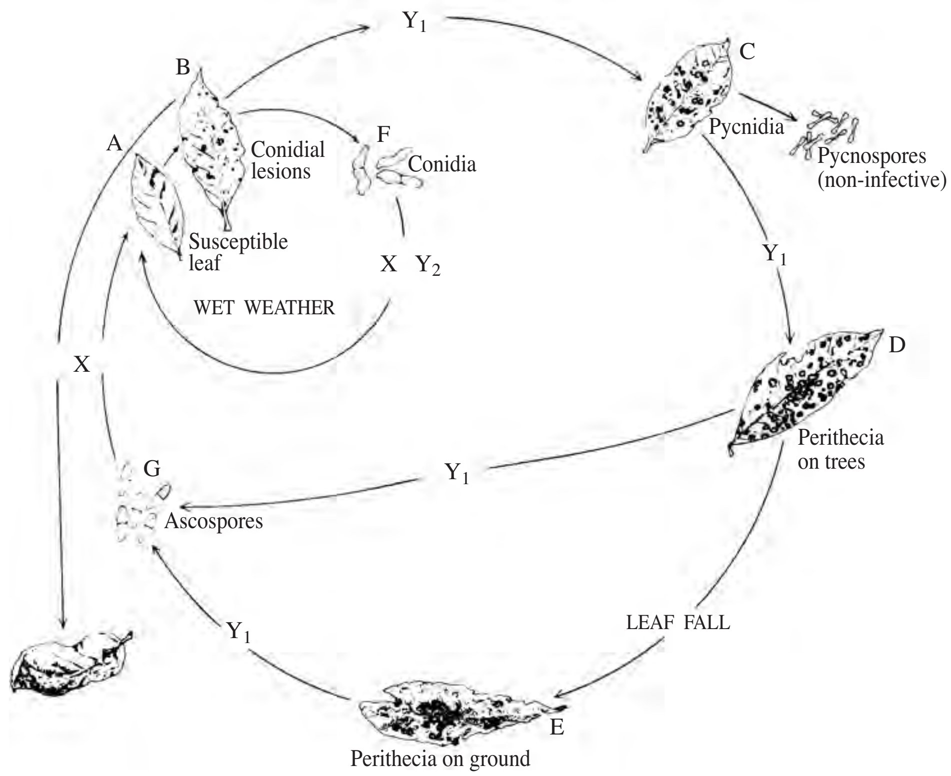
5.1 Disease dispersal

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 ºC (Chee, 1976). However, conidia and ascospores germinated between 14-36 ºC and 14-29 ºC 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 ºC and high humidity favours sporulation. Maximum infection occurred at 24 ºC and less at 18 ºC. 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 pycnospores had not caused infection following artificial inoculation though the pycnospores 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; Giesemannn, *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	• 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 186 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.

Lieberei, 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 *et al*., 1997) caused total kill
X-ray irradiation	Killed the conidia (Lebai Juri *et al*., 1997).
Commercial disinfectant, detergent, formalin liquid and gas or moist heat	Killed the conidia (Lebai Juri *et al*., 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. rigidofolia* 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.

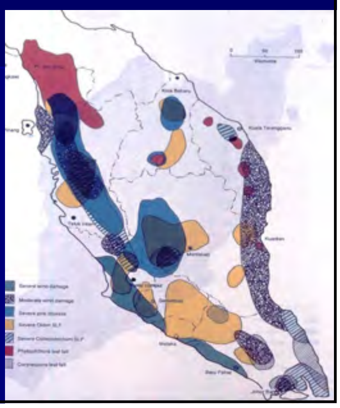
LEAF DISEASES

- 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

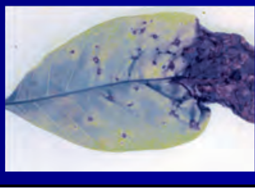


MAJOR LEAF DISEASES

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

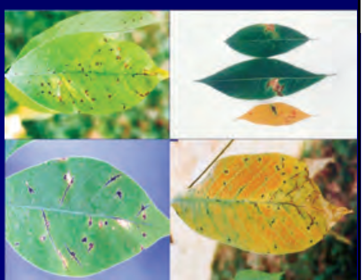
- Fungus – *Oidium heveae* (powdery mildew);
- China, India, Indonesia, Malaysia, Vietnam;
- Important on young and mature rubber;
- Cause leaf defoliation and reduces latex yield;
- Light rain with cool misty nights.

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 cassiicola*;
- 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.

Fusiccocum leaf disease

- *Fusiccocum* 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, Tjir 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, artifial 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
- Ustulina 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 DISEASEA

DISEASES	CONTROL METHODS
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 I'voire, 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	Ganoderma	Rigidoporus
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 I'voire, 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 n Asia and Africa.

Black crust and target leaf spot

- Black crust (Catacauma huberi)
- Target leaf spot

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

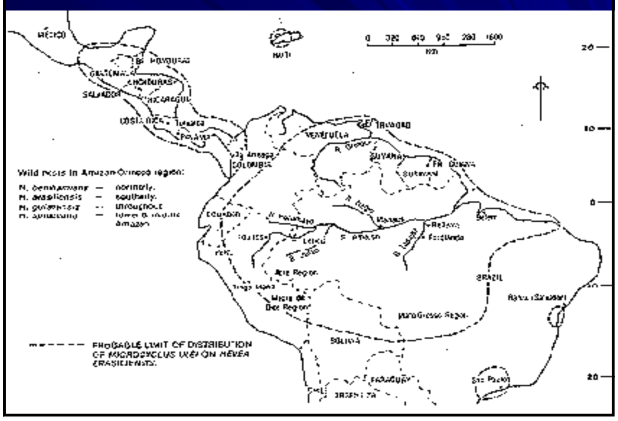
COSTA RICA

- 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 ºC (maximum 24 ºC)*
- 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

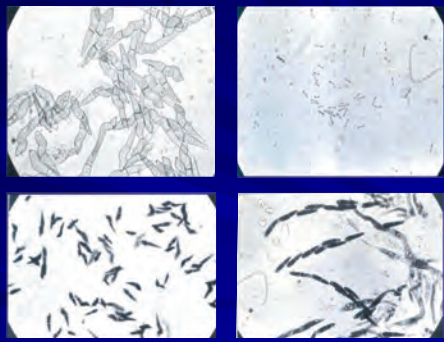
Material	Germination (%)
Infected Leaves	53.3
Cloth	31.6
Polyethylene	29.3
Leather	26.5
Glass	26.0
Hevea Leaves	21.0
Metal	6.3
Paper	5.8
Dry Soil	50.0
Moist Soil	10.0

THANK YOU

SALB – Epidemiology

THE EPIDEMIOLOGY AND HOST PARASITE INTERACTION OF SALB

SPORES OF *M. ulei*



DISEASE INFECTION

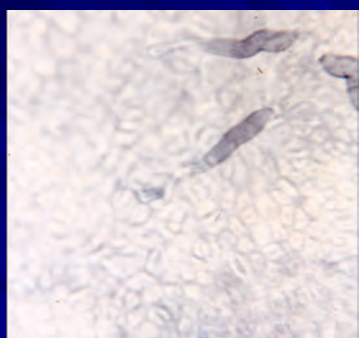
Conidia and ascospores are responsible for infection.

DISEASE SPREAD

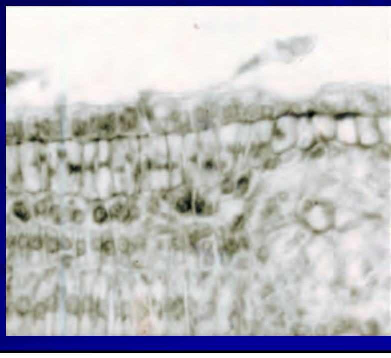
- Wind and rain splash;
- Insects and other animals;
- The ascospores initiate new disease cycle and the conidia are responsible for local spread of the disease.

GERMINATION

Conidia Infecting *Hevea* leaf

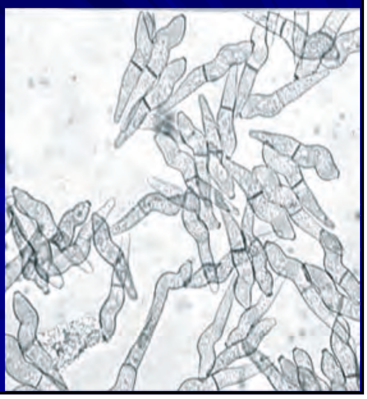


Infection by conidia



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

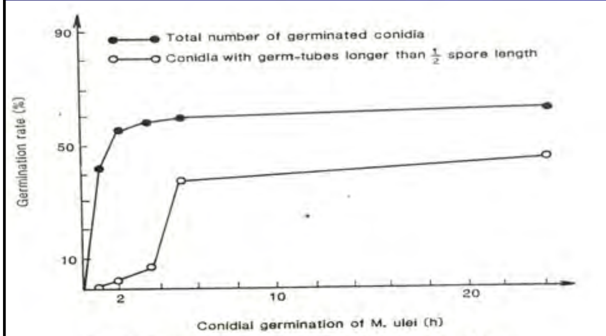


Figure 3. Rate of conidial germination of M. ulei *in relation to time.*

SEASONAL EFFECT OF CONIDIAL GERMINATION

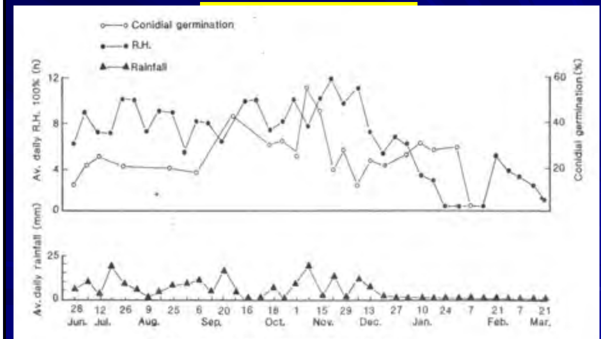
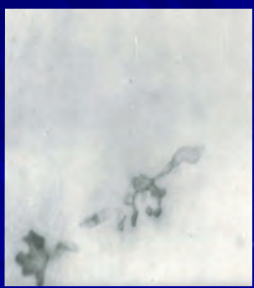
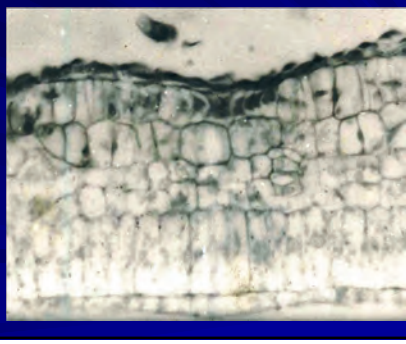


Figure 4. Seasonal effect of conidial germination of M. ulei.

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

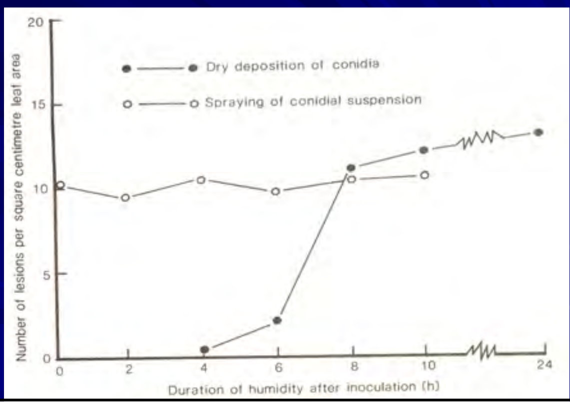
EFFECT OF RAINFALL ON SEVERITY

- **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 ºC;**
- **High humidity favors spore production.**

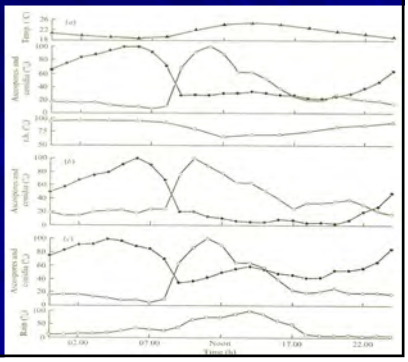
SPORE LIBERATION

SPORE LIBERATION

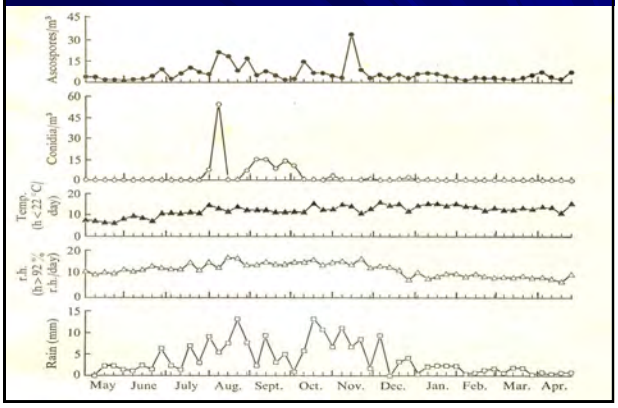
- Spore liberation varies with weather conditions;
- Diurnal periodicity in liberation of spores;
- Conidia liberation:
  - Low at night and rises in the morning;
  - Peak at mid day (10 a.m. to 12 p.m.) and declines there after.
- Ascospore liberation:
  - Ascospore are released at night and peak at 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 ^{0}C and 70% R.H.
  - 80 ^{0}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. 24 °C, desiccation	2 weeks 16 weeks
Ascospores	24 °C, 85-100% R.H.	9 days
Perithecia	24 °C, 65% R.H. 24 °C, 100% R.H.	3 weeks 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 macrosporuum (Kuyper)
Passalora *heveae* (G. Masee)
Scolecotrichum ulei (Griffon and Maublanc)
Melanosammopsis ulei (Stahel)
Microcyclus ulei (P. Henn.) von Arx

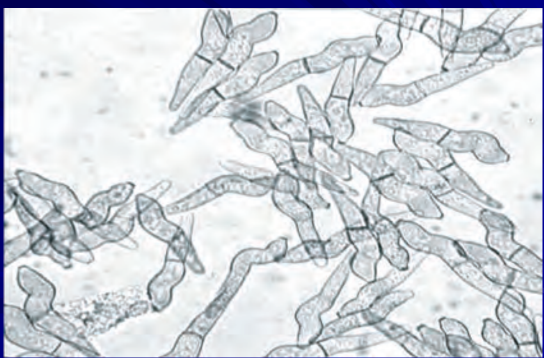
NOMENCLATURE

- 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

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

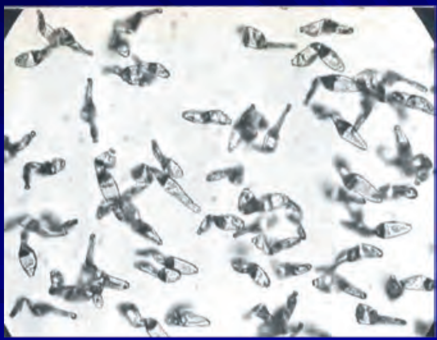
Microcyclus ulei − conidia



CONIDIA

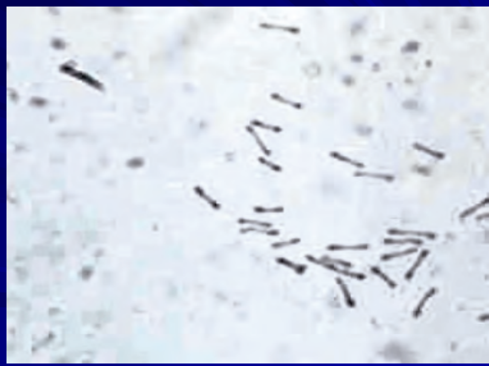
- Either septate (two cells) or aseptate (one cell). Percentage of aseptate conidia increased in drier periods and more common from laboratory cultures.
- Septate conidia are obclavate with broad proximal cell with truncate distal end.
- Possess a characteristic twist.
- Hyaline when young and turn grayish 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

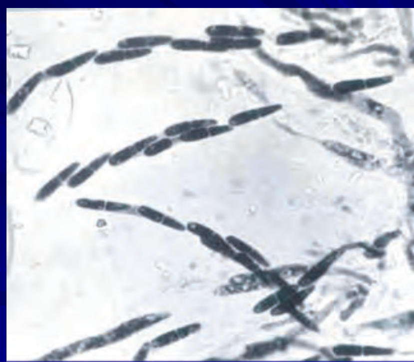
Microcyclus ulei – pycnospores



Pycnospores

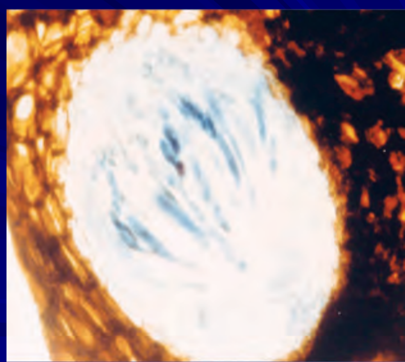
- Dumb bell shaped.
- One end larger (12-25 µm) than the other end (2-5 µm).
- 6-10 µm in length.
- Borne on hyphal elements.
- Germinate but do not cause infection.

Microcyclus ulei – ascospores

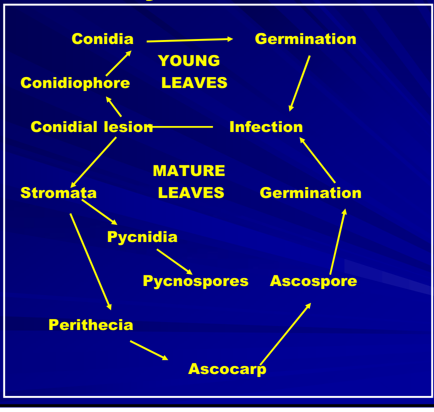


ASCOSPORES

- 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*



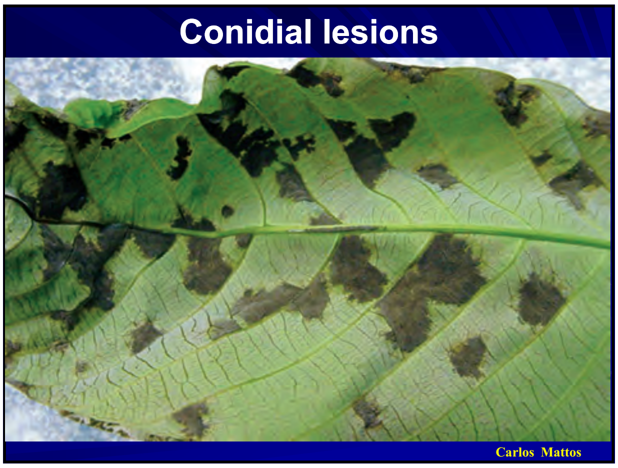
PLANT PARTS INFECTED

- 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

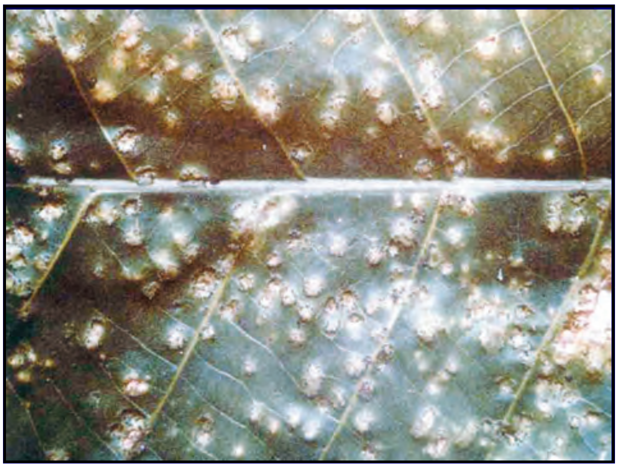
- The symptoms depend on the age of leaves at time of infection;
- The young copper brown leaflets shrivel, curl, turn blackish and drop-off leaving the petioles for several days on the stems;
- The fully expressed conidial lesions are seen on the lower surface of the green leaflets;
- The lesions are 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



SYMPTOMS

- First visible symptoms are the distortion of leaves.
- Visible symptoms occur 2-3 days after inoculation.
- A few days later irregular shaped lesions developed on lower surface of leaves.
- Lesions appear dark or olive green.
- Size of lesions depends on susceptibility of leaves (age & clone).

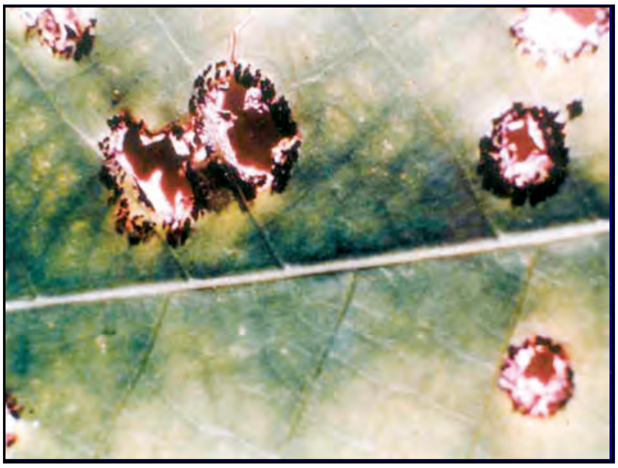


THE PYCNIDIA

- The pycnidia are small (120-160 µm diameter) dark bodies forming on the upper leaf surface along the periphery of lesions on the lower leaf surface;
- The pycnidia produce the pycnospores.

THE PERITHECIA

- At the site of the pycnidia large (200-400 µm diameter) raised black bodies (perithecia) developed;
- The perithecia produced the ascospores.



OTHER PLANT PARTS INFECTED

- Flower stalks
- Young fruits
- Young shoots
- Young stems


Infection of inflorescence


Infected fruit pods


Cocoa plants growing under rubber infected with SALB

Shoot dieback and dead branches

PHYSIOLOGICAL RACES OF *M. ULEI*

- Occurrence of new race causes breakdown of resistance;
- Many races occur;
- Miller identified four races;
- Chee identified 9 races in Bahia;
- Ismail & Almeida confirmed 4 races (2, 3, 4 & 6);
- Rivano identified 12 races;
- Large number of strains - >50 (Pinheiro);
- Strains also differ in virulence.

THANK YOU

SALB Disease management

MANAGEMENT OF SOUTH AMERICAN LEAF BLIGHT (SALB)

STRATEGIES TO CONTROL SALB

- Chemical Control
- Biological Control
- Cultural practices:
  - Plant Resistant Clones;
  - Plant in Disease Escape Areas;
  - Crown Budding With Resistant Clones.

CHEMICAL CONTROL OF SALB

Fungicides Effective Against *M. ulei*

- Dithane M-45 *(mancozeb)*
- Benlate *(benomyl)*
- Cercobin M *(thiophanatemethyl)*
- Daconil *(chlorothalonil)*
- Bayleton *(triadimefon)*
- Saprol *(triforine)*
- Bayfidan *(triadimenol)*
- Tilt *(propiconazole)*

FUNGICIDE SCREENING METHODS

- Laboratory methods:
  - Germination of conidia in fungicide solutions or fungicide treated cellophane film disks;
  - Infection of fungicide treated detached leaflets or leaf disks.
- Nursery methods

Spraying of fungicides

CHEMICAL CONTROL

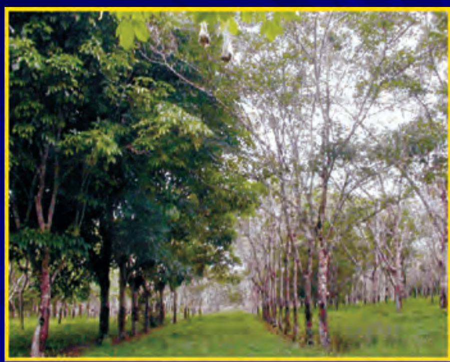
- Commence spraying when young leaves are emerging after annual leaf change;
- Repeat weekly spraying until leaves mature;
- Numerous rounds are required;
- Tractor mounted mist blowers, helicopters and aeroplanes had been used;
- Fogging machines were tried;
- Chemical control increased latex yield.

INTEGRATED CONTROL

- Integrating fungicide spraying with chemical control to rehabilitate an area;
- Integrating chemical control with disease tolerant clones;
- Integrating chemical control with biological control.

RESISTANT CLONES

RUBBER CLONES RESISTANT AND SUSCEPTIBLE TO SALB



RESISTANT CLONES

- High yielding resistant clones are lacking;
- Breakdown of resistance of a clone e.g. IAN 717 when a new race (Race 2) of *M. ulei* occurs;
- Some tolerant clones have been planted;
- Immune *Hevea* species e.g. *H. pauciflora* (PA 31) has been utilized as source of resistance;
- Important to breed for clones with horizontal resistance.

USE OF MOLECULAR TECHNIQUES

- Traditional breeding techniques
- Use of molecular techniques in rubber breeding
  - QTLs for SALB resistance identified.

<u>MECHANISM OF *HEVEA* RESISTANCE TO SALB</u>

- Vertical resistance (Hypersensitive cell collapse);
- Horizontal resistance – infected but tolerate disease;
- Passive resistant factors not important;
- Resistance contributed by active resistant factors:
  - Increase in certain enzyme activities;
  - Accumulation of polyphenols (scopoletin);
  - Associated with HCN liberation.

<u>BIOLOGICAL CONTROL</u>

- *Hansfordia pulvinata* (*Dicyma pulvinata*) is antagonistic to *M. ulei*;
- Shown to control SALB in glasshouses and small scale field trials.

Biological control of SALB by *Dicyma pulvinata* (*Hansfordia pulvinata*)

<u>OTHER BIOLOGICAL CONTROL AGENTS</u>

- *Periconia manihoticola*
- Avirulent strain of *M. ulei*
- VA mycorhiza

<u>Induced resistance by incompatible race of *M. ulei*</u>

POLYPLOIDY

- Polyploid plants were produced by colchicine or X-ray treatments
- Some polyploid (4n) plants are more resistant to SALB

CULTURAL CONTROL OF SALB (1)

- Planting in disease escaped areas. Disease escaped areas are areas with climatic conditions not suitable for serious disease development;
- Areas with low rainfall and long dry periods;
- Escaped areas – Sao Paulo and Matto Grosso;
- Common oriental clones such as Gt 1, RRIM 600 and PB 260, PB 235 were successfully planted.

Gt 1 in an escaped area

PB 235 in an escaped area

CULTURAL CONTROL OF SALB (2)

- Crown budding with immune or tolerant crown;
- Immune species *H. pauciflora* (PA 31) has been commercially used;
- Other tolerant clones (FX 3899, FX 3810, FX 3925, IAN 7388) were used as crown;
- There is a problem of incompatibility and crown clones depressing latex yield of trunk clones.

Crown budding

PA 31 Crown on trunk of oriental clone

QUARANTINE MEASURES

SPECIFIC QUARANTINE MEASURES

- National SALB Committee
- National SALB Contingency plan
- Advise returning passengers from SALB areas to break journey
- Announcement in plane
- Plant quarantine declaration card
- Treatment measures on bag ages – UV irradiation, air tunnel, floor mats soaked with disinfectant etc.

POSSIBLE METHODS OF INTRODUCTION OF SALB

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

EFFECT OF UV IRRADIATION ON CONIDIA GERMINATION

Exposure time (min)	Germination (%)	
	6 h incubation	24 h incubation
5	5-10%	30%
10	1-3%	10-15%
15	0%	5-10%

EFFECT OF UV LIGHT AND OTHER TREATMENTS ON SPORE SURVIVAL

Treatment	Spore survival
UV irradiation	Some conidia (5-10%) germinated after 15 min however 45-60 min exposure totally killed conidia.
X-ray	Killed the conidia
Disinfectant, Detergent, Formalin	Killed the conidia

EFFECT OF HEAT ON CONIDIA GERMINATION

Temperature °C	Germination %	
	Dry heat 30 min	Moist heat 30 min
50	–	3-5
55	–	0
70	30	–
75	–	–

INCREASE AWARENESS AND MANAGEMENT CAPABILITIES

ANRPC

- Workshop on SALB in Brazil
  - 1984, 1991, 1994, 1997
- Courses on SALB
  - Conducted in Malaysia / Indonesia

IRRDB

ACTIVITIES OF IRRDB ON SALB

- IRRDB SALB fellowship – produced trained diagnosticians
- Widening of genetic base of rubber for breeding
- 1984 Workshop on SALB in Brazil
- Workshop on SALB in Ivory Coast (1988) and Brazil (May 2004)
- Promotes research on SALB

Quarantine measures againt

QUARANTINE MEASURES AGAINST SOUTH AMERICAN LEAF BLIGHT (SALB)

ECONOMIC IMPORTANCE OF 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*).

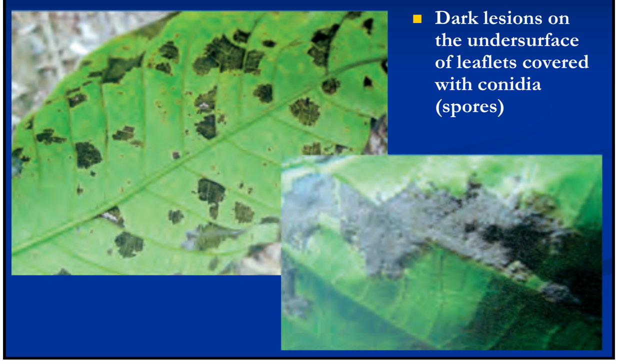
THE PATHOGEN OF SALB

- *Microcylus ulei* – a fungus
- An ascomycete with asexual and sexual stages

SYMPTOMS

- First visible symptoms are the distortion of leaves.
- Visible symptoms occur 2-3 days after inoculation.
- A few days later irregular shaped lesions developed on lower surface of leaves.
- Lesions appear dark or olive green.
- Size of lesions depends on susceptibility of leaves (age & clone).

YOUNG LEAVES

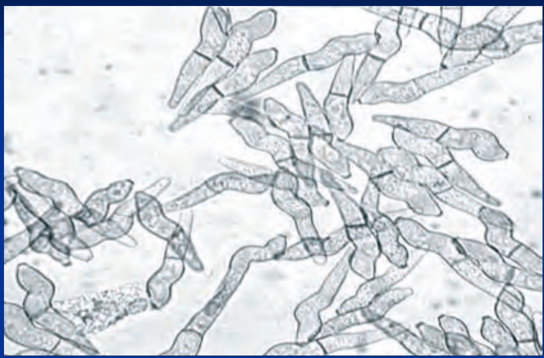


- Dark lesions on the undersurface of leaflets covered with conidia (spores)

Conidial lesions

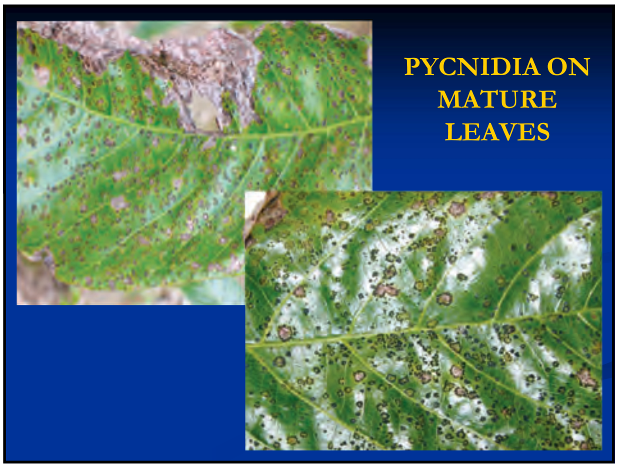
Carlos Mattos

Microcyclus ulei – conidia



CONIDIA

- Mostly septate with two cells with proximal cell broader and tapering distal cell;
- Sometimes single cell depending on weather and growing conditions;
- Characteristic twist;
- Most important for infection and disease spread;
- Present in abundance during wet weather.



PYCNIDIA ON MATURE LEAVES

THE PERITHECIA

- At the site of the pycnidia large (200-400 µm diameter) raised black bodies (perithecia) developed;
- The perithecia produced the ascospores
- Ascospores cause infection and spread SALB;
- Present throughout the year.

Microcyclus ulei – ascospores

PAST DESTRUCTION BY SALB

SURINAM	1911 – 40,000 Tree Planted
	1918 – Plantation Destroyed
PANAMA	1935 – Good year plantation started
	1941 – Plantation destroyed
BRAZIL	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 as 100,000 ha were infected with SALB
COSTA RICA	1935 – Goodyear Speedway estate was planted
	1941 – Severely infected by SALB.

History indicated that SALB caused a serious problem within 6-7 years of establishment of a plantation

ECONOMIC IMPORTANCE OF SALB

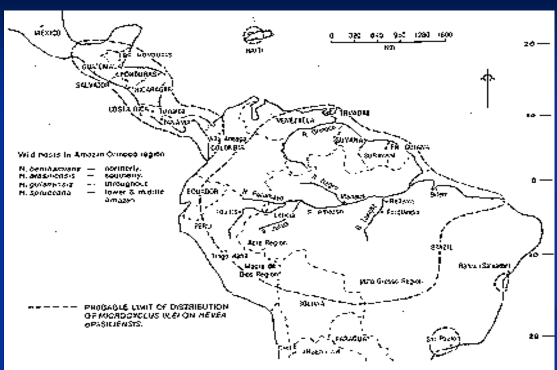
- Reduces tree growth
- Prolongs the immaturity period
- Reduces latex productivity by as much as 70%
  - Productivity of RRIM 600 in Brazil – 11.2 g/t/t and 15.9 g/t/t
  - Productivity of RRIM 600 in Malaysia – more than 60 g/t/t
- Kills the rubber plants and reduce density of stand
- Increases cost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

Trees with poor canopy and dead branches

IMPACTS OF SALB ON THE TREE

- Repeated leaf defoliation
- Shoot dieback
- Trees with poor canopy
- Kill the trees

The distribution of SALB (Holliday, 1970)



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

PHYSIOLOGICAL RACES OF *M. ULEI*

- Occurrence of new race causes breakdown of resistance;
- Many races occur;
  - Miller identified four races;
  - Chee identified 9 races in Bahia;
  - Ismail & Almeida confirmed 4 races (2, 3, 4 & 6);
  - Rivano identified 12 races;
  - Large number of strains >50 (Pinheiro);
- Strains also differ in virulence.

SALB IS A THREAT TO RUBBER IN ASIA AND AFRICA

THE THREAT OF SALB IS REAL

- Suitable climatic conditions
- Abundant susceptible clones
- Contiguous rubber plantings
- Rubber plant is mainly planted in smallholdings and hence early disease detection and control difficult.

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 (Negeri Sembilan)
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

Chee

EFFECT OF RAINFALL ON SEVERITY OF 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

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.

POSSIBLE METHODS OF INTRODUCTION OF SALB

- Infected *Hevea* plant parts
- Viable spores contaminating travelers, their belongings and imported commodities
- Spores of *M. ulei* could survive for a reasonably long time

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
Conidia (intact)	24 °C, desiccation	16 weeks
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

Zhang, 1986

QUARANTINE MEASURES

FAO ESTABLISHED THE PLANT PROTECTION AGREEMENT FOR THE SOUTH EAST ASIA AND PACIFIC REGION IN 1955

PLANT PROTECTION AGREEMENT FOR THE SOUTH EAST ASIA AND PACIFIC REGION

- Article IV

MEASURES TO EXCLUDE SALB OF HEVEA FROM THE REGION

In view of the importance of the *Hevea* rubber industry in the Region, and the danger of introducing the South American leaf blight of *Hevea* rubber tree, the Contracting Governments shall take the measures specified in Appendix B to this Agreement. Appendix B to this Agreement may be modified by a decision of the Committee taken unanimously.

PLANT PROTECTION AGREEMENT FOR THE SOUTH EAST ASIA AND PACIFIC REGION

- Appendix B: MEASURES TO EXCLUDE SALB
  - Prohibit the importation of any plant or plants of the Genus *Hevea* from outside the region unless ….(certain conditions are met);
  - Prohibit the importation of any plant or plants of the Genus *Hevea* capable of further growth (excluding seeds) from American Tropics or SALB country;
  - Prohibit the importation of any seed of any plant of the Genus *Hevea* unless …. (specific requirements are met);
  - Prohibit the importation of any plant or plant parts of the Genus *Hevea* not capable of further growth or propagation unless ….(specific requirements are met);
  - Prohibit the importation of any plant or plants other than the Genus *Hevea* capable of further growth or propagation from American Tropics or SALB country unless ….(specific requirements are met);
  - The Competent Authority must ensure that any importation of *Hevea* plants for propagation must be grown under control and release only after they are free of any pests and diseases.

AMENDMENTS OF THE AGREEMENT

- The Plant Protection Agreement for Asia and Pacific region had been revised to update and align the Agreement with the International Plant Protection Convention (IPPC, 1997) and the WTO Application of Sanitary and Phytosanitary (SPS) Measure;
- The Amendments were adopted at the 21st Session of the APPPC in Yogyakarta in 1999.

PEST RISK ANALYSIS (PRA)

- PRA is the process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it;
- PRA of SALB was done.

PRA OF SALB

(1) Examine and evaluate risks of SALB being associated with the relevant commodities/ pathways from the SALB endemic countries into the Asia and Pacific region;

(2) Evaluate risks of introduction and spread of SALB into region;

(3) Evaluate the economic consequences resulting from the occurrences of SALB and;

(4) Evaluate various management options to mitigate these risks.

VECTORS (PATHWAYS) OF SALB INTRODUCTION

(1) Host material (*Hevea* species):
- Budded stumps or budwood
- Foliage (stem and leaf material not for planting)
- Flowers, fruits and seeds
- Plants *in vitro*
- Wood

(2) Non-host materials:
- Inanimate goods or non-host organic materials
- Inanimate goods or non-host organic material contaminated by host plant materials.

PROBABILITY OF ENTRY THROUGH HOST MATERIALS (*Hevea* Species)

Vector	Probability of association	Probability of transit by Sea/Air	Probability of transfer to a suitable host	Conclusion of Probability of Entry
Budded stumps or budwood	High	High	High	High
Foliage (stem and leaf material not for planting)	High	High	Low (< $1cm^2$)	Low (< $1cm^2$)
Flowers, fruits and seeds	Moderate	Low (sea) to Moderate (Air)	Low	Low
Plants *in-vitro*	Negligible	N/A	N/A	Negligible
Wood	Negligible	Negligible	Negligible	Negligible

PROBABLY OF ENTRY THROUGH NON-HOST MATERIALS

Vector	Probability of association	Probability of transit by Sea/Air	Probability of transfer to a suitable host	Conclusion of Probability of Entry
Inanimate goods or non host organic material	Low	Negligible	N/A	Negligible
Inanimate goods or non-host organic material contaminated by host plant material	Moderate	Low (Sea), Moderate (Air)	Low (< $1 cm^2$)	Low (< $1 cm^2$)

PROBABILITY OF INTRODUCTION, SPREAD AND CONSEQUENCES THROUGH HOST MATERIALS

VECTOR	ENTRY	ESTABLISHMENT	SPREAD	IMPACT	RISK
Budded stumps or budwood	High	High	High	High	High
Foliage (leaf and stems not for planting)	Low	High	High	High	Moderate
Flowers, fruits and seeds	Low	High	High	High	Low
Plants *in vitro*	Negligible	Not applicable	Not applicable	Not applicable	Negligible

PROBABILITY OF INTRODUCTION, SPREAD AND CONSEQUENCES THROUGH NON-HOST MATERIALS

VECTOR	ENTRY	ESTABLISHMENT	SPREAD	IMPACT	RISK
Inanimate goods or non-host organic materials	Negligible	N/A	N/A	N/A	Negligible
Inanimate goods or non-host organic materials contaminated by host plant materials	Low (if <1 cm)	High	High	High	Low (if <1 cm)

PROBABILITY OF ESTABLISHMENT AND SPREAD

- The probability of establishment within the rubber growing areas of the PRA area should be considered high if SALB is introduced into a suitable environment on appropriate host material.
- The probability of spread within the rubber growing areas of the PRA area should be considered high if SALB is introduced into a suitable environment and an area where sufficient host material is available.

STANDARD ON SALB

- A Standard on SALB was established;
- Aims to assist APPPC member countries to protect the Region against SALB;
- The Standard provides guidelines to improve or develop phytosanitary measures including prevention, eradication and control against SALB.

STANDARD ON SALB – MAJOR AREAS

- The prevention of the introduction of SALB;
- The establishment of eradication or control programmes in the case of entry of SALB;
- The development of training programmes on inspection and diagnostic methods, surveillance, eradication and control programmes;
- The description of minimum requirement for personnel and facilities;
- The establishment of co-ordination and co-operation activities for SALB programme.

RISK MANAGEMENT

A. Viable host material:

- Plants for planting: Whole plants and cuttings, and plants *in-vitro*;
- Seeds, flowers and fruit.

B. Non-viable (inanimate) host material:

- Cargo pathway (including sea freight, airfreight and mail);
- Passenger pathway (including accompanied luggage).

STANDARD ON SALB – RELEVANT POINTS

- The Outline of Requirements in the standard is specific to APPPC rubber growing countries;
- The PRA and Standard apply only to FAO member countries in the Asia and Pacific region. Non member countries in the Region are not compelled to adopt measures in the Agreement;
- Similar quarantine measures should be taken for Africa;
- The risk of SALB establishing in Africa is real due to close proximity, existence of direct flights.

ANRPC SALB COMMITTEE

- National SALB Committee was established in some member countries
- National SALB Contingency plan
- Advise returning passengers from SALB areas to break journey
- Announcement on SALB in plane
- Establish plant quarantine declaration card
- Undertake treatment measures on baggage of passengers from SALB areas – UV irradiation, air tunnel, floor mats soaked with disinfectant etc.
- Increase awareness through workshops and courses.

IRRDB: ACTIVITIES OF IRRDB ON SALB

- IRRDB SALB fellowship – produced trained diagnosticians
- Widening of genetic base of rubber for breeding
- 1984 Workshop on SALB in Brazil
- Workshop on SALB in Ivory Coast (1988) and Brazil (May 2004)
- Promotes research on SALB

Section 1.5. Banner and poster

Banner


CAUTION!
South American Leaf Blight
(SALB)
the most
destructive
disease which can
destroy our rubber
PREVENT
ITS ENTRY
INTO OUR
COUNTRY!

Poster


CAUTION!
South American Leaf Blight
(SALB)
a serious disease
which can destroy
our rubber
PREVENT ITS
ENTRY INTO
OUR
COUNTRY!

Section 1.6. Bibliography

BIBLIOGRAPHY ON SOUTH AMERICAN LEAF BLIGHT

INTRODUCTION

Research on SALB and the causal pathogen *Microcyclus ulei*, commenced in the 1960s mainly in the American universities and research institutions in Central America and Brazil. However, research on the disease intensified in the 1970s especially in Brazil. The Rubber Research Institute of Malaysia (RRIM) established a special unit based in Trinidad and Tobago in 1960s to 1970s. In 1980, the RRIM conducted research on SALB in Brazil. Several Brazilian institutions notably Instituto Agronomico do Norte (IAN) and Centro Nacional de Pesquisa de Seringueira and Dende (CNPSD) and CEPLAC also carried out research on SALB. France through CIRAD is also involved in research on SALB. The private sector also contributes to research on SALB. The Ford Motor Company carried some research when they were involved in the early cultivation of rubber in the Americas. Currently, Michelin conducts research on SALB especially at its plantation in Brazil.

This publication is a collection of articles on SALB and its causal agent *M. ulei* with a brief abstracts. The publication is a reference for plant pathologists and plant quarantine officers to gather information on SALB.

PUBLICATIONS

1. Albuquerque, P.E.P., Pereira, J.C.R. and Santos, A.F. dos. (1987). Efficiency of impaction of fungicides by thermal fogging in leaves of *Hevea* spp. *Revista Theobroma*, 17: 189-199.

   In Southeast Bahia, Brazil, Phytophthora leaf wither (*Phytophthora* spp.) and South American leaf blight (*Microcyclus ulei*) were the most destructive rubber (*Hevea* spp.) diseases. Leaf diseases are the limiting factor for a viable cultivated rubber. Disease control requires timely and rapid applications of fungicides for protection of young leaves and shoots appearing after the wintering season. The effectiveness of thermal fogging of copper in oil (0.9 1/ha) was tested. Copper in oil at recommended doses did not perform well as high zoospore germination (>80 percent) occurred and only few droplets of fungicides impacted on artificial targets (10 droplets per cm^2). Field observation and laboratory bio-assays showed that thermal fogging produced inconsistent results suggesting ineffective control.

2. Alencar, H., Peixoto, E. and Ferreira, H.I.S. (1975). Controle do mal das-folhas (*Microcyclus ulei*) da seringueira na Bahia. II. Relacao custo/beneficio da aplicacao aerea de fungicida, regiao de Itubera, 1972-73. *Revista Theobroma,* 5: 12-20.

   The cost benefit of aerial spraying of mancozeb using a Piper 235 aircraft to control *Microcyclus ulei* in a rubber plantation (clone IAN 873) was analysed. At the additional cost of Cr$400.00 per ha, net additional returns of Cr$3,000.00 per ha were obtained, implying a net return for the treatment of 825 percent. In order to check this excellent result, similar trials have to be carried out in plantations with different clones.

3. Almeida, H.A., Santana, S.O. and Sa, D.F. (1987). Edaphic-climatic zoning for rubber in southeast Bahia, with emphasis for incidence of the South American leaf blight. *Revista Theobroma*, 17: 111-123.

   A study on climate-soil-plant interactions was carried out to identify the agricultural limits for rubber cultivation. Climatic parameters such as rain-fall, air temperature, relative humidity, water deficit, water excess and hydric index and soil factors associated with agricultural characteristics (natural fertility, texture, drainage, effective depth and mechanization suitability) were used to

identify potential zones for rubber cultivation that is free from the South American Leaf Blight, a disease caused by *Microcyclus ulei* (P. Henn.) v. Arx. The results indicated that Southeast Bahia has: (1) a suitable area (10 000 km^2) for the expansion of the rubber crop; (2) two intermediate areas (24 000 km^2) classified as Marginal to Moderate and the Fully Suitable to Moderate; and (3) five unsuitable areas, comprising 54 000 km^2 characterized by hydric excess (Marginal area) and water deficit and/or thermic deficiency. Based on edaphic factors and climatic elements, an area of about 6 500 km^2 was suitable for rubber. There are areas with excellent or good edaphic-climatic conditions for rubber crop in Southeast Bahia.

4. Altson, R.A. (1924). Report of the assistant botanist and mycologist. *Report Department Science Agriculture British Guiana*, 1923, 39 pp.

   Infection by SALB had contributed to the abandonment of large cultivation of rubber.

5. Altson, R.A. (1955). South American leaf blight. *Journal Rubber Research Institute Malaysia,* 14: 338-354.

   This original article was published in 1948. The article draws attention to the importance of SALB to the rubber industry in Malaya. The defence measures against its introduction and means to deal with the disease once established were presented.

6. Anonymous (1914). Leaf diseases of *Hevea*. *Planters' Chronicle*, 9: 272-273.

   Dothidella ulei, Fusicladium macrosporum and *Passalora heveae* were reported on rubber leaves in South America.

7. Anonymous (1917). Plantation rubber in British Guiana. *India Rubber World,* 56: 552.

   Rubber plant in British Guiana was infected by *Fusicladium macrosporum*, *Hymenochaete noxia*, *Thyriduria tarda* and *Fomes semitostus*.

8. Anonymous (1941). South American leaf spot disease of *Hevea*. *Report Canal Zone Experimental Gardens*, 1940, p. 28-29.

   The outbreak of SALB coincided with the beginning of planting of rubber by Goodyear near Gatun Lake in 1935. The rubber planting materials originated either from Philippines or Panama Canal Zone where the first outbreak of SALB occurred in 1939. Many seedlings from Haiti were badly infected in an isolated site near Summit. These seedlings were apparently healthy in 1938.

9. Anonymous (1950). Natural rubber production in the western hemisphere. *World Crops,* 2: 75-77.

   The cooperative programme between USA and 12 Latin American countries to establish rubber production in the American tropics was documented. SALB is controlled by fungicides as well as top budding susceptible clone with a resistant crown.

10. Anonymous (1952). South American leaf blight. *Planters' Bulletin Rubber Research Institute Malaysia,* 3: 54-56.

    Measures against entry of SALB to Malaya were listed. These measures include introduction of legislation governing the importation of planting material, acquisition of resistant planting material, and development of measures to eradicate the disease should it enter into the country.

11. Anonymous (1953). South American leaf blight of rubber. *Planters' Bulletin Rubber Research Institute Malaysia,* 5: 35-38.

The symptoms of SALB with colour illustrations were presented and method of despatching suspected diseased specimen given.

12. Anonymous (1953). South American leaf blight. *Planter' Bulletin Rubber Research Institute Malaysia,* 5: 48.

SALB was reported in the Republic of Honduras. Its spread to Central America from its source in the Amazon basin was believed to be through windborne spores.

13. Anonymous (1960). Secondary leaf fall and South American leaf blight. *Planters' Bulletin Rubber Research Institute Malaysia,* 46: 3-7.

Symptoms of SALB were described to assist planters in the recognition of the disease.

14. Anonymous (1961). Jaarverslag 1960. *Meded. Landb. Proefst. Suriname* 25, 92 pp.

Rubber plantings were kept free from *Dothidella ulei* by weekly fogging with 5 percent zineb.

15. Anonymous (1962). Plant quarantine announcements. *FAO Plant Protection Bulletin*, 9: 158-159.

The article presents information on regulations governing importation of *Hevea* rubber to Malaya from South America.

16. Anonymous (1963). A note on *Hevea spruceana*. *Planters' Bulletin Rubber Research Institute Malaysia,* 67: 100-106.

H. spruceana crown depressed growth and yield when crown budded onto *H. brasiliensis* trunk. However, as *H. spruceana* is resistant to SALB, it is valuable as a crown clone to overcome SALB.

17. Anonymous (1971). South American leaf blight: Precautions to be taken by visitors to and from Tropical America. *Planters' Bulletin Rubber Research Institute Malaysia,* 117: 333.

Persons who visited SALB endemic countries should break their return journey in Europe or temperate North America. Precautions should be taken to ensure clothes and other personal belongings are free of *M. ulei*.

18. Anonymous (1972). South American leaf blight: measures against its introduction. *Planters' Bulletin Rubber Research Institute Malaysia,* 122: 161-164.

SALB is still confined to South and Central America. The possible modes of entry into South East Asia and measures to prevent the introduction of SALB through planting materials and travellers were presented.

19. Anonymous (1976). Research on South American leaf blight at the Unit of the RRIM in Trinidad. *Planters' Bulletin Rubber Research Institute Malaysia,* 144: 69-72.

The article presents research activities on SALB conducted by the Rubber Research Institute of Malaysia at the Unit in Trinidad and Tobago.

20. Anstead, R.O. (1919). *Hevea* leaf disease in Surinam. *Planters' Chronicle,* 14: 320-324.

Occurrence of SALB caused by *Fusicladium macrosporum* was reported in Surinam, British Guiana and Brazil.

21. Araujo, A.E., Kalil, A.N. and Nobrega, M.B.M. (1997). Assessment of *Hevea* rubber tree genotypes to *Microcyclus ulei* to identify sources of horizontal resistance. *Acta Amazonica,* 27: 27-32.

The resistance of *Hevea* genotypes to *Microcyclus ulei* was evaluated. The latent period, lesion diameter, lesion type and reaction type were determined. Most of the clones are susceptible to at least one of *M. ulei* isolates. Genotypes that showed moderate resistance to one isolate were susceptible to other isolates. Clone Am/86/271 showed incomplete resistance characterized by longer latent period, smaller lesions and low sporulation. The genotypes evaluated were not suitable for breeding programmes for horizontal resistance.

22. Araujo, A.E., Kalil, A.N., Nobrega, M.B.M., Reis Sousa, N. and Dos Santos, J.W. (2001). Reaction of ten clones of *Hevea* (*Hevea benthamiana*) to three *Microcyclus ulei* isolates. *Acta Amazonica,* 31: 349-356.

Majority of the clones were resistant to the three isolates. Clones CNSAM 8218 and CNSAM 8219 were highly resistant. There was no interaction between clones and isolates for incubation period but interaction occurred between clones and isolates for lesion size. These clones exhibited characteristics of vertical resistance thus are not suitable as parents in breeding for horizontal resistance.

23. Aziz S.A.K. (1976). South American leaf blight: a proposed national and regional plan for emergency eradication. *ANRPC Technical Committee on SALB, 2nd Meeting, Bogor* 1976, 7 pp.

The article outlines measures against accidental introduction of SALB to the Far East.

24. Bancroft, C.K. (1913). A leaf disease of Para rubber. *Journal Bd Antic. British Guiana*, 7: 37-38.

SALB was found on nursery plants in British Guiana. The causal fungus was named *Passalora heveae* by G. Massee.

25. Bancroft, C.K. (1916). Report on the South American leaf disease of the Para rubber tree. *Journal Bd. Agric. British Guiana* 10: 13-23.

SALB was not a serious problem in British Guiana until 1916. The causal fungus *Fusicladium macrosporum* is propagated by three forms of spores.

26. Bancroft, C.K. (1916). Report on the Botanic Gardens and their work. *Report Department Science Agriculture British Guiana* 1915, 12 pp.

Several fungi were reported on *Hevea*. *Fusicladium macrosporum*, first recorded in 1909, occurred in all parts of the country.

27. Bancroft, C.K. (1917). The leaf disease of rubber: conditions in Surinam. *Journal Bd. Agric. British Guiana,* 10: 93-103.

SALB was more severe in Surinam than in British Guiana. There were 2 400 acres of *Hevea* and the epidemic occurred in 1914. Trees of all ages were attacked and died causing up to 1/3 losses in some holdings.

28. Bancroft, C.K. (1918). Disease in plants with special reference to fungi parasitic on crops in British Guiana. *Journal Bd. Agric. British Guiana*, 11: 47-57.

It was mentioned that *Melanopsammopsis ulei* occurred on *Hevea*.

29. Bancroft, C.K. (1919). Report on the Botanic Gardens. *Report Department Science Agriculture British Guiana*, 1917: 45-52.

Melanopsammopsis ulei was reported on rubber. SALB spread from indigenous rubber plants *(Hevea confusa)* in the forest.

30. Baptiste, E.D.C. (1961). Breeding of high yield and disease resistance in *Hevea*. *Proceedings Natural Rubber Research Conference, Kuala Lumpur,* 1960, p. 430-445.

The breeding and selection of *Dothidella*-resistant *Hevea* clones in Brazil was reviewed. The objective of breeding was to combine disease resistance with high yield from oriental clones using the backcross method of breeding. The susceptibility of clones to *Dothidella* and *Phytophthora* was presented. Examples on breakdown of disease resistance were presented and the importance and the need for diversification of highly resistant material for use in breeding were stressed. It was suggested that all natural rubber producing countries should co-operate and take joint action to implement projects with the assistance of an international body such as the FAO of the United Nations.

31. Begho, E.R., (1990). Biological characteristics of four races of *Microcyclus ulei*. *Indian Journal of Natural Rubber Research*, 3: 126-130.

The morphology of colonies and conidia, growth and sporulation of cultures, spore germination of eight isolates were presented.

32. Bekkedahl, N. (1945). Brazil's research for increased rubber production. *Science Month*, 61: 199-209.

Attempts at large scale *Hevea* cultivation were ruined by the endemic leaf blight caused by *Dothidella ulei*. Brazil possessed a wide selection of *Hevea brasiliensis* and other *Hevea* species. The leaf blight was controlled by crown budding.

33. Belgrave, W.N.C. (1921). Notes on the South American leaf disease of rubber. *Agriculture Bulletin Federated Malay States*, 9: 179-183.

The damage to *Hevea* caused by SALB in Surinam and British Guiana was reported. A visit in 1920 revealed that SALB was flourishing on nursery seedlings. Disease symptoms and the spore stages were described. In Guiana, wintering was not sharply defined as in Malaya; SALB may not therefore be severe in Malaya.

34. Belgrave, W.N.C. (1922). Notes on the South American leaf disease of rubber. *Tropical Agriculture,* 59: 109-113.

SALB was first attributed to *Fusicladium macrosporum*, later to *Passalora heveae* and finally to *Melanopsammopsis ulei*. It was present in Trinidad and British Guiana.

35. Bergamin Filho, A. (1982). Alternativas para o controle do mal das folhas da seringueira: uma revisao. *Summa Phytopathologia*, 8: 65-74.

Various possibilities to control *M. ulei* were discussed. It was concluded that horizontal resistance and chemical control proceeding artificial defoliation were the most promising alternatives to control SALB.

36. Bergamin Filho, A. (1984). Disease progress of South American leaf blight of rubber in different Brazilian region. *European Journal Forest Pathology*, 14: 386-391.

Abstract is not available.

37. Berger, P. (1992). Foliar phenolic compounds of the rubber tree and their implication in the resistance to *Colletotrichum gloeosporioides* and *Microcyclus ulei*. *Thesis, Universite de Montpellier 2 (France),* 235 pp. (In French).

Abstract is not available.

38. Bezerra, J.L., Castro, A.M.G., Vale, F.X.R., Rao, B.S., Souza, A.R., Araujo, A.C. and Neves, M.I. (1980). Controle quimico de *Microcyclus ulei* no Brasil atraves do PROMASE. Seminario Nacional da Seringueira, 3, 1980, Manaus. *Anais Brasilia, SUDHEVEA, 1980*, Vol. I, pp. 130-161.

Rubber plantations established after 1950 were planted with clones supposedly resistant to SALB. After an initial good promise the plantations faced disease problems within the first ten years after planting and some plantations were at the verge of being abandoned. In 1974, SUDHEVEA started a special programme (PROMASE) to rehabilitate the plantations to be economically productive. The plantations were sprayed with fungicides using helicopter to control SALB.

39. Blandin, J.J. (1941). Why rubber is coming home. *Agriculture America*, 1: 1-10.

SALB was one of the many problems encountered in starting a natural rubber industry in Central and South America. Research on the disease was initiated by Goodyear Plantations Co. in Costa Rica primarily to breed clones combining the high yield of Oriental clones with blight resistant South American clones.

40. Blazquez, C.H. (1959). Host-parasite relations of the fungus *Dothidella ulei* P. Henn. on *Hevea* rubber tree. *Ph.D. Thesis, University of Florida*, 97 pp.

Abstract presented in 40 and 41.

41. Blazquez, C.H. and Owen, J.H. (1957). Physiological studies of *Dothidella ulei*. *Phytopathology,* 47: 727-732.

D. ulei was grown successfully on an agar medium containing extract of 20 g rubber leaf and 2.5 g malt extract/l and on Difco LBA (23 g/l) + 200 mg quebrachitol. In semi-synthetic media containing vitamins and amino acids, the best growth was obtained in media with i-inositol + glutamine and nicotinic acid + glycine, and the highest conidial production was achieved with combination of riboflavin with glutamine, leucine, arginine or glycine. Both spermogonia and conidia formed on the fungal stroma. Conidial germination was best at pH 7-8 and at 24-28 ºC. Fungus cultured *in vitro* did not lose its pathogenicity to rubber.

42. Blazquez, C.H. and Owen, J.H. (1963). Histological studies of *Dothidella ulei* on susceptible and resistant *Hevea* clones. *Phytopathology*, 53: 58-65.

Growth of *D. ulei* in leaves of various stages of development was described: Black exudates were produced on stage 1 leaf (susceptible or resistant). Conidia germinating on resistant leaves produced abundant appressoria, but were few appressoria developed on susceptible leaf as the fungus penetrated directly into susceptible leaf. A yellow substance occurred in resistant tissue soon after penetration and also in old lesions in susceptible tissue. In highly resistant leaves (stages 1, 2 and 3) cells disorganisation occurred but no sporulation, stromatic mycelium or fructification were seen. Collapsed tissue was replaced by sclerenchyma-like cells with a positive tannin reaction; leaflets attained regular size and shape. On susceptible, mature leaves germination and penetration occurred, but the fungus did not develop further.

43. Bodkin, G.E. (1922). Report of economic biologist. *Report Department Science Agriculture British Guiana* 1920, 92 pp.

Rubber cultivation was abandoned as up to 95 percent of the trees were damaged by SALB. *Hevea confusa* and *H. guianensis* suffered to a lesser extent than *H. brasiliensis*. The ravages of the disease were particularly severe during protracted periods of heavy rainfall. Young leaflets shrivelled-up even hours after the buds burst. Even slightly infected trees decreased in yield. Every plantation had a few trees immune to the disease, but the reason for this was not known.

44. Bos, H. and McIndoe, K.G. (1965). Breeding of *Hevea* for resistance against *Dothidella ulei*. *Journal Rubber Research Institute Malaysia,* 19: 98-107.

A programme to breed *Hevea* clones resistant to SALB was initiated by the Firestone Plantations Company in 1949. Yield of introduced clones developed in Brazil were given. New crosses between susceptible and resistant clones were made in isolated seed gardens in Liberia. The progeny of these crosses were screened for resistance in Guatemala and Brazil. Yield of the resistant selections was tested in Liberia.

45. Brandes, E.W. (1943). Progress in hemisphere rubber plantation development. *India Rubber World,* 108: 143-145.

SALB, which caused the requiem for all early attempts to establish plantations in the Americas, was considered no longer a barrier to success. The disease can be controlled by protective measures. Cooperating with 14 Latin American countries and building on previous commercial work, the U.S. in 1940 began extensive expansion of the *Hevea* rubber industry, including establishment of experiment stations and nurseries and plant improvement by selection of wide varieties and breeding. Crown budding had controlled SALB.

46. Brandes, E.W. (1947). Progress towards an assured natural rubber supply. *India Rubber World,* 116: 491-497.

The efforts to establish *Hevea* plantations in Latin America by U.S. Government and Tire Companies were reported.

47. Brookson, C.W. (1956). Importation and development of new strains of *Hevea brasiliensis*. *Journal Rubber Research Institute Malaysia,* 14: 423-447.

Twenty-five selected *Hevea* clones and oil palm materials from Malaysia were exchanged for 25 *Hevea* clones resistant to *Dothidella ulei* with Brazil during 1953 to 1954. In the year 1951/l952, 1 614 seedlings of *H. brasiliensis, H. guianensis, H. benthamiana, H. spruceana* and *H. pauciflora* and their hybrids were also imported. Detail of the importation was described and a breeding programme and variety trials were established. The clonal material was exported to Ceylon, Indonesia and Indochina.

48. Camargo, A.P. de (1963). Possibilidades climaticas da cultura da seringueira em Sao Paulo. *Instituto Agronomico Campinas Boletim* 110, 24 pp.

It was mentioned that the climatic conditions in Sao Paulo is not favourable for the development of SALB.

49. Camargo, A.P. de, Cardoso, Rosa M.G. and Schmidt, N.C. (1967). Comportamento e ecologia do 'mal-das-folhas' da seringuiera nas condicoes climaticas do Planalto Paulista. *Bragantia*, 26: 1-17.

The development of SALB in relation to the phenology of the rubber plant grown in Sao Paulo was presented. During the four year study, susceptible clones planted in areas with low humidity were infected periodically. Infection generally occurred on leaf whorls that came out during January to May i.e. the period with most favourable humidity condition. Normally, only two to

three whorls out of six whorls were infected per year. The whorls developing in September to December and plants planted on higher elevation in Sao Paolo were free of SALB.

50. Camargo, A.P. de, Schmidt, N.C. and Cardoso, Rosa M.G. (1975). South American leaf blight epidemics and rubber phenology in Sao Paulo. *Proceedings International Rubber Conference*, 1975, Kuala Lumpur, 3: 251-265.

The behaviour of South American leaf blight in relation to the phenology of the rubber tree was studied based on macro and micro climatic conditions in Sao Paolo. Young leaf flushes were infected from midsummer to mid autumn. In winter when the temperature was below 20 ºC, the lesion was generally non-sporulating. This behaviour along with complete defoliation during wintering season in late September contributed to low inoculum level in spring. Disease occurs in badly drained areas exposed to long lasting dew conditions. No SALB was observed in well drained areas and on upland areas. These areas may escape SALB.

51. Campanharo, W.E., Cecilio, R.A., Sperandio, H.V., Jesus-Junior, W.C. and Pezzopane, J.E.M. (2011). Modification of the climatic zoning of rubber trees for the Espirito Santo state, Brazil due to climatic change scenarios. *Scientia Forestalis Piracicaba*, 39: 105-116.

The potential impact of climate change on geographical distribution of rubber and *Microcyclus ulei* in Espirito Santo state, Brazil was presented. Espirito Santo climate is suitable for rubber cultivation in areas with little likelihood for South American leaf blight.

52. Cano, H.H., (1997). Physiological races of *Microcyclus ulei* in Mexico. *Proceedings Scientific Technological Meeting on Forestry, Agriculture and Husbandry Research in Vera Cruz State, Mexico,* 27-28 November 1997, p. 143-145.

53. Carefoot, G.L. and Sprott, E.R. (1969). Vulcan's victims: one life equals eight pounds. In "*Famine on the Wind - plant diseases and human history'*, p. 139-159.

The discovery of natural rubber and its usefulness led to the domestication of the crop. Central and South America would have become the world's leading producer of natural rubber, if not for SALB.

54. Carpenter, J.B. (1950). Plant pathological investigation in the United States. *Plant Disease Reporter, Supplement*, 191: 60-66.

Disease symptoms were described and measures to control the disease by fungicides or resistant clones in tropical America were presented.

55. Cayla, V. (1913). Maladis cryptogamiques des feuilles de 1' *Hevea* en Amerique. *Journal Agriculture Tropical,* 13: 186-188.

A review of the literature indicated that *Dothidella ulei* P. Henn., *Aposphaeria ulei* P. Henn. and *Fusicladium macrosporum* Kuyper were different forms of the same fungus. Trees in a water-logged situation were more severely attacked and cutting of diseased tissue was recommended as a remedial measure.

56. Chee, K.H. (1976a). South American leaf blight of *Hevea brasiliensis*: spore behaviour and screening for disease resistance. *Proceedings International Rubber Conference,* 1975, Kuala Lumpur, 3: 228-235.

Spore germination varied from 90 percent in wet season to 10 percent in dry season. Germination of ascospore was consistently high. The survival period of the spores under various weather conditions was presented. Conidia in lesions survived longer at low temperature and under

desiccation (up to 25 weeks). Spore viability was shorter under high humidity. Ascospore from fallen leaves, probably, is the source of inoculum to initiate disease in a new season. Ascospore and also perithecia survived longer under dry condition. The diurnal spore release was also presented. More ascospores were trapped in the early morning or after a rain. No conidia were trapped during dry season but ascospores were trapped all year round. The degree of resistance of clones was proportional to lesion size on the leaves.

57. Chee, K.H. (1976b). Assessing susceptibility of *Hevea* clones to *Microcyclus ulei*. *Annals Applied Biology*, 84: 135-145.

Leaf disks of 7-day-old *Hevea* leaves floating on water produced lesions of varying sizes following inoculation with conidia of *M. ulei*. Based on 188 *Hevea* clones, lesion size on leaf disks correlated with leaf area infected in the field. Lesion size varied little with leaf age or inoculum level. Leaves treated with sodium hypochlorite and stored for three days could still be infected by desiccated conidia. The method is suitable for quick screening for resistance of rubber plants.

58. Chee, K.H. (1976c). South American leaf blight of *Hevea brasiliensis*: spore dispersal of *Microcyclus ulei*. *Annals Applied Biology*, 84: 147-152.

Trapping of ascospores and conidia of *M. ulei* among young trees of *H. brasiliensis* in Trinidad over a period of two years showed that ascospores occurred throughout the year whilst conidia were present only during the wet season. Peak ascospore concentrations occurred in August and November during the wet season. In dry weather, the number of ascospores increased during the night to a maximum at 06.00 hours, and decreased to a low level during the day. On rainy days heavy ascospore discharge also occurred during the day. Ascospore concentration decreased significantly after dawn on sunny days whilst on overcast days the concentration remained high most of the day. Conidia production was highest around 10.00 hours and decreased towards the evening, reaching a minimum at 07.00 hours.

59. Chee, K.H. (1976d). Factors affecting discharge, germination and viability of spores of *Microcyclus ulei*. *Transaction British Mycological Society*, 66: 499-504.

Ascospores of *M. ulei* are forcibly discharged in rapid succession when leaves are wetted at sub-ambient temperatures (14 ºC). Leaves which fall during wintering discharge ascospores readily after rain. Ascospores are released from green leaves throughout the dry season. Under moist conditions at 24 ºC, perithecia lose their viability after 12 days on green leaves and after 9 days on fallen brown leaves. At the optimum temperature (24 ºC), ascospores germinated in $2^1/_2$ h in darkness and 6 h in light. Ascospores die at high humidity (>80 percent RH), but survived up to 15 days when kept dry in a desiccator. They were killed by 4 min exposure to ultra violet light. The percentage germination of fresh conidia was 10-90 percent whereas the percentage germination of ascospores was consistently high. The percentage germination of floating conidia and ascospores was higher than submerged spores. Conidia on sporulating lesions survived for several weeks at sub-zero temperatures or under desiccation. On glass slides, conidia survived for up to 16 weeks under desiccation and for 4 weeks at humidifies >65 percent. Conidial infection on leaf disks was most severe at 24 ºC and much less so at 28 ºC, suggesting that mean temperatures in Peninsular Malaysia are slightly above the optimum for SALB development.

60. Chee, K.H. (1977). Combating South American leaf blight of *Hevea* by plant breeding and other measures. *Planter, Kuala Lumpur*, 53: 287-296.

International co-operation in the enforcement of plant quarantine measures was presented. The potential of using various species of *Hevea* for breeding purposes was discussed. The performance of some progenies from crosses between high yielding and SALB resistant clones was presented. Thiophanate methyl and benomyl fungicides were effective in preventing infection as well as sporulation. The life cycle of the disease and the methods of control were illustrated diagrammatically.

61. Chee, K.H. (1978a). Evaluation of fungicides for control of South American leaf blight of *Hevea brasiliensis*. *Annals Applied Biology,* 90: 51-58.

Of 43 fungicides tested *in vitro,* 19 showed strong, seven moderate and 17 weak inhibitions of germination of conidia and ascospores of *Microcyclus ulei*. The formation of lesions on *Hevea brasiliensis* leaf discs was also suppressed by the first category of fungicides as well as by the five adjuvants tested. Ascospores release was inhibited following treatment of perithecia with urea, thiabendazole or alcoholic mercuric chloride at 10.0, 0.1, 1.0 g/l respectively; other fungicides had no such inhibitory effect.

In field trials, thiophanate methyl (0.07 percent a.i.) and benomyl (0.025 percent a.i.) were most effective, followed by chlorothalonil (0.15 percent a.i.) and mancozeb (0.32 percent a.i.) in controlling leaf infection. Benomyl suppressed conidial sporulation, whereas one application of thiophanate methyl (0.14 percent a.i.) to perithecia inhibited ascospore release; and when conidial lesions or pycnidia was treated with half of this concentration caused the perithecia formed subsequently to abort. Thiophanate methyl had promise to control and eliminate SALB and benomyl may be valuable in later rounds of spraying to control conidial sporulation. After six days of rain (2 mm for 17 min per day), water collected from sprayed leaves completely inhibited spore germination. However, inhibition markedly reduced after 6 days of heavy rain (over 8 mm for 24 min per day).

62. Chee, K.H. (1978b). South American leaf blight of *Hevea brasiliensis*: culture of *Microcyclus ulei*. *Transaction British Mycological Society*, 70: 341-344.

The best method of isolating *M. ulei* was to deposit fresh conidia on plain agar and then transfer it to potato sucrose agar (PSA). Some brands of agar inhibited growth and sporulation. Dried rubber leaf extract stimulated growth. Two morphological strains of *M. ulei* occurred amongst field isolations. The free sporulating strain appeared to be associated with resistant clones. One isolate produced ascospores. Plating laboratory-produced conidia produced three colony types. Variants with high degree of sporulation were obtained by successive sub-culturing of spores. Cultures from single conidium differed in mycelial growth and production of conidia and pycnospores. Single ascospore culture was uniform in appearance. The fungus grew best at 23 ºC, produced maximum conidia after three weeks, but optimum germination occurred with younger spores. Stromata were produced saprophytically on leaf disks bearing conidial lesions or pycnidia.

63. Chee, K.H. (1979). Movement of benomyl, thiophanate methyl and mancozeb on leaves of *Hevea brasiliensis* and their fungicidal action on *Microcyclus ulei*. *Proceedings Rubber Research Institute of Malaysia Planters' Conference, Kuala Lumpur*, p. 409-418.

The actions of three fungicides (benomyl, thiophanate methyl and mancozeb) were studied. Benomyl and thiophanate methyl were more persistent than mancozeb and moved into the cuticle more readily. Only the soluble form of benomyl could penetrate the lamina of 14-day old leaves. The three fungicides moved more readily through the abaxial cuticle or lamina. Conidial germination was not inhibited by the three fungicides at 5 μg/ml. In poison food test, mycelial growth was inhibited by benomyl and thiophanate methyl at 1 μg/ml and by mancozeb at 5 μg/ml. Conidia harvested from leaves sprayed with benomyl were less viable compared to conidia from leaves sprayed with thiophanate methyl or mancozeb.

64. Chee, K.H. (1980a). The suitability of environment conditions in Asia for the spread of South American leaf blight of *Hevea* rubber. *Planter, Kuala Lumpur*, 56: 445-454.

The article describes the role of spores in disease infection and their release and dispersal. The viability period of spores kept under various conditions were also presented. The weather conditions in Brazil and Trinidad and Tobago were compared with weather conditions in Malaysia

and Thailand. Based on the similarity of weather conditions, it was concluded that SALB would be severe in Malaysia and other neighbouring countries.

65. Chee, K.H. (1980b). Management of South American leaf blight. *Planter, Kuala Lumpur*, 56: 314-325.

Three approaches can be adopted to control SALB i.e. crown budding; breeding for disease resistant clones and application of fungicides. Crown budding using PA 31 as the crown showed promise. Emphasis on breeding should be to produce clones with horizontal resistance. The mechanics of fungicide control and the use of spray oils and surface active agents were discussed.

66. Chee, K.H. (1984). Improved control of South American leaf blight of *Hevea* in Brazil. *Journal Plant Protection in the Tropics,* 1: 1-7.

Three approaches to manage SALB were suggested i.e. crown budding, breeding for resistant clones and fungicide application. Breeding and selection should focus on breeding for clones with horizontal resistance. The aim of disease control is to reduce the amount of inoculum and also to reduce the rate of increase of disease. The theory related to the strategy was presented. When fungicides are used, there is a possibility of the pathogen developing resistance to a fungicide. This possibility was discussed. The effectiveness of fungicide can be increased with proper use of fungicide carriers and additives. Fogging of thiophanate methyl was effective on SALB. A disease control programme for SALB was presented.

67. Chee, K.H. (1985). An analysis of possible preventative measures against the introduction of South American leaf blight to Malaysia. *Regional Conference in Plant Quarantine Support for Agricultural Development, 1985, Kuala Lumpur, Malaysia,* p. 261-263.

Devastating consequences are likely to result if South American leaf blight (*Microcyclus ulei*) of *Hevea* rubber spreads to the Orient. Hence, high priority is given to erecting and maintaining effective quarantine barriers at the frontiers of SALB free regions. The conidia of *M. ulei* survived on commonly-used substances, such as cloth, polyethylene, glass, metal and paper, and in soil, for over a week. Travellers who have been to SALB-infected rubber-growing areas are recommended to pass through a temperate country and launder their clothing before returning. Soap solution at 40 mg/l as well as exposure to moist heat at 55 ºC or dry heat at 75 ºC for 30 min killed the conidia. Fumigation with formaldehyde (35 percent strength) at 100 ml/cu m was also effective. When the dosage is increased twice, it inhibited ascospore release. Ultra-violet light irradiation for 15 min killed most conidia, but all conidia were killed in the presence of low concentration of formaldehyde (50 ml/cu m). Plant quarantine officers, plant pathologists and rubber growers should know how to recognize the symptoms of SALB and a contingency plan should be ready to eradicate the disease should it occurs.

68. Chee, K.H. (1990). Present status of rubber diseases and their control. *Review of Plant Pathology*, 69: 423-430.

The major diseases of rubber, their distribution and economic importance and disease control methods were presented. SALB is a highly destructive disease. The merits and demerits of disease control by several methods including planting resistant clones, fungicide spraying, crown budding and planting rubber in escaped areas were discussed.

69. Chee, K.H., Darmono, T.W., Zhang, K.M. and Lieberei, R. (1985). Leaf development and spore production and germination after infection of *Hevea* leaves by *Microcyclus ulei*. *Journal Rubber Research Institute Malaysia,* 33: 124-137.

South American leaf blight (*M. ulei*) infection of *H. brasiliensis* caused a reduction of up to one-third in leaf size. The younger the leaf when infected the greater the reduction in leaf growth

and the higher the percentage of leaf fall. Formation and size of conidial lesions, the degree of sporulation, the extent of stroma formation and leaf fall, differed among the ten clones examined. Abundant conidia but few stroma were produced on leaves of FX 985, FX 4163 and IAN 873, but the reverse occurred on clone FX 3864. Heavy stroma formation was not positively correlated with the degree of leaf fall among over 200 clones examined. Desiccated conidia after three months of storage were still capable of infecting *Hevea* leaves. Washing the conidia with water accelerated the production of germ-tube initials but did not lead to increased germ-tube growth. Shallow water was more favourable for development of germ-tube initials and germ-tubes. *Hevea* leaf diffusate from susceptible clones stimulated conidial germination, while that from resistant clones inhibited it. Viable conidia were stainable by acid fuchsin in acetic acid. The highest rate of germination of conidia was obtained from fourteen-day-old leaves and those produced during the months with least rain. Two-celled conidia germinated better than one-celled ones, which were produced in greater numbers during dry weather. Conidia removed by tapping lesion gave a higher rate of germination than conidia harvested by brushing or conidia produced at lower relative humidity instead of at saturation.

70. Chee, K.H., Darmono, T.W. and Santos, A.F. dos. (1986). Laboratory screening of fungicides using cellulose film and leaf discs against South American leaf blight pathogen, *Microcyclus ulei*. *Journal Natural Rubber Research*, 1: 98-103.

Cellulose film coated with fungicide was suitable to replace agar medium in laboratory screening of fungicides against *Microcyclus ulei*. It revealed the fungicidal, fungistatic and residue effects of the chemical examined. Discs of young *Hevea* leaves sprayed with a fungicide and inoculated with conidia also gave a good estimate of the effectiveness and curative property of fungicides. The effectiveness of chlorothalonil, mancozeb, tridemorph, dithianon, benomyl, triforine, triadimefon, carbendazim and thiophanate methyl on South American leaf blight was compared.

71. Chee, K.H. and Holliday, P. (1986). South American leaf blight of *Hevea* rubber. *Monograph No. 13, Malaysian Rubber Board,* 50 pp.

The monograph reviews the South American leaf blight (SALB) disease and the causal pathogen *M. ulei*. The review covers the pathogen especially its morphology, life history and the methods to culture the fungus. The economic importance of SALB, distribution and host range were also covered. The monograph also describes the symptoms, epidemiology of SALB and measures to control the disease.

72. Chee, K.H. and Wastie, R. L. (1980). The status and future prospects of rubber diseases in Tropical America. *Plant Pathology*, 59: 541-548.

The status of rubber diseases in the New World was reviewed. The most important disease in Brazil is South American leaf blight (*Microcyclus ulei*). With the exception of leaf wither and black stripe caused by *Phytophthora palmivora* in Bahia and possible target leaf spot (*Thanatephorus cucumeris*) in Manaus, other diseases are of minor importance. *Erinnyis ello* is the most serious insect pest. Research areas on SALB were suggested.

73. Chee, K.H., Zhang, K.M. and Darmono, T.W. (1986). The occurrence of eight races of *Microcyclus ulei* on *Hevea* rubber in Bahia, Brazil.*Transaction British Mycological Society,* 87: 15-21.

Conidia of *Microcyclus ulei* from infected leaves of 12 clones of *H. brasiliensis* and its hybrids with *H. benthamiana* were used to inoculate leaf disks of 19 selected clones of diverse genetic background. Eight physiologic races of *M. ulei* were distinguished. Races 1 and 2 have previously been recorded only from Central America whereas races 4, 5 and 6 (previously 4A, 4B and 4C) have been reported from Amazonas, Belem, and Bahia respectively. The new races 7, 8 and 9 are described, and a set of six clones (IAN 710, IAN 717, FX 2261, FX 985, FX 2804 and FX 25) is proposed for differentiating the eight races.

74. Commonwealth Mycological Institute (1975). Distribution maps of plant diseases, No. 27.

The disease was present in North America (Mexico); Central America and the Caribbean (Costa Rica, Guatemala, Honduras, Nicaragua, Panama, Trinidad and Tobago); and South America (Bolivia, Brazil, Colombia, French Guiana, Guyana, Peru, Surinam and Venezuela).

75. Compagnon, M.P. (1971). Note on the *Dothidella ulei* in Brazil. Mimeograph, 3 pp.

Clones FX 3810, FX 3925 and FX 3899 were resistant to SALB in most situations. Clones FX 25, FX 2261, FX 2804, FX 3864, IAN 873 and IAN 717 were variable in resistance depending on localities possibly connected to the occurrence of fungus races, climatic conditions and the phenology of the clones, an inherent character subject to modification by attacks of disease and growing conditions.

76. Compagnon, M.P. (1976). Note on the influence of climatic conditions on the spread of SALB. Mimeograph, 8 pp.

The severity of SALB in various localities in South America was related to the local climatic conditions. SALB has reached Haiti and evidence suggests it was brought over by wind and rain from Guiana and Trinidad. A similar explanation was given regarding a newly infected site in Venezuela. A new SALB-free planting in Guadeloupe provides a valuable site to confirm the above observation should SALB eventually reach Guadeloupe.

77. Compagnon, M.P. (1976). Review on progress and spread of SALB. *ANRPC Technical Committee on SALB 2nd Meeting, Bogor,* 1976, Mimeograph, 16 pp.

The geographical range of SALB has expanded since it was last mapped in 1970. The disease occurred a few months or a few years after rubber was planted and wind/rain was responsible for its spread. The current disease situation in Mexico, Guatemala, Haiti, Trinidad, Venezuela, Guiana and Brazil was discussed. Disease control by suppressing the 'over winter' ascospores was suggested but a fungicide for this purpose is yet to be found. Dithane M 45, benomyl, and thiophanate methyl are effective in controlling the infection. Application of fungicide by fogging appears promising. Crown budding *Hevea brasiliensis* with certain *H. pauciflora* clones did not seem to suppress yield.

78. Cuellar, A.S., Rodriguez, L.C.G. and Diaz, J.C. (2010). Incidence and severity of *Microcyclus ulei* in a collection of rubber tree in the Colombian Amazonia. *Ingeniarias and Amazonia*, 3: 93-104.

In Colombia, planting of IAN 873, IAN 710 and FX 3864 are widespread. However, these clones increasingly were infected by SALB. The susceptibility of 12 rubber clones to SALB was assessed. The incidence of SALB was influenced by rainfall regime and not by genotypes. However, rainfall and genotypes influenced severity of disease. More tolerant clones were MDF 180, FDR 5597, IAN 717 and FX 4098.

79. Darmono, T.W. and Chee, K.H. (1985). Reaction of *Hevea* clones to races of *Microcyclus ulei* in Brazil. *Journal Rubber Research Institute Malaysia*, 33: 1-8.

The resistance of over 100 progenies of *Hevea* species and their hybrids to SALB was tested in the laboratory. Clone MDX 42 was resistant while FX 2261 and FX 3864 were less susceptible to five races of *M. ulei*. FX 2261 was susceptible only to Race 1; clone FX 985 to Race 7 and Race 9 whereas FX 3864 was infected by all races of *M. ulei*.

80. Davis, W. (1997). The rubber industry's biological nightmare. *Fortune*, August 4, p. 36-46.

The article describes the historical development of rubber cultivation in South America. In the event of SALB being introduced, it would wipe out the rubber industry in Asia.

81. Delamadi, L.C., Neto, D.C. and Rocha, V.F. (2009). Avaliacao do potencial do uso de Dicyma pulvinata no controle biologico mal-das-folhas (*Microcyclus ulei*) de seringueira (*Hevea brasiliensis*). *Ciencia Florestal*, 19: 183-193.

Matto Grosso state is a major producer of rubber with 45 727 ha in 2002. The occurrence of South American leaf blight, a major disease of rubber, is a factor limiting expansion in rubber cultivation. A promising option, biological control, could overcome the problem. This study evaluates the potential of *Dicyma pulvinata* to control *Microcyclus ulei* in comparison with chemical control. The studies were conducted in the field and green house. Three concentrations of *D. pulvinata*, benomyl, and mancozeb were evaluated. In the field, good control was obtained with application of *D. pulvinata* at 8.1×10^6 and 1.25×10^7 conidia/ml. In the greenhouse, better results were obtained with 2.025×10^7 and 3.037×10^7 conidia/ml.

82. Demmon, E.L. (1942). Rubber production opportunities in the American tropics. *Journal Forestry*, 40: 207-210.

Hevea may be grown successfully in many parts of Latin America. The main difficulty is SALB. Yields in Central and South America compare favourably with those of plantations in the Far East.

83. Denis, C., Troispoux, V., and Pinard, F. (2001). The South American leaf blight of the rubber tree due to *Microcyclus ulei*. *Phytoma la Defense des Vegetaux*, 535: 37-40.

South American leaf blight plays a major role in the reduction of rubber production in South America. The disease causes severe defoliation and death of trees. CIRAD conducts research on the disease in French Guiana on host pathogen interaction especially on resistance.

84. Deslandes, J.A. (1944). Observacoes fitopatologicos na Amazonia. *Boletim fitossanitario Ministerio Agricultur, Rio de Janeiro*, 1: 197-242.

Dothidella ulei was found on the dead branches of *Hevea*.

85. Djikman, M.J. (1951). *Hevea*, thirty years of research in the Far East. Miami Press, 329 pp.

SALB was a major consideration in the selection for resistance to diseases. It was mentioned that other workers observed that occasional trees in abandoned plantations in British Guiana were resistant to SALB.

86. Duarte, H.L.R., Albuquerque, F.C., Pinheiro, E. and Begeer, J.J. (1973). Control of wilting of foliage of rubber plants *(Microcyclus ulei)* through aerial spraying. Mimeograph, 9 pp.

Several fungicides (Benlate 0.6 kg/ha or 0.3 kg/ha, Dithane M45 0.6 kg/ha) were applied from the air. The percentage of leaves infected by SALB after treatment was 12 percent (Benlate 0.6 kg/ha), 25 percent (0.3 kg/ha or 77 percent (Dithane M45).

87. Ducke, A. (1946). Novas contribuicoes para o conhecimento das seringueiras da Amazonia Brasileira. *Boletim Tecnico Instituto Agronomico do* Norte, No. 10, 24 pp.

The number of *Hevea* species previously described was reduced from 24 to 12. Only nine species were recognised i.e. *H. guianensis, H. benthamiana*, *H. brasiliensis, H. viridis*, *H. pauciflora*, *H. comporum, H. spruceana* and *H. minor*.

88. Edathil, T.T. (1986). South American leaf blight: a potential threat to the natural rubber industry in Asia and Africa. *Tropical Pest Management*, 32: 296-303.

South American leaf blight (SALB) caused by the fungus *Microcyclus ulei* (P. Henn.) von Arx is the main limiting factor to the development of the natural rubber (*Hevea brasiliensis*) industry in South and Central America. It also poses a great danger to the rubber grown extensively in Africa and South East Asia. Disease distribution, epidemiology and spore viability, the risks of its entry into Asia and Africa and its possible behaviour in these countries were reviewed. Application of defoliants and fungicides, breeding for resistance and crown budding of high yielding panel clones with leaf blight-resistant crowns are measures to control SALB. As the existing quarantine regulations were inadequate, more rigorous measures are needed.

89. Feldman, F., Junqueira N.T.V. and Lieberei, R. (1989). Utilization of VA-mycorrhiza as a factor in integrated plant protection. *Agriculture, Ecosystem Environment*, 29: 131-38.

VA-mycorrhiza infected rubber trees were more resistant to South American leaf blight. Lesion size and spore production were significantly lowered in VAM inoculated plants, but the number of lesions remained unchanged. This suggests that the resistance response of the plant was influenced by VAM and demonstrates that enhanced resistance is not due to inhibition of penetration or early growing phases of the pathogen but was due to modification of late resistance responses. The increase in resistance by VAM inoculation is an important means to control the epidemiological development of the leaf disease. The chemical control measures are combined with plant management, breeding and use of hyperparasites in an integrated control system.

90. Feldman, F., Idczak, E., Martins, G., Nunes, J., Gasparotto, L., Preisenger, H., Moraes, V.H.F. and Lieberei, R. (1995). Recultivation of fallow low lying areas in Central Amazonica with equilibrated polycultures: Response of useful plants to monoculture with VA-mycorrhizal fungi. *Angewandte Botanik*, 69: 111-118.

Severity of leaf diseases caused by *M. ulei* and *Thanatephorus cucumeris* was not altered significantly by mycorrhizal treatment.

91. Fernando, E.B. and Ismail Hashim (1986). Reactions of oriental *Hevea* clones to isolates of *Microcyclus ulei* and response of isolates to fungicides. *Journal of Rubber Research Institute of Sri Lanka*, 66: 14-21.

The resistance of oriental clones especially those bred in Sri Lanka were tested against *M. ulei*. The responses of races of *M. ulei* to specific fungicides were presented.

92. Fernando, D.M and Liyanage, A. de S. (1975). *Hevea* breeding for leaf and panel disease resistant in Sri Lanka. *Proceedings International Rubber Conference, 1975, Kuala Lumpur*, Vol. III, pp. 236-246.

Preliminary studies on breeding for resistance to SALB were reported. The source of resistance for the breeding programme was from introduced clones such as FX 4098, FX 516, IAN 3434, IAN 2750, IAN 873 and IAN 710. These clones had been crossed with Sri Lankan clones. The initial yield of some of the progenies was presented.

93. Fernando, D.M and Liyanage, A. de S. (1980). South American leaf blight studies on *Hevea brasiliensis* selection in Sri Lanka. *Journal Rubber Research Institute Sri Lanka*, 57: 41-47.

The resistance of selected Sri Lankan clones to SALB was presented. Clones RRIC 119, RRIC 115, RRIC 117 and 6004 exhibited high degree of resistane but only RRIC 117 had favourable latex yield. Clones RRIC 121 and RRIC 130 had better yield and were also resistant to SALB.

94. Figari, A. (1965). Sustancias fenolicas toxicas al hongo *Dothidella ulei* en hojas de clones de *Hevea brasiliensis*. *Turrialba*, 15: 103-110.

Inhibition of conidial germination was greater in aqueous leaf extract of the resistant clone IAN 710 than in extract of the susceptible clone GA-1126. The toxic substance appeared as a yellow spot on chromatograms and was possibly a flavonol. Other phenolic compounds such as chlorogenic acid, caffeic acid and catechol were also highly toxic to *D. ulei*.

95. Fox, R.A. (1965). International plant protection and the FAO. *Research Archives Rubber Research Institute Malaysia,* 51, 25 pp.

The regional plant protection agreement established under the FAO. International Plant Protection Convention of 1951 was summarised. The Plant Protection Committee for S.E. Asia and the Pacific region recommended measures on movement of *Hevea* to safeguard against the introduction of SALB.

96. Furtado, E.L., Cardoso, R.M.G., Oliveira, D.A. and Rolim, R.R. (1991). Systemic fungicide effects on lifecycle of *Microcyclus ulei*, agent of South American leaf blight. *Summa Phytopatologica*, 17: 238-245.

97. Furtado, E.L., Menten, J.O.M., Carualho, J.C., Godoy Junior, G. (1995). Ergosterol synthesis inhibitors fungicides for South American leaf blight control. *Fitopatologia Brasileira,* 20: 203-207.

Abstract is not available.

98. Furtado, E.L., Menten, J.O.M. and Passos, J.R. (2008). South American leaf blight intensity evaluated on six clones of young and adult rubber trees in Vale do Ribeira region, Sao Paolo state, Brazil. *Tropical Plant Pathology,* 33: 130-137.

Rubber trees present different intensity of symptoms depending on their age. Evaluation of the intensity of symptoms on six clones of one and eight years old plants showed that young trees of clones FX 3864, IAN 717, RRIM 600, IAN 873 and mature trees of clones RRIM 600, IAN 717 and FX 3864 were severely infected. Mature IAN 873 was less severely infected as their leaf change was uniform and leaf refoliation occurred during the weather conditions not favourable to disease thus avoiding the disease.

99. Furtado, E.L., Sambugaro, R. and Mattos, C.R.R. (2004). SALB management. *IRRDB/Michelin/CIRAD International Workshop on SALB*, 2004, Bahia, Brazil, Mimeograph, pp. 7.

Various methods to control SALB were discussed. Various clones were recommended for planting in areas with different climatic conditions. Susceptible clones (RRIM 600, PB 235, PR 255, IAN 873) were recommended for disease escaped areas. In areas with more suitable climatic conditions for SALB, the above clones should be crown budded with *H. pauciflora* hybrids. Biological control of SALB with *Dicyma pulvinata* was effective. SALB can be controlled with various old and newer fungicides.

100. Garcia, D. (2004). Breeding CMB (CIRAD-Michelin-Brazil) clones. *IRRDB/Michelin/CIRAD International Workshop on SALB*, 2004, Bahia, Brazil, Mimeograph, pp. 3.

The SALB resistance breeding programme was presented. The genetic source of resistance was from the more resistant Wickham Amazonian clones. 212 clones were selected for further evaluation and 11 clones were evaluated under controlled condition.

101. Garcia, D., Cazaux, E., Rivano F. and D'Auzac, J. (1995). Chemical and structural barriers to *Microcyclus ulei*, the agent of South American leaf blight in *Heve*a spp. *European Journal of Forest Pathology*, 25: 282-292.

Six hours after inoculation, intense blue fluorescent light was emitted from the infection site. The speed of appearance of the discoloration correlated with degree of resistance of the clones i.e. faster in more resistant clones. This substance may be the coumarin scopoletin. Lignin accumulation also occurred following penetration of resistant clones. Accumulation of scopoletin and lignin was linked to resistance.

102. Garcia, D., LeGuen, V., Mattos, C.R.R. Gonsalves, P.S. and Clement Demange (2002). Relationship between yield and some structural traits of the laticiferous system in *Hevea* clones resistant to South American leaf blight. *Crop Breeding and Applied Biotechnology*, 2: 307-318.

Latex yield and six anatomical bark traits (average yield, girth, bark thickness, latex vessels ring number, density of latex vessel rings, diameter of latex vessels and average distance between latex vessel rings) were measured in a five year old clonal trial. There were considerable genetic variations between clones for average yield, bark thickness and number of latex vessel rings. The correlation between average yield and number of latex vessel rings was significant. Several SALB resistant clones with good yields were selected.

103. Garcia, D., Mattos, C.R.R., Clement-Demange, A. and LeGuen, V. (2004). Genetic parameter estimations of three traits used to evaluate South American leaf blight (SALB) in rubber tree. *Crop Breeding and Applied Biotechnology*, 2: 453-462.

Disease severity, sporulation density and stromata density were evaluated in the field on one to three year old trees. Results from small scale clone trials were better than seedling trials for individual values. There was high correlation between the three parameters.

104. Garcia, D., Mattos, C.R.R., Goncalves, P. S. and LeGuen, V. (2004). Selection of rubber clones for resistance to South American leaf blight and latex yield in the germplasm of Michelin Plantation of Bahia, Brazil. *Journal of Rubber Research*, 7: 188-198.

SALB is a threat to rubber cultivation in Asia and Africa which produced more than 98 percent of world's natural rubber. The performance of 36 clones from the Michelin Plantation in Bahia, Brazil was evaluated. Several clones were resistant to SALB and also high yielding. Clones MDX 624, FDR 5788, CD 1130, MDX 607, CDC 312, FDR 5665, FDR 5802 and CD 1174 were selected for further evaluation.

105. Garcia, D., Sanier, C. Macheix, J.J. and D'Auzac, J. (1995). Accumulation of scopoletin *in Hevea brasiliensis* infected by *Microcyclus ulei* and evaluation of its fungitoxicity to three leaf pathogens of rubber tree. *Physiological and Molecular Plant Pathology,* 47: 213-223.

Accumulation of a coumarin, scopoletin, occurred at the infection site of leaves inoculated with *M. ulei*. The degree of resistance of clones was related to the rapidity and intensity of scopoletin accumulation. In immune clones and clones with partial resistance, early accumulation of scopoletin occurred and lasted for more than 48 h. The level of partial resistance was positively correlated with scopoletin concentration. *In vitro* test indicated that scopoletin at 2 mm strongly inhibited germtube elongation and conidium germination. At 24 h after inoculation, conidia germination and number of infection sites were lower in resistant clones. Scopoletin was also toxic to *Colletotrichum gloeoeporioides* and *Corynespora cassiicola* but required higher concentration than for *M. ulei* to totally inhibit germination and germtube elongation.

106. Garcia, D., Troispoux, V., Grange, N., Rivano, F. and D'Auzac, J. (1999). Evaluation of the resistance of 36 *Hevea* clones to *Microcyclus ulei* and relation to their capacity to accumulate scopoletin and lignin. *European Journal of Forest Pathology*, 29: 323-338.

Thirty six *Hevea* clones were inoculated and components of resistance (latent period, infectious period, lesion size, percent leaf area damaged, lesion number, spore production, and stroma

generation period) were compared. Clones could be differentiated based on these parameters. Components with high correlation were spore production, size of lesion, number of lesion and percent leaf area damaged. Stroma generation period was slightly correlated with all the other components. Latent period and infectious period were lightly correlated with lesion size and lesion size was slightly correlated with lesion density. For disease screening purposes, the important components of resistance were spore production and percent leaf area damaged. Scopoletin production also correlated strongly with resistance.

107. Gasparotto, L., Albuquerque, P.E.P., D'Antona, O. de J., Ribeiro, I.A., Rodrigues, F.M. and Lim, T.M. (1985). Reabilitacao de seringais de cultivo na Amazonia. *EMBRAPA-CNPSD Boletim de Pesquisa*, 1, 30 pp.

Integrated Pest Management combining weed control, fertilizer application and fungicide spraying was evaluated to rehabilitate a rubber area seriously affected by SALB. One year before fungicide application, weed control and fertilizer application was carried out to boost growth of trees. During refoliation the following season, fungicide (mancozeb, thiophanate methyl and triadimephon) treatment was carried out. Spraying of the three fungicides improved canopy retention. However, only mancozeb was effective when applied by fogging.

108. Gasparotto, L. and Junqueira, N.T.V. (1994). Ecophysiological variability of *Microcyclus ulei*, causal agent of rubber tree leaf blight. *Fitopatologia Brasileira,* 18: 22-28.

The minimum period of leaf wetness required to cause infection and the effect of temperature on infection, incubation period, generation period, size of lesion and sporulation of six *Microcyclus ulei* isolates from different regions of Brazil were evaluated. At 24 ºC, the *M. ulei* isolate from Manicore-AM required only 3 hr of leaf wetness for infection while both the isolates from Manaus-AM and Viana-ES required 4 hr of wetness. On the other hand, the isolates from Itubera-BA and Registro-SP required 8 hr for infection. All isolate had similar effects of temperature on infection except the Viana isolate which infected and produced conidia at 16 ºC. These findings indicate the existence of ecotypes or ecological races of *M. ulei* able to cause disease under climatic conditions unfavorable for disease development.

109. Gasparotto, L, Zambolim, L., Maffia, L., Vale F.X.R., and Junqueira N.T.V. (1989b). Epidemiologia do mal das folhas da seringueira. I. Ponte Nova-MG. *Fitopatologia Brasiliera*, 14: 65-70.

110. Gasparotto, L, Zambolim, L., Ventura, J.A., Costa, H., Vale F.X.R., and Maffia, L. (1991). Epidemiologia do mal das folhas da seringueira no estado do Espirito Santo. *Fitopatologia Brasileira*, 14: 65-70.

111. Gasparotto, L., Zambolim, L. Junqueira N.T.V., Maffia, L.A. and Vale F.X.R. (1991). Epidemiology of South American Leaf blight of rubber tree: Manaus Region. *Fitopatologia Brasileira,* 16: 18-21.

Abstract is not available.

112. Gasparotto, L., Zambolim, L., Ribeiro do Vale, F.X. and Junqueira N.T.V. (1989). Effect of temperature and humidity on the infection of the rubber tree (*Hevea* spp.) by *Microcyclus ulei*. *Fitopatologia Brasileira,* 14: 38-41.

113. Giesemann, A., Biehl, B. and Lieberei, R. (1986). Identification of scopoletin as a phytoalexin of rubber tree *Hevea brasiliensis*. *Journal Phytopathology,* 117: 373-376.

Various fungi induced formation of a blue fluorescent substance, a phytoalexin, in rubber leaves. This substance was identified as scopoletin by chromatographic and spectrophotometric methods.

114. Gilman, G.A. (1963). Some problems associated with the culture of *Dothidella ulei*. *Thesis for Diploma in Tropical Agriculture, University of the West Indies,* 42 pp.

Mannose at 20 g/l was optimum for the growth of *D. ulei*. A mixture of mercuric chloride and propylene oxide was most effective for disinfecting rubber seeds.

115. Goncalves, J.R.C. (1967). Observacoes sobre resistencia de clones de seringueira a *Dothidella ulei*. *Boletim Informativo IPEAN 120*. Mimeograph, 2 pp.

The susceptibility of rubber clones to SALB was determined in different localities in Brazil based on the number of stroma produced, lesion development and sporulation.

116. Goncalves, J.R.C. (1968). The resistance of FX and IAN rubber clones to leaf disease in Brazil. *Tropical Agriculture Trinidad*, 45: 331-336.

The degree of resistance of rubber clones to leaf diseases in the Brazilian states of Amazonas, Para, Acre, Mato Grosso and Bahia were reported based on observation in clonal gardens and plantations. FX 3925 (one parent is F4542) was resistant to SALB. Clones IAN 710, IAN 713 and FX 2261 were susceptible.

117. Goncalves, J.R.C. (1970). Resistancia de clones de seringueira provenientes do Brasil e da America Central a 'Isolares' de *Dothidella ulei* sob condicoes de Cosa de Vidro. *Instituto Pesquisas e Experimentacao Agropecuarias do Norte Fito-tecnia*, 4: 27-43.

FX and IAN clones from Brazil and MDF, MDX and P clones from Central America were inoculated with four isolates of *D. ulei*. None of the clones was immune. The Brazilian isolates appeared to belong to Race 4. Observations were made on sporulation and viability of the fungus.

118. Goncalves, P. de S. (1968). The resistance of FX and IAN clones to leaf disease in Brazil. *Tropical Agriculture*, 45: 331-336.

119. Goncalves, P. de S., Fernando, D.M. and Rossetti, A.G. (1980). A nursery progeny test of SALB resistant hybrids of inter-specific crosses of *Hevea*. *Journal Rubber Research Institute Sri Lanka*, 67: 13-21.

Abstract is not available.

120. Goncalves, P. de S., Paiva, J.R. de and Souza, R.A. de (1983). Retrospectiva e atualidade do melhoramento genetico da seringueira (*Hevea* spp.) no Brasil e em paises Asiaticos. *Serie Documentos No. 2, EMBRAPA*, Brazil, 69 pp.

The history of rubber cultivation in Brazil was presented. The taxonomy of *Hevea*, method of *Hevea* breeding and the history and development of *Hevea* breeding in South East Asia and Brazil were also presented.

121. Grant, T.J. (1946). Cooperative rubber research in Costa Rica. *Agriculture America*, 6: 47-50.

SALB was detected in 1935. SALB was prevalent on the Atlantic slope at an elevation of 2 000 feet where humid weather and dew periods were long. Plants from Africa and Philippine were very susceptible. However, plants from South America were resistant.

122. Griffon, E. and Maublanc, A. (1913). Sur quelques champignons parasites des plantes tropicals. *Bull. Soc. mycol. Fr.*, 29: 244-249.

Dothidella ulei was recorded on *Hevea brasiliensis* in Brazil.

123. Guyot, J., Condina, V., Doare, F., Cilas, C.C. and Sache, I.I.(2010). Segmentation applied to weather-disease relationships in South American leaf blight of the rubber tree. *European Journal of Plant Pathology*, 126: 349-362.

South American leaf blight is managed by planting rubber in areas not conducive to the disease. However, knowledge on effects of climate on the disease is lacking. This knowledge would assist in identifying zones in Asia and Africa with high risks to the disease. Using the segmentation method, it is possible to list climatic factors that influence disease severity.

124. Guyot, J. and Doare, F. (2010). Obtaining isolates of *Microcyclus ulei*, a fungus pathogenic to rubber trees, from ascospores. *Journal of Plant Pathology*, 92: 765-768.

A technique was developed to isolate the fungus using ascospores in the stroma. The stroma was crushed and the ascospores were used in inoculation studies and successfully caused infection.

125. Guyot, J., Sache, I.I. and Cilas, C.C. (2008). Influence of host resistance and phenology on South American leaf blight of the rubber tree with special consideration of temporal dynamics. European Journal of Plant Pathology, 120: 111-124.

South American leaf blight is responsible to the insignificant rubber production in South America and is a threat to Asia and Africa. Clonal resistance influences disease severity, asexual sporulation, stroma density and disease dynamics at the leaflet level. Latent period and infection period were longer on more resistant clones. Stroma density was dependent on disease severity. The period of leaflet development also influenced disease development and the shorter the period, the less severe is the disease.

126. Hagen, J., Gasparotto, L., Moraes, V.H.F., and Lieberei, R. (2003). Reactions of cassava leaves to *Microcyclus ulei*, causal agent of South American leaf blight of rubber trees. *Fitopatologia Brasileira*, 28: 477-480.

Young cassava leaves inoculated with conidia induced formation of blue fluorescent compounds in the inoculation site causing leaf distortion and sometimes abscission. Restricted fungal growth developed but no sporulation occurred.

127. Hargis, O.D., Stakman, E.C., Johnson, K.E., La Rue, C.D., Sorensen, H.G. and Whally, W.G. (1946). Cooperative inter-American plantation rubber development, Colombia. *U.S.D.A. Washington D.C.* 1940.

SALB was present in the Leticia area and conditions of damp weather during eight months of the year were extremely favourable to its development. Many small seedlings however were absolutely disease free. The material would seem to possess an unusual degree of disease resistance.

128. Harrison, J.B. (1922). Report of the Department of Science and Agriculture for 1920. *Report Department Science and Agriculture British Guiana* 120, 35 pp.

Conditions affecting the development and spread of SALB were described.

129. Hennings, P. (1904). Fungi Amazonici II. *Hedwigia*, 43: 242-273.

New species: *Aposphaeria ulei, Dothidella ulei*.

130. Hilton, R.N. (1955). South American leaf blight. A review of the literature relating to its depredations in South America, its threat to the Far East and the methods available for its control. *Journal Rubber Research Institute Malaysia,* 14: 287-337.

Information on SALB and the causal fungus was reviewed. Disease spread and effects of the disease in tropical America were presented. Measures to prevent and combat the possibility of spread to Asia, particularly Malaysia were suggested.

131. Ho, C.Y., Tan, H., Ong, S.H., Sultan, M.O and Abdul Ghani, M.N. (1977). Breeding and selection strategies at the Rubber Research Institute of Malaysia. *Workshop on International Collaboration in Hevea Breeding, Kuala Lumpur*, Mimeograph, 13 p.

The problems hindering rapid *Hevea* improvement in the East were outlined. The RRIM breeding and selection strategies to alleviate these problems were presented. These include broadening the genetic base for field resistance to diseases particularly to SALB. Field or horizontal resistance is more stable against SALB than vertical or major gene resistance. Combining horizontal resistance with the 'early or off-seasonal wintering' or 'non-wintering' character is advantageous for 'disease escape'. Clone RRIM 600 and PR 107 appear to possess field resistance.

132. Hoedt, T.G.E. (1953). Opmerkingen over *Hevea*-selectie in Z.O. Azie en Latijns Amerika in verband methet optreden van *Dothidella ulei*. *Archive Rubberculture*, 30: 1-37.

The genetic factor for resistance to *D. ulei* may be present in the progenies of the Wickham seeds which have been used in all the rubber plantings of South East Asia. For instance, AVROS 1301 was highly resistant. A study of the fundamental reason for the resistance of different *Hevea* species and clones was suggested.

133. Hoedt, T.G.E. (1961). *Dothidella ulei* and the selection and breeding of *Hevea*. *Proceedings Natural Rubber Research Conference,* 1960, Kuala Lumpur, pp. 446-452.

The spread of *D. ulei* and its relation to climatic conditions were discussed. Disease control by fungicide spraying and the use of resistant planting material was also discussed. The yield of Brazilian and Far Eastern clones was compared.

134. Holliday, P. (1969). Dispersal of conidia of *Dothidella ulei* from *Hevea brasiliensis*. *Annals Applied Biology*, 63: 435-447.

Conidial production was maximum at 10.00 hours and minimum at night or in the early morning. Transient increases occurred after rain. On wet days almost equal numbers of conidia were dispersed between 10.00 hours and 12.00 hours. Large increases occurred following rain between 09.00 and 13.00 hours but no such increase occurred following rain after 13.00 hours. Twice the number of conidia was trapped on sunny days than on overcast days. The morning maximum spore caught was more pronounced on windy as compared to calm days. Conidial sporulation was low on drier days and sporulation was abundant on wetter days.

135. Holliday, P. (1970). *Microcyclus ulei* in *'IMI Description of Fungi and Bacteria', No. 23, Sheet 225, Cab International, U.K.*

The symptom of the disease caused by *M. ulei* was described and information on disease transmission, geographical distribution and hosts was also presented. *M. ulei* infects only *Hevea* species (*H. brasiliensis, H. benthamiana, H. guianensis* and *H. spruceana*). It infects young foliar parts of the plant i.e. young leaves, petioles, stems, inflorescences, flowers and fruits. The disease is spread by windborne conidia.

136. Holliday, P. (1970). South American leaf blight *(Microcyclus ulei)* of *Hevea brasiliensis*. *Phytopathological Papers No.12*, Commonwealth Mycological Institute, England, 31 pp.

The information on SALB was reviewed in considerable detail. It covers subjects on hosts, disease identification, fungal morphology, economic significance, distribution and disease spread, disease symptoms, life history and biology of the pathogen and disease control.

137. Honig, P., Vollema, J.S. and Kortleven, J. (1947). Selectie van *Hevea*. *Chron. Natur.,* 103: 63-67.

Cooperation between United States Department of Agriculture and Surinam over testing of American clones resistant to SALB was reported.

138. Hutchinson, F.W. (1958). Defoliation of *Hevea brasiliensis* by aerial spraying. *Journal Rubber Research Institute Malaysia,* 15: 241-274.

Defoliation of old rubber leaves was recommended as a measure to eradicate SALB. A defoliant, n-butyl 2, 4, 5-T sprayed from the air (5 percent (8 percent acid equivalent) in 3 gallon gasoline/ acre) was effective to defoliate the rubber trees. After one application, treated trees remained leafless for 4-6 weeks. Concentration was not critical in defoliation, but had marked effect upon the rate and amount of refoliation.

139. Ismail Hashim (1978). Histological and biochemical studies on South American leaf blight of *Hevea* species. Ph. D. Thesis, University of the West Indies, Trinidad and Tobago.

The development of the fungus in leaves from resistant and susceptible clones was presented. The activities of selected enzymes were presented and their possible roles in disease resistance were suggested. The anatomy of leaf abscission of infected leaves was compared with abscission caused by other factors.

140. Ismail Hashim (1979). Possible mechanism of *Hevea* resistance to South American leaf Blight. *ANRPC SALB Technical Committee Meeting*, 1979, Chiang Mai, Thailand.

The possible mechanism of resistance of *Hevea* to SALB was presented. The mechanism of resistance may be biochemical in nature. For certain clones, resistance may be linked to hypersensitivity. The roles and relationship of phenolic compounds and certain enzymes with resistance were presented.

141. Ismail Hashim (1979). South American leaf blight: Recent advances. *Planters' Bulletin Rubber Research Institute Malaysia*, 158: 20-24.

The methods to control SALB with fungicides and resistant clones were reviewed. The host parasite relation of *M. ulei* with *Hevea* was also presented.

142. Ismail Hashim (1980). Clonal characteristics and susceptibility of *Hevea brasiliensis* to *Microcyclus ulei*. *Proceedings Second South East Asian Symposium of Plant Diseases*, 1980, Bangkok, Thailand, 12 pp.

Clones of *Hevea brasiliensis* varied in their susceptibility to *Microcyclus ulei*. Host response to infection of susceptible and resistant clones and the anatomy of resistant and susceptible clones was presented. The clones differ in content of cuticular wax, total phenols and activities of certain enzymes but the contents did not correlate with resistance of clones. Conidia germinated readily on resistant and susceptible clones but the conidia developing appressoria were more numerous on resistant clones as compared to susceptible clones. Lesion formation and sporulation occurred earlier on susceptible clones than on resistant clones. The occurrence of cell collapse in some resistant clones inhibited disease spread. Following infection, the increase in activities of IAA oxidase and peroxidase was higher and occurred earlier in resistant clones as compared to susceptible clones.

143. Ismail Hashim (1983). Biology and economic importance of South American leaf blight of *Hevea* rubber. In '*Exotic Plant Quarantine Pests and Procedures for introduction of Plant Materials*,' ASEAN PLANTI, pp. 27-34.

The article describes the disease symptoms, the spores of *M. ulei*, the physiological races, spore production, liberation and the viability period of the spores. Information on methods of disease control was also covered.

144. Ismail Hashim (1986). Induced resistance of *Hevea* to South American leaf blight by incompatible races of *Microcyclus ulei*. *Journal Natural Rubber Research,* 1: 195-201.

Inoculation of leaf discs of *Hevea* by an isolate of *Microcyclus ulei* incompatible to a *Hevea* clone induced resistance to subsequent infection by a compatible race. Simultaneous inoculation of compatible and incompatible races reduced the size of lesions but not their numbers. Inoculation of an incompatible race 24-hour prior to inoculation of a compatible race reduced both the number and size of lesions. The reduction was proportional to the concentration of the incompatible race inoculum. On intact leaves, inoculation of a compatible race prior to an incompatible race reduced the number of lesions and the conidia produced.

145. Ismail Hashim (1988). Detection and characterisation of benomyl resistant strains of *Microcyclus ulei*. *Journal Natural Rubber Research,* 3: 155-162.

Benomyl resistant isolates of *Microcyclus ulei* were detected by inoculating potato sucrose agar medium amended with 1 mg/l benomyl. Race 6 and to a lesser extent Race 2 of the fungus had a higher frequency of yielding benomyl resistant isolates. Resistant isolates developed longer germtubes on benomyl-treated cellophane and required higher concentrations of benomyl to control infection. Benomyl resistant isolates were also cross-resistant to thiophanate methyl and carbendazim. Sporulation of a benomyl resistant isolate was not significantly reduced by the presence of low concentrations of benomyl or a benomyl sensitive isolate.

146. Ismail Hashim and Almeida, L.C.C. de (1987). Identification of races *and in vitro* sporulation of *Microcyclus ulei*. *Journal Natural Rubber Research,* 2: 111-117.

Culture characteristics viz. colony appearance, growth habits and *in vitro* sporulation of pure isolates of *Microcyclus ulei* from different *Hevea* clones were studied. The physiologic races of these isolates were identified by inoculating leaf discs and differential clones grown in polyethylene bags. The isolates could be classified into two morphological groups and four physiologic races i.e. Races 2, 4, 5 and 6. Generally, results of leaf discs were similar to those of plants in polyethylene bags.

147. Ismail Hashim and Aziz, S.A.K. (1983). South American leaf blight – Further measures against its introduction. *Planters' Bulletin Rubber Research Institute Malaysia,* 177: 128-132.

The quarantine measures to exclude the introduction of SALB into Malaysia were described. Travellers originating from SALB endemic areas are advised to take special precautions including breaking their return journey in temperate North America or Europe. In the event of an outbreak of SALB, a disease eradication procedure involving spraying of fungicide and defoliant will be undertaken.

148. Ismail Hashim, Chee, K.H. and Duncan, E.J. (1978). Reaction of *Hevea* leaves to infection with *Microcyclus ulei*. *Journal Rubber Research Institute Malaysia,* 26: 67-75.

The germination rate and length of the germ tube of conidia of *M. ulei* were similar on *Hevea* clones of different susceptibility at 12 h after inoculation but hyphal growth was slower on resistant leaves after 18 h. Appressoria were observed within 3-6 h on leaves of resistant clones and 12 h on susceptible ones. Penetration of the epidermis occurred within 12 h on both resistant and susceptible material, but internal spread was prevented in resistant leaves due to collapse of the epidermal and sub-epidermal cells. On less resistant clones, this collapse was delayed, and in susceptible clones was confined to the epidermis.

149. Ismail Hashim, Chee, K.H. and Wilson, L.A. (1980). The relationship of phenols and oxidative enzymes with resistance of *Hevea* to South American leaf blight. *Phytopathologische Zeitschrift,* 97: 332-345.

There was no direct correlation between total content of phenolic compounds in healthy *Hevea* and their degree of resistance to South American leaf blight (*Microcyclus ulei*). However, quercetin seemed to be higher in leaves from resistant clones. Total phenolic compounds and orthodihydroxyphenol contents in diseased resistant leaves were not significantly different from those in diseased susceptible leaves. IAA oxidase and peroxidase activities were generally higher in susceptible leaves and these enzymes increased with infection giving greater increases, and earlier detection, after infection of resistant leaves. Presence of growth substances reduced lesion size which could be related to increased peroxidase activities.

150. Ismail Hashim, Chee, K.H., Wilson, L.A. and Duncan, E.J. (1980). A comparison of abscission of rubber (*Hevea brasiliensis*) leaves infected with *Microcyclus ulei* with leaf abscission induced by ethylene treatment, deblading and senescence. *Annals Botany*, 45: 681-691.

Studies on the histology and on effects of growth substances and phenols as well as changes in activities of pectinmeythl esterase indicated that the mechanism of abscission of *Hevea* leaflets infected with *Microcyclus ulei* differed from the mechanism of abscission of debladed, ethylene treated and senescent leaves. An abscission layer which was formed during abscission of debladed, ethylene-treated and senescent leaves was absent during abscission of heavily diseased leaves. The ratio of pectinmethyl esterase activities in tissues distal to the abscission zone to activities in tissues proximal to the zone decreased in debladed and ethylene treated leaves but such decreases were not detected during abscission of *Hevea* leaves infected with *M. ulei*.

151. Ismail Hashim and Lim, T.M. (1983). Screening for defoliants of *Hevea* rubber leaves. *ANRPC SALB Technical Committee Meeting,* 1983, Kotayam, India, 6 pp.

Triclopyr at 250 g/ha was effective in defoliating mature rubber leaves. Triclopyr was recommended as an alternative defoliant to 2, 4, 5-T for emergency eradication of SALB.

152. Ismail Hashim and Pereira, J.C.R. (1986). Influence of resistance of *Hevea* on deveploment of *Microcyclus ulei*. *Journal Natural Rubber Research*, 4: 212-218.

The histological development of Race 2 of *Microcyclus ulei* and the components of resistance of 13 *Hevea* clones of various levels of resistance were compared. At least two mechanisms of resistance were observed. On the highly resistant clones, colony development was arrested early and sometimes host cell collapse occurred. On the marginally resistant clones, resistance arrested the development of some lesions while increasing the latent period and reducing the amount of conidia produced on others. On some marginally resistant clones (FX 4098 and FX 3864) and the susceptible clone SL 26, host cell collapse also occurred. *Hevea* clones with partial resistance to *M. ulei* could be selected by determining latent period and conidia production.

153. Ismail Hashim and Pereira, J.C.R. (1989). Lesion size, latent period and sporulation on leaf discs as indicators of resistance of *Hevea* to *Microcyclus ulei*. *Journal Natural Rubber Research*, 4: 56-65.

There were clonal differences in the rate of development of mycelium and appearance of lesions, size of lesions, latent period and the quantity of conidia produced on discs of *Hevea* leaves. There was a positive correlation between conidial production and lesion size, and negative correlation existed between conidial production and latent period and lesion size and latent period. Latent period and sporulation are also important components for assessment of resistance. Clones GT 711, RRIM 501, CNS AM 7701, SIAL 842 and SIAL 263 developed relatively smaller lesions, had longer latent periods and reduced sporulation. On these clones, the differences in lesion size were significant between clones but not between races of *Microcyclus ulei*. However, differences in conidial production between clones, races and the interaction between clones and races were significant.

154. Ismail Hashim, Wilson, L.A. and Chee, K.H. (1978). Regulation of indole acetic acid (IAA) oxidase activities in *Hevea* leaves by naturally occurring phenolics. *Journal Rubber Research Institute Malaysia,* 26: 105-111.

Indole acetic acid (IAA) oxidase activities of preparations from *Hevea* leaves were stimulated by 2, 4-dichlorophenol as well as by naturally occurring phenolics, p-coumaric acid, scopoletin, 4-methylumbelliferone and chlorogenic acid. Kaempferol and quercetin which had been associated with resistance to SALB were shown to function both as cofactors and as competitive inhibitors of *Hevea* leaf IAA oxidase. The contribution of these findings to the understanding of pathogenicity of SALB was discussed.

155. Jayasinghe, C.K. (1992). South American leaf blight: Likelihood behaviour in Sri Lanka and strategies in management. *Bulletin of the Rubber Research Institute of Sri Lanka*, 29: 21-26.

Abstract is not available.

156. Jayasekera, N.E.M. and Fernando, D.M. (1977). *Hevea* introduction (non-Wickham) into Sri Lanka. *Workshop on International Collaboration on Hevea Breeding, Kuala Lumpur*, Mimeograph, 4 pp.

Dothidella resistant clones of Latin American origin (F, FX, IAN) were introduced into Sri Lanka between 1955 and 1959. Clones with possible *Oidium* resistance include the *H. benthamiana* clone F 4542 and its progeny FX 590, FX 614, IAN 45-717, IAN 3793, IAN 3828, FX637 and FX 3810. Crosses of the introduced clones 2473, 6004, 5329 and 8798 were resistant to SALB; the latter clone was a cross between *H. spruceana* and LCB 1320.

157. John, C.K., Aziz S.A.K. and Subramaniam, S. (1976). South American leaf blight – an overview. *RRISL International Rubber Conference,* 1976, Sri Lanka, 16 pp.

A review covering dispersal of *Microcyclus* spores, possible introduction and behaviour in Asia, preventive measures and eradication, crown budding and chemical control and on breeding for disease resistance which is considered the most important. The Ford Motor Company breeding programme in Brazil had produced several promising clones such as FX 25, FX 3899 and FX 3164, while a similar effort by the Firestone Rubber Company in Liberia and Guatemala had created numerous resistant clones in their MDF and MDX series. Breeding for SALB resistance in Asia was primarily carried out by the Rubber Research Institutes in Malaysia and Sri Lanka. *Hevea brasiliensis* from Madre de Dios and *H. benthamiana* from Rio Negro were useful as sources of resistance against SALB.

158. Johnston, A. (1941). The Ford rubber plantations I. *India Rubber World,* 104: 35-38.

The effort of the Ford Motor Co. to establish rubber plantations in Brazil from 1927 to 1941 was documented. Eastern clones were introduced for source of high yield, and crown budding was considered the ultimate solution to the SALB problem.

159. Junior, J.H. (2010). Mal das folhas da seringueira: Danamica de inoculo do patogeno, progreso e danos em tres condicoes topograficas. Thesis, Universidade Federal do Vicosa, 91 pp.

The dynamics of the conidia and ascospores release, host phenology and disease progress, effects of tree height on disease severity and leaf production on tree growth were assessed. Ascospore and conidia were trapped throughout the period of study (18 months). Concentration of ascospores was higher at night but the conidia in the air were more during the day. Weather variables affect conidia concentration. Lower spore concentration in the air and less severe disease occurred on the hill tops disease was more severe in the lowland. Thus altitude affected disease severity. Yield was reduced by 47.7 percent in the lowland and leaf density reduced by 50.1 percent.

160. Junqueira, N.T.V. (1991). Controle biologico do mal das folhas da seringueira, Mimeograph, pp. 115-129.

The efficiency of mycoparasite *Dicyma pulvinata* and *Acremonium strictum* for biological control of *Microcyclus ulei* was evaluated. *A. strictum* was tested only under controled environmental-conditions. The control of *M. ulei* by *D. pulvinata* was satisfactory in plantations with intercalary lines of *Hevea* clones varying in resistance to this pathogen. Under controlled environmental conditions, both mycoparasites were able to colonize stromata and conidial phase of *M. ulei*. Recommendations for the utilization of these mycoparasites for integrated control of rubber tree leaf blight were presented.

161. Junqueira N.T.V., Alfenas A.C., Chaves, G.M., Zambolim L. and Gasparotto, L. (1987). Isoenzyme patterns of *Microcyclus ulei* isolates differing in virulence. *Fitopatologia Brasileira,* 12: 208-214.

Protein and isoenzyme patterns of *Microcyclus ulei* isolates differing in virulence were analysed on polyacrilamide gel electrophoresis. Gels were stained for α and β esterase (EST), malate dehydrogenase (MDH), lactate dehydrogenase (LDH), β-glucosidase (GLU), polyphenoloxidase (PPO), alcohol dehydrogenase (ADH), alkaline phosphatase (AP), tetrazolium oxidase (TO), hexokinase (HK) and peroxidase (PO). Better visualization of bands of enzyme activity was obtained by treating the stained gels with acetone. Electrophoretic data were compared to the virulence of the isolates. Isolates were classified into three groups according to their virulence. EST, LDH and PO patterns differentiated 6, 5 and 4 isolates, respectively. On the other hand, MDH and HK differentiated onIy 2 and 3 isolates, respectively. GLU, PPO, ADH and AP showed very low enzyme activity. The HM^{I} isolate was avirulent to all tested clones, nonsporulating, and displayed different isoenzyme patterns in comparison to the other isolates. Virulence of *M. ulei* isolates correlated with their isoenzyme patterns. It was concluded that the electrophoretic analysis of enzymes may be usefull to identify and characterize isolates of *M. ulei* varying in their degrees of virulence.

162. Junqueira, N.T.V., Chaves, G.M., Zambolin, L., Gasparotto, L. and Alfenas, A.C. (1986). Variabilidade fisiologica de *Microcyclus ulei* (Physiological variability of *Microcyclus ulei*). *Fitopatologia Brasileira*, 11: 823-833

The physiological variability of 16 isolates of *M. ulei* collected from rubber plantations in different regions of Brazil was studied by inoculations of different clones. At 15 days after inoculation, the diameter of lesions and sporulation was determined. The isolates showed a great physiological variation. Three groups of isolates of *M. ulei* were determined and were designated as Groups I, II and III. Isolates of Group I sporulated on all clones carrying the genes of F 4242 (*H. benthamiana*) and in the majority of clones of *H. brasiliensis*, but did not sporulate on clones MDF 180 and FX 985 (*H. brasiliensis).* Isolates of Group II sporulated on all or in the majority of clones of *H. brasiliensis*, including clones MDF 180 and FX 985, and on some clones with genes from F 4542. Isolates of Group III sporulated on the majority of clones with genes of F 4542 and on the majority of clones of *H. brasiliensis*.

163. Junqueira N.T.V., Chaves G.M., Zambolim L., Alfenas, A.C. and Gasparotto, L. (1988). Reaction of rubber tree clones to various isolates of *Microcyclus ulei*. *Pesquisa Agropecuaria Brasileira*, 23: 877-893.

The reactions of 33 clones of *Hevea* to various *M. ulei* isolates collected from rubber plantations in different regions of Brazil were studied. Isolates were inoculated with a suspension of conidia (2×10^5 conidia/ml). The clonal reaction varied with isolates and clones. Most of the clones showed complete resistance to some of the isolates, but the same clones were susceptible or highly susceptible to other isolates. Some clones showed complete resistance and varying levels of incomplete resistance. The latent period and the diameter of lesions may be related to *Hevea* resistance to *M. ulei*, but these two parameters are not sufficient to explain this resistance. The contribution of various other resistance components is needed. The most important component of resistance was "sporulation on lesions". The incubation period and number of lesions are not good parameters for analysing the rubber tree resistance to *M. ulei*.

164. Junqueira, N.T.V., Chaves, G.M., Zambolim, L., Romeiro, R.S. and Gasparotto, L. (1987). Isolation, culture and sporulation of *Microcyclus ulei*, causative agent of South American leaf blight of *Hevea* rubber trees. *Revista Ceres*, 31: 322-331.

This study was undertaken to evaluate several culture media to enhance spore production of *Microcyclus ulei*. Media were incubated in Erlenmeyer flasks at 24 ºC under an alternate regime of light periods (1 hr under a 40 W, fluorescent light, at 2000 lux, daylight, followed by 3 hr in the dark, repeated three times in the first 9 hr), followed by 15 hr in complete darkness. Each medium was inoculated with a mixture of mycelia and conidia harvested from a twelve-day old *M. ulei* culture. Maximum yield of conidia was obtained from a twelve-day old culture medium containing 6 g neopeptone, 10 g sucrose, 2 g KH_2P0_4, 1 g $MgS0_4.7H_20$, 20 g agar, and 2 ml of 'Panvit', a complex of mineral salts, vitamins and amino acids. Another culture medium with a per liter composition of 10 g sucrose, 2 g $K_2HP0_4.7H_20$, 0.25 percent w/v potato, 13 g of 'Bonzo' dog food and 1.5 ml of 'Panvit' also gave a good yield of conidia.

165. Junqueira, N.T.V. and Gasparotto, L. (1991). Controle biologico de fungos estromaticos causados de doencas foliares em seringueira. In 'Bettiol, W., ed., *Controle Biologicos de Doencas de Plantas'*, EMBRAPA-CNPDA, Brazil, Document 15, p. 307-331.

The effectiveness of *Dicyma pulvinata* to control *Microcyclus ulei* was experimented. *D. pulvinata* was isolated using potato dextrose agar supplemented with chloramphenicol (100 ppm). Spores produced in the laboratory were used to treat *M. ulei* on one year old rubber plants. The colonization of stromas of *M. ulei* by *D. pulvinata* varied with season. *D. pulvinata* successfully reduced the incidence of *M. ulei* in an area with polyclonal clones with heterogenous genetic lines. However, it did not reduce incidence in a monoclonal planting of IAN 717. This may be due to the ability of *D. pulvinata* to survive in a polyclonal area as leaves were present continuosly as compared to an area planted with a single clone.

166. Junqueira, N.T.V., Gasparotto, L.; Kalil Filho, A.N.; Lieberei, R. and Lima, M.I.P.M. (1989). Identificacao de fontes da resistencia ao *Microcyclus ulei*, agente causal do mal das folhas da seringueira. *Fitopatologia Brasileira*, 14: 147.

167. Junqueira, N.T.V., Lieberei, R., Kalil Filho, A.N. and Lima, M.I.P.M. (1990). Components of partial resistance in *Hevea* clones to rubber tree leaf blight, caused by *Microcyclus ulei*. *Fitopatologia Brasileira*, 15: 211-214.

Several components of resistance that reduced the rate of rubber tree leaf blight were evaluated. The components evaluated (susceptible leaf period, fungal pathogen generation period, number of fungal generations per leaf flush, lesion diameter and the spore production on the lesions) differed strongly among various clones of *Hevea*. These biological, plant inherent factors are suitable for use in controlling epidemic development of SALB. The utilization of these factors for rubber tree breeding for SALB resistance to *Microcyclus ulei* is discussed.

168. Junqueira, N.T.V., Lima, M.I.P.M., Gasparotto, L. and Luiz, A.J.B. (1992). Integrated control of rubber tree leaf blight, association between genetic resistance and chemical control. *Pesquisa Agropecuaria Brasileira*, 27: 1027-1034.

The efficiency of chemical control of leaf blight (*Microcyclus ulei*) on rubber tree clones varying in partial resistance to this disease was studied. In the field, leaf flushes were weekly sprayed once, twice, thrice or four times with a mixture of thiophanate methyl (0.125 percent) + triadimephon (0.025 percent) + methamidophos (0.06 percent). The first fungicide spraying was carried out during bud burst (A_2/A_3 leaf stage). The response to chemical control was proportional to the resistance level of the *Hevea* clones. The influence of each component of partial resistance on the effectiveness of chemical control of leaf blight was discussed.

169. Junqueira, N.T.V., Mevenkamp, G, Lieberei, R. and Normando, M.C.S. (1991). Resistance activation in rubber tree to leaf blight (*Microcyclus ulei*) by non-and weakly-pathogenic fungi. *Fitopatologia Brasileira*, 16: 268-270.

Conidia of *Periconia manihoticola* and *Corynespora cassiicola* (weak *Hevea* pathogens in Brazil), *Hansfordia pulvinata* (*Hevea* non-pathogen) and avirulent *Mycrocyclus ulei* isolates when inoculated in young *Hevea* leaves 24-hour before the challenge inoculation of a virulent *M. ulei* isolate, led to a distinct, but transient, resistance activation against the biotrophic leaf pathogen *M. ulei*. On pre-inoculated leaves, the *M. ulei* generation period was markedly enhanced while lesion diameter and spore production per lesion was reduced.

170. Junqueira, N.T.V., Moraes, V.H.F., Lieberei, R. and Gasparotto, L. (1993). Induced polyploidy potential for improving resistance in *Hevea* clones to Rubber Tree Leaf Blight. *Fitopatologia Brasileira*, 18: 12-18.

Components of resistance that reduce the epidemic rate of rubber tree leaf blight, were evaluated on colchicine-induced polyploids (CIP) *Hevea* clones and on their respective natural diploids after inoculation of virulent *Microcyclus ulei* isolates to the diploid clones. Some CIP clones presented high level of resistance in comparison to their susceptible diploid clones, whereas other CIP clones were susceptible. The polyploid plant inherent factors controlling resistance to *M. ulei* and the potential of induced polyploidy for control of SALB were discussed.

171. Junqueira N.T.V., Zambolim L., Chaves G.M., and Gasparotto, L. (1986). Sporulation *in vitro* and viability of conidia and pathogenicity of *Microcyclus ulei*. *Fitopatologia Brasileira*, 11: 667-682.

172. Kajornchaiyakul, P., Chee, K.H., Darmono, T.W., and Almeida, L.C. de (1984). Effect of humidity and temperature on the development of South American leaf blight (*Microcyclus ulei*) of *Hevea brasiliensis*. *Journal Rubber Research Institute Malaysia*, 32: 217-223.

Dry conidia of *M. ulei* require 6-8 hr of high humidity after deposition to infect young leaves of *H. brasiliensis*. After inoculation high disease intensity was observed on plants incubated at 19-22 ºC or 23-25 ºC, but little infection occurred at 26-29 ºC and none at 30-32 ºC. Lesion development was optimum at 23-25 ºC. Conidial sporulation occurred, between 19 and 28º C and was increased by high humidity, especially in the range 23-25 ºC.

173. Kalil-Filho, A.N., Lama M.A., Mestriner, M.A. and Del-Lama, M.A. (1995). Association between iso-enzymatic phenotypes and resistance to the fungus *Microcyclus ulei* in rubber tree clones. *Brazilian Journal of Genetics*, 18: 511-516.

Starch gel electrophoresis was done on 78 rubber clones. Seven enzymatic systems were studied. Association between specific enzymatic phenotypes and resistance indicates that selection for resistance is possible using these markers.

174. Kalil-Filho, A.N. and Junqueira, N.T.V. (2001). Correlacao fenotipicas entre vigor e resistencia ao mal das folhas no hibrido IAN 6158 × FX 985 da seringueira. *Communicado Tecnico*, 67, 4 pp.

Characteristics associated with vigour and resistance were evaluated. Phenotypic correlation existed in one of the progenies. Low positive (0.26) or negative correlation were obtained between vigour and resistance. These characters must be considered separately in breeding programmes.

175. Klippert, W.E. (1941). The cultivation of *Hevea* rubber in tropical America. *Chronicle Botany*, 6: 199-200.

The transfer of the industry from America to the Far East was the result of the successful method of cultivation in the Far East and also the presence of SALB in the Americas. Satisfactory progress is being achieved to bring back the rubber industry to western hemisphere.

176. Kuyper, J. (1912). Een *Fusicladium*-ziekte on *Hevea*. *Meded. Dep. Landb. Suriname*, 28: 1-10.

The causal fungus of SALB was described as *Fusicladium macrosporum*. The disease was not serious but was widespread in Suriname and in plantations and ‘virgin’ forest 38 m from the coast. *H. guianensis* was infected. Breading for disease resistance was discussed.

177. Kuyper, J. (1913). *Fusicladium* leaf disease of *Hevea* in Surinam. In Rubber disease: a warning. *J. Bd. Agric. British Guiana*, 6: 103-104.

Symptoms on leaves and leaf stalks were described. The causal fungus was named *Fusicladium macrosporum*. The fungus was difficult to culture. *Hevea guianensis* was also infected. Six-year-old trees were infected and killed.

178. Langdon, K.R. (1963). Culture and pathogenicity of *Dothidella ulei*. *Ph.D. Thesis, University of Florida,* 35 pp.

The subject of the thesis is described in the two papers below.

179. Langdon, K.R. (1965). Relative resistance or susceptibility of several clones of *Hevea brasiliensis* and *H. brasiliensis* x *H. benthamiana* to two races of *Dothidella ulei*. *Plant Disease Reporter,* 49: 12-14.

Hevea clones with F 4542 (*H. benthamiana*) parentage were more susceptible to Race 2 of *D. ulei* from Costa Rica than to Race 1 from Guatemala whereas those without F 4542 parentage were equally resistant or susceptible to both races.

180. Langdon, K.R. (1966). Development of a new medium for culturing *Dothidella ulei* in quantity. *Phytopathology*, 56: 564-565.

PDA with peptone, phytone, malt extracts (5 g/1) and yeast extract (0.5 g/l) supported best growth. The pathogen also grow on a basal medium containing 1 g NH_4NO_3; 0.3 g KH_2PO_4; 0.3 g $MgSO_4.7H_20$; 0.005 g $FeSO_{4.}7H_2O$ and 10 g glucose/1 and growth promoting substances - *Hevea* leaves, peptone or phytone. Sporulating cultures may be maintained by sub-culturing every 3 months; and virulence by passage through hosts every 6-12 months.

181. Langford, M.H. (1943). Fungicidal control of South American leaf blight of *Hevea* rubber trees. *Circular United States Department of Agriculture*, 686, 20 pp.

SALB could be economically controlled by weekly spraying with insoluble copper (basic copper sulphate, copper silicate, copper phosphate, copper oxychloride, cuprous oxide) or dusting with wettable sulphur, with the addition of a spreader (casein, wheat flour). Spraying high yielding, susceptible trees and top budding with resistant crowns is practical.

182. Langford, M.H. (1944). Science fights for healthy *Hevea*. *Agriculture America*, 4: 151-153, 158.

SALB was controlled using fungicides, crown budding and resistant clones.

183. Langford, M.H. (1945). South American leaf blight of *Hevea* rubber trees. *Technical Bulletin U.S. Department of Agriculture*, 882, 31 pp.

A report on the influence of environmental factors on severity of leaf blight severity and on resistance of *Hevea* plants obtained from many parts of the world. A technique for testing *Hevea* clones for resistance to SALB was described, and a system of classifying resistance or susceptibility was presented and illustrated.

184. Langford, M.H. (1946). Regional differences in resistance of *Hevea* selections to South American leaf blight. *Phytopathology*, 36: 686 (Abstract).

Hevea clones were grown in Costa Rica, Panama, Trinidad, Brazil and Peru. Clones that were highly susceptible in some areas were infected slightly or not at all in other areas.

185. Langford, M.H. (1953). *Hevea* diseases of the Amazon Valley. *Boletim Tecnico Instituto Agronomico do Norte*, 27: 1-28.

One of the diseases described was SALB which infected the leaves and could kill the plant. It was the most destructive disease in the Amazon Valley. Spraying of protective fungicides and planting of resistant clones were the means to control the disease.

186. Langford, M.H. (1957). The status of *Hevea* rubber planting material for use in tropical America. *Turrialba*, 7: 10-110.

Top budding SALB resistant crowns to susceptible panel clones did not depress yield significantly. However, the climatic conditions of a few areas in Latin America (notably the Pacific side of Guatemala) make it possible to grow blight-susceptible, oriental clones with their own crowns. The following blight resistant clones were mentioned to perform satisfactorily in Mexico, Central America and northern South America: FX 2261, IAN 873, IAN 717, FX 2187, IAN 710, IAN 713, FX 1042 and FX 25. The first four clones were also more resistant to *Phytophthora*.

187. Langford, M.H. (1960). A new strain of leaf blight on rubber trees in Costa Rica. Mimeograph, 2 pp.

Two new strains of *Dothidella ulei* were reported. One appeared in Brazil in 1946, attacking *Hevea brasiliensis* clones such as F 409 and F 1619 which were previously resistant to SALB. The other strain occurred in Costa Rica in 1959 attacking progeny of F 4542, originally a blight resistant *H. benthamiana* selection.

188. Langford, M.H. (1961). A new strain of leaf blight on rubber trees in Costa Rica (second report). Mimeograph, 2 pp.

Occurrence of a new strain of *M. ulei* in Costa Rica was reported. Clones that derived their resistance from sources other than F 4542 (such as IAN 500, 710, 713, 873, 833, 893 and FX 25) were more heavily attacked by the new strain than by previously existing strains.

189. Langford, M.H. and Echeverri, H. (1953). Control of South American leaf blight by use of a new fungicide. *Turrialba,* 3: 102-105.

Dithane Z 78 (zinc ethylene bisdithiocarbamate) applied every 8 days gave better control than the standard insoluble copper fungicide applied every 4 days. Parzate (same a.i. as Dithane) at

5-day intervals also gives excellent control and reduced infection to <1 percent. Both fungicides produced larger leaves and more vigorous growth than the copper sprays.

190. Langford, M.H. and Osores, A. (1965). Enfermedades del jebe y recomendaciones para su control. *Boletim Tecnico S I P A*, 63: 1-16.

Nine important diseases of *Hevea* in Peru (including SALB) were described under symptoms and method of control.

191. Langford, M.H. and Townsend, C.H.T. (1954). Control of South American leaf blight of *Hevea* rubber trees. *Plant Disease Reporter, Supplement*, 225: 42-48.

A review on selection of resistant clones, control with fungicides, top budding, breeding programme, specialisation of the fungus and long distance spread of the disease.

192. Lamont, N., Freeman, W.G., Warner, A. and Rogers, C.S. (1917). Rubber cultivation in Trinidad and Tobago. *Bulletin Department Agriculture Trinidad and Tobago*, 16: 95-152.

The only disease affecting *Hevea* in the region was SALB.

193. La Rue, C.D. (1926). The *Hevea* rubber tree in the Amazon Valley. *Bulletin United States Department of Agriculture,* No. 1422, 69 p.

The possibility of the introduction of SALB into the Orient exists. Best means of control is to plant resistant varieties. There is a need to introduce new species of *Hevea*. An account of trees yielding rubber and their geographical distribution in the Amazon Valley was presented.

194. Lebai-Juri, M., Bahari, I., Lieberei, R. and Omar, M. (1997). The effects of X-rays, UV, temperature and sterilants on the survival of fungal conidia, *Microcyclus ulei*, a blight of *Hevea* rubber. *Tropical Science,* 37: 92-98.

Contrary to earlier work where tap water was sufficient to induce germination, the conidia strains used in this study required nutrient to germinate. Radio-sensitivities (D_{10}) of conidia irradiated in air-equilibrium, oxygen and nitrogen-saturated tap water were 263, 119 and 333 Gy respectively. Conidia were inactivated by 60 min UV exposure, but temperatures of -74 ºC and -28 ºC failed to arrest germination. Commercial disinfectant arrested germination of conidia.

195. LeGuen, V. (2008). Exploration de la diversite des resistances genetique a la maladie sud americaine des feules de l/*hevea* par centographie et genetique d'association au sein population naturelles, Theses, Universite Montpellier, 184 pp.

Genetic mapping carried out on a resistant progeny revealed two major resistant genes. Analysis of genotypes indicated three main clusters corresponding to the three source states of Brazil. Genetic association with SALB resistant traits was located.

196. LeGuen, V., Garcia, D., Doare, F. And Mattos, C.R.R. (2011). A rubber tree's durable resistance to *Microcyclus ulei* is conferred by a qualitative gene and a major quantitative resistance factor. *Tree Genetics and Genomes*, 7: 877-889.

The components of genetic resistance from *Hevea* clone MDF 180 was determined by QTL mapping. The resistance of progenies from crosses between MDF 180 with and a susceptible clone was assessed following controlled inoculations by three races of *Microcyclus ulei* and also in the field. No resistant QTL was obtained from the susceptible clone. However, a qualitative gene responsible for resistance was isolated. The qualitative resistance gene was denominated M15md and was located in the linkage group g15. Four minor resistance QTLs were also identified.

197. LeGuen, V., Garcia, D., Mattos, C.R.R., Doare, F. Lespinasse, O.G. and Seguin, M. (2000). Bypassing of a polygenic *Microcyclus ulei* resistance in rubber tree analysed by QTL detection. *New Phytologist*, 173: 335-345.

Interval mapping and a non-parametric test were used to detect resistance QTLs. Eight significant QTLs were detected but only one contributed to partial resistance against a highly pathogenic isolate. No QTL was detected against the most pathogenic isolate of *M. ulei*. Unexpectedly, a single isolate can completely bypass partial resistance.

198. LeGuen, V., Garcia, D., Mattos, C.R.R. and Clement Demange (1995). Evaluation of field resistance to *Microcyclus ulei* of a collection of Amazonian rubber tree (*Hevea brasiliensis*) germplasm. *Crop Breeding and Applied Biotechnology*, 2: 141-146.

A collection of *Hevea* progenies from the IRRDB 1981 Expedition was assessed. 81 progenies originating from Matto Grosso were susceptible to SALB. More progenies from Acre and Rondonia were resistant to SALB. The resistance of progenies from Matto Grosso was unstable.

199. LeGuen, V., Guyot, J., Mattos, C.R.R., Seguin, M. and Garcia, D. (2008). Long lasting rubber tree resistance to *Microcyclus ulei* characterized by reduced conidial emission and absence of teleomorph. *Crop Protection*, 27: 1498-1503.

The resistance of MDF 180 to South American leaf blight (SALB) was studied. The clone produced sporulating lesions when inoculated but at moderate intensity thus depicting partial resistance. The teleomorph stage was never observed on this clone either following inoculations or in the field. Since this clone was resistant to SALB for more than 30 years, its resistance is durable. The yield of this clone is not high enough for commercial planting but this clone is suitable for SALB resistance breeding.

200. LeGuen, V., Lespinasse, O.G. and Rodier-Goud, M. (2003). Molecular mapping of genes conferring field resistance to South American leaf blight (*Microcyclus ulei*). *Theoretical Applied Genetics*, 108: 160-167.

The resistance of 192 progenies of plants in the field was scored based on resistance type (RT), presence of stromata (ST), and the level of attack (AT). The search for QTL was performed using the Kruskall-Wallis's tests. One major QTL located on linkage group G13 was detected on the RO38 map was responsible for 36-89 percent variance of resistance. This QTL was called M13-1bn. Other minor QTLs were also detected.

201. LeGuen, V., Rodier-Goud, M., Troispoux, V., Xiong, T.C., Brottier, P., Billot, C. and Seguin, M. (2004). Characterisation of polymorphic microsatellite markers for *Microcyclus ulei*, causal agent of South American leaf blight. *Molecular Ecology Notes*, 4: 122-124.

The process to design 11 microsatellite markers was described and the usefulness of the microsatellite markers was evaluated. Nine of the markers were polymorphic among six isolates from Brazil and four markers were polymorphic among four *M. ulei* isolates from French Guiana.

202. Lespinasse, D., Grivet, L., Troispoux, V., Rodier-Goud, M., Pinard, F. and Seguin, M. (2000). Identification of QTLs involved in the resistance to South American leaf blight (*Microcyclus ulei*) in the rubber tree. *Theoretical and Applied Genetics*, 100: 975-984.

Quantitative trait loci (QTLs) for resistance were mapped using 195 F1 progenies of PB 260 × RO 38. The response of the progenies was evaluated in controlled conditions following artificial defoliation with five isolates of *M. ulei*. All isolates infected PB 260 and four isolates did not infect RO 38 and one isolate infected RO 38 on lesser degree. The search for QTLs was performed using the Krunskal-Wallis method. Eight QTLs for resistance were identified on the RO 38 map.

Only one QTL was identified on the PB 260 map. A common QTL was detected for the five isolates. Two QTLs were common for complete resistance to four fungal strains. Perspectives for breeding for horizontal resistance were discussed.

203. Lespinasse, D., Rodier-Goud, M., Grivet, L. and Leconte, A. (2000). A saturated linkage map of rubber tree (*Hevea* spp.) based on RFLP, AFLP, microsatellites and isozyme markers. *Theoretical and Applied Genetics*, 100: 127-138.

The first genetic map of *Hevea* was presented based on 106 F1 progenies of PB 260 x RO 38. Homologous linkage groups between the two parental maps were merged and 717 loci formed the map including 301 RFLPs, 388 AFLPs, 18 microsatellites and 10 isozymes. *Hevea* origin and genome organisation was discussed.

204. Lesser, T. and Rodriguez, L.A. (1944). *Dothidella ulei* en Venezuela. *Boln. Soc. Venez. Cienc. Mat.*, 10: 117-119.

SALB was discovered on *Hevea* in Caripito, Venezuela. Disease symptoms, life history of the pathogen, mode of dissemination and environmental factors affecting disease development were described.

205. Lems, G. (1963). Verleden, heden en toekomst van de rubber culture. *Suriname Landbouw*, 11: 19-26.

The rubber industry in the colony was interrupted after the outbreak of SALB in about 1900. Attempt to restart the industry by replanting with resistant clones was described. The resistant clone IAN 45-17 was used in breeding programme.

206. Lieberei, R. (1986). Cyanogenesis of *Hevea brasiliensis* during infection with *Microcyclus ulei*. *Journal Phytopathology,* 115: 134-146.

Eight *Hevea* species were shown to be cyanogenic. They liberated HCN following mechanical tissue injury. Infection of *Hevea* leaves by *Microcyclus ulei* leads to a large reduction of hydrocyanic acid potential, while only small amounts of HCN were set free from the leaves into the atmosphere. HCN production by infected leaves followed a reproducible pattern with a maximum between 40 and 60 hours after infection. During the entire process of infection, free HCN can be detected in the leaves. High amounts of HCN were liberated from leaves of susceptible clones whereas only very little HCN was released from resistant clones. During *Hevea* infection with *M. ulei*, cyanogenesis does not lead to control of the fungal pathogen but impairment of the resistance reaction.

207. Lieberei, R. (1988). Relationship of cyanogenic capacity (HCNc) of the rubber tree *Hevea brasiliensis* to susceptibility to *Microcyclus ulei*, the agent causing South American leaf blight. *Journal Phytopathology,* 122: 54-67.

A high capacity for hydrogen cyanide liberation following infection was correlated with the susceptibility of rubber leaves to *M. ulei* infection.

208. Lieberei, R. (2000). Physiological characteristics of *Microcyclus ulei*, a fungal pathogen of the cyanogenic host *Hevea brasiliensis*. *Journal of Applied Botany and Food Quality*, 80: 63-68.

HCN was liberated from lesions during the development of fungus in the *Hevea* leaf tissues. Despite high liberation of HCN, the fungus developed hyphae. The reaction of *M. ulei* to HCN and the biochemical properties of β-glucosidase were reported.

209. Lieberei, R. (2007). South American leaf blight of the rubber (*Hevea* spp.) tree: New steps in plant domestication using physiological techniques and molecular markers. *Annals of Botany*, 100: 1125-1142.

Hevea contributes to the economies of many producing countries and especially to small farmers worldwide. SALB disease affects the development of the crop in South and Central America. The disease is still restricted to its continent of origin, but the risk of spreading around the world increases with transcontinental airline connection. There is an urgent need to develop control measures. All control efforts since 1910 failed even with new systemic fungicides and modern application methods. New areas of studies were suggested.

210. Lieberei, R., Biehl, B., Giesemann, A. and Junqueira N.T.V. (1989). Cyanogenesis inhibits active defense reactions in plants. *Plant Physiology*, 90: 33-36.

HCN was liberated from infected tissues following infection of the cyanogenic rubber tree (*Hevea brasiliensis* Muell. Arg.). HCN interferes with plant host and fungal pathogen. It inhibited active defence responses which were dependent on biosynthetic processes.

211. Lieberei, R., Junqueira, N.T.V. and Feldmann, F. (1989). Integrated disease control in rubber plantations in South America. *Proceedings Integrated Pest Management in Tropical and Subtropical Cropping System,* 1989, Germany, p. 445-456.

Rubber tree cultivation in South America is threatened by many factors and diseases. The most important factor retarding successful development of natural rubber industry in South America is SALB caused by *M. ulei*. This disease cannot be controlled by chemicals due to application problems. This paper reports on studies to find tolerant plant material, biological control procedures and plant management systems for successful establishment of rubber plantation. It was mentioned that *Hansfordia pulvinata* was effective for biological control of *M. ulei*.

212. Lieberei, R., Schrader, A., Biehl, B., and Chee, K.H. (1983). Effect of cyanide on *Microcyclus ulei* cultures. *Journal Rubber Research Institute Malaysia,* 31: 227-235

The influence of cyanide on cultures of *Microcyclus ulei*, a pathogen of the cyanogenic host *Hevea brasiliensis* was tested under laboratory conditions. Low cyanide concentrations promoted conidial germination and mycelial growth, while high concentrations inhibited fungal development and sporulation. Application of cyanide to young sporulating mycelia caused severe cessation of mycelial growth, indicating a higher sensitivity during this developmental stage.

213. Lim, T.M. (1982). Fogging as a technique for controlling rubber leaf diseases in Malaysia and Brazil. *Planter, Kuala Lumpur*, 58: 197-212.

In Malaysia, *Oidium heveae, Colletotrichum gloeosporioides* and *Phytophthora botryosa* annually cause severe defoliation of susceptible cultivars resulting in loss of tree vigour and latex yield The discovery of oil-based fungicidal formulation and the availability of powerful fogging machines, led to the successful development of ground thermal fogging as a novel, efficient and most economical method of applying fungicides to tall, mature rubber trees. Fogging tridemorph-in-oil thrice at 0.5 kg/ha/round at seven to ten day intervals gave better control of *O. heveae* than four to five weekly rounds of sulphur dusting especially when treatments meet with rainy weather. Against *P. botryosa*, pre-monsoon fog of captafol-in-oil at 1.7 kg/ha or copper-in-oil at 1.2 kg/ha effectively reduced leaf fall. Fogging of captafol-in-oil at 0.6 kg/ha/round or chlorothalonil-in-oil was effective against *Colletotrichum*, and fogging of the defoliant thidiazuron to hasten wintering was promising to avoid leaf diseases. Fogging covers 100 to 150 ha/day, a rate of spray five times faster than existing ground machines, resulting in 70 percent savings in application cost. SALB is the destructive leaf disease affecting rubber in the states of Bahia,

Para, Amazonas, Acre and Sao Paulo of Brazil. Aerial spraying of benomyl (0.1 kg/ha) followed by mancozeb 91.6 kg/ha) and then thiophanate-methyl (0.2 kg/ha), in oil/water carrier, and ground fogging of the same fungicides in oil gave satisfactory control of the disease. Infection and defoliation caused *Pellicularia filamentosa* and *Catacauma huberi* reduced the benefit of control of SALB. Therefore fogging of fungicides effective against these diseases would be beneficial.

214. Lima, M.P.I.M., Gasparotto, L., Araujo, A.L. and Dos Santos, A.R. (1992). Surto do mal das folhas (*Microcyclus ulei*) em seringal enxertado com copa do clone IAN 6158 em Manaus. *Fitopatologia Brasileira,* 17: 192.

215. Lindsay, W.R. (1941). South American leaf disease of *Hevea*. *Annual Report Canal Zone Experiment Gardens*, 1939/40, p. 28-29.

SALB was unknown in Panama prior to 1935 but it appeared soon after the introduction of *H. brasiliensis* in experimental plantings, although the sources from which the introduced stocks derived were free from the disease. As *H. brasiliensis* does not occur in the native state in Panama, it was suggested that the fungus may occur there, on other indigenous trees.

216. Lins, A.C.R. and Brito, P.F.A. (1981). Avaliacao de 7 clones de seringueira quanto ao 'mal-das-folhas na micro-regiao Alta Purus-Acre'. *Fitopatologia Brasiliera*, 6: 509, 513.

Evaluation of clones IAN 717, IAN 873, FX 3899, FX 3810, FX 3864, FX 2261 and PFB 5 indicated that the most promising clones were FX 3899, IAN 717, PFB 5 and FX 3810. Clone FX 2261 was most susceptible and PFB 5 was most resistant to SALB.

217. Liyanage, A. de S. (1981). Long distance transport and deposition of spores of *Microcyclus ulei* in Tropical America – a possibility. *Bulletin Rubber Research Institute Sri Lanka*, 16: 3-8.

There was strong circumstantial evidence that the spread of SALB from the Amazon basin to the surrounding areas was through long distance dissemination and deposition of *M. ulei* spores. A scheme was suggested to confirm the evidence.

218. Liyanage A. de S. and Chee, K.H. (1981). The occurrence of a virulent strain of *Microcyclus ulei* on *Hevea* Rubber in Trinidad. *Journal Rubber Research Institute Sri Lanka,* 58: 73-78.

In Trinidad, many hitherto resistant *Hevea* clones were infected by *Microcyclus ulei* in recent years. A laboratory test of 37 rubber clones of diverse genetic backgrounds showed that conidial inoculum from a newly affected clone was more virulent than the previously existing fungus strain. The occurrence of more virulent strains rather than appearance of new physiologic races of *M. ulei* were responsible for the infection of resistant clones.

219. Mainstone, B.J., McManaman, G. and Begeer, J.J. (1977). Aerial spraying against South American leaf blight of rubber. *Planter's Bulletin Rubber Research Institute Malaysia,* 148: 15-26.

Several fungicides were applied aerially using an aeroplane to control SALB in a rubber plantation at Guama (Para). Better results were obtained when non-toxic low volatility spray oil was included in the spray mixture. Poor result was obtained in the trial at Una (Bahia) and this was attributed to poor timing of commencement of spray. In addition, the rates used there were too low and, spray oils were not used, and the spray interval was too long. However, ground applications did control SALB in Una and resulted in better canopies and higher latex yield relative to untreated controls.

220. Marassi, A. (1951). *Hevea brasiliensis*. *Riv. Aqric. Subtrop*., 45: 176-178.

The *Hevea* development programme in Tingo Maria, Peru was presented. This included selection and propagation of material of high yield and resistance to SALB and other leaf diseases. Material from Costa Rica, Honduras, Haiti and Mexico, Fordlandia and Belterra (Brazil), Leticia (Colombia) and from the Peruvian forest was established to produce lines resistant to SALB.

221. Martains, E.M.F., Moraes, W.B.C., Cardosa, P.M.G. and Kuc, J. (1970). Purification and identification a substance connected with resistance in rubber (*Hevea brasiliensis*). *Biologico*, 36: 112-114.

The article reports on the methods used to isolate, purify and identify the substance developing in rubber leaves in response to infection by *M. ulei*. This substance was identified as kaempferol-3-rhamnodiglucoside. The substance strongly inhibited germination of conidia of *M. ulei*.

222. Martin, W.J. (1947). Diseases of the *Hevea* rubber tree in Mexico during 1943-46. *Plant Disease Reporter,* 31: 155-158.

SALB of *Hevea* caused by *Dothidella ulei* was included among leaf diseases and fungi recorded.

223. Martin, W.J. (1948). The occurrence of South American leaf blight of *Hevea* rubber trees in Mexico. *Phytopathology*, 32: 157-158.

SALB of *Hevea* was discovered in Southern Mexico in 1946 and subsequently the disease was found in most of the *Hevea* plantings in Mexico. The pathogen was probably introduced into Mexico through *Hevea* planting material introduced and planted about 1910. *Hevea* plantings in Guatemala, Honduras, El Salvador, Nicaragua, Haiti and the Dominican Republic apparently were still blight-free.

224. Matthews, G.A. (1976). Fungicide application for the control of South American leaf blight of *Hevea brasiliensis*. Mimeograph, 29 p.

SALB is a major cause of low yield of rubber in South America. The critical period for disease control is during refoliation following ‘wintering’. Fungicide sprays are recommended by sequential aerial application using 40-60 μm droplets during the refoliation period. This control technique has to be integrated with selection of resistant clones, use of fertilizer and insect control.

225. Mattos, C.R.R. (1999). Culture media containing green coconut water for sporulation of *Microcyclus ulei*. *Fitopatologia Brasilieira*, 24: 470.

Coconut water added to modified culture medium of Junqueira increased conidia production by 12 times.

226. Mattos, C.R.R. (2004). Crown grafting – a way of fighting the *Microcyclus ulei* - The experience at the Michelin Bahia Plantation. IRRDB/MICHELIN/CIRAD International Workshop on SALB, 2004, Bahia, Brazil, 3 pp.

227. Mattos, C.R.R., Garcia, D., Pinard, F., LeGuen, V. (2007). Variability of *Microcyclus ulei* from South East Bahia. *Fitopatologia Brasileira*, 28: 502-507.

South American leaf blight is the cause of poor rubber development in Brazil. Inoculation with 50 isolates of *M. ulei* on 12 rubber clones produced 36 variations of disease reactions. The intensity of sporulation varied between clones and isolates. Twenty one isolates were virulent on more than nine *Hevea* clones while no isolate was virulent on all the clones.

228. McRae, W. (1920). The Surinam or South American leaf disease. *Planters’ Chronicle*, 15: 303-305.

SALB caused by *Fusicladium macrosporum* put an end to rubber cultivation in Surinam.

229. Medeiros, A.G. (1973). Tecnica simples para isolar *Microcyclus ulei* (P. Henn.) v. Arx, fungo responsavel pela 'Queima sul-Americana' das folhas da seringueira. *Revista Theobroma*, 3: 57-76.

A technique for isolating *M. ulei* was described. A small block of agar was used to pick up the conidia from leaf lesions and then transfer to potato dextrose agar (PDA) media slants.

230. Medeiros, A.C. (1975). Novos conceitos tecnicos sobre controle quimico do 'mal-das-folhas' da seringueira. *Boletim Tecnico CEPEC-CEPLAC,* 35, 20 pp.

The life cycle of *Microcyclus ulei* consists of two months for stroma formation, two months for asci development and one month for ascospore maturation and discharge. The annual leaf change occurred gradually about five months for FX 25 and all year round for IAN 717. A new approach to disease control aims at disrupting the disease cycle by four rounds of fungicides i.e. two rounds during formation of stroma and two rounds during formation of young leaves. Artificial defoliation should be adopted to defoliate leaves before normal leaf change season.

231. Mello, D.F., Mello, S.C.M., Mattos, C.R.R. and Cardoso, S.E.A. (2008). Compatibility of *Dicyma pulvinata* with pesticides and biocontrol efficiency of South American leaf blight of rubber tree under field conditions. *Pesquisa Agropecuaria Brasileira*, 43: 179-185.

The fungus was incompatible with benomyl, carbendazim, mancozeb, propiconazole and endosulfan. Two isolates of *D. pulvinata* (CEN 62 and CEN 93) were as effective as propiconazole + mancozeb on the control of South American leaf blight.

232. Mello, S.C.M. de (2004). *Dicyma pulvinata*, a biological control agent for South American leaf blight (*Microcyclus ulei*). *IRRDB/Michelin/CIRAD International Workshop on SALB*, 2004, Bahia, Brazil, Mimeograph, pp. 5.

Aspects related to genetic and morphological variability, pathogen and antagonist interaction, production of conidial biomass and biological activity were presented.

233. Mello, S.C.M., Estevenato, C.E., Brauna, L.M., Capdeville, G., Queroz, P.R. and Lima, L.C. (2008). Antagonistic process of *Dicyma pulvinata* against *Fusicladium macrosporum* on rubber tree. *Tropical Plant Pathology*, 33: 5-11.

The interaction between *D. pulvinata* and F. *macrosporum* was studied using E.M. *D. pulvinata* parasitized the spores of *F. macrosporum* 24 h after inoculation causing the spores to disintegrate. The antagonist completely overgrew the pathogen and sporulated 6-7 days after inoculation. *D. pulvinata* also produced hydrolytic enzymes which could contribute to the parasitisation.

234. Mello, S.C.M, Santos, F., Silva, M. da J.B.T. (2006). *Dycima pulvinata* isolates colonizing *Microcyclus ulei* stromata in rubber. *Pesquisa Agropecuaria Brasileira*, 41: 359-364.

D. pulvinata is an efficient biocontrol agent of *Microcyclus ulei*. 52 isolates of the fungus were obtained in a survey of rubber plantations in several states of Brazil

235. Menten, J.O.M., Pereira, W.S.P., Godoy, Junior, G. And Cardoso, M. (1990). Two new fungicides for the control of South American leaf blight of the rubber tree. *Summa Phytopatologica*, 16: 275-278.

236. Miller, J.W. (1965). Biology of *Dothidella ulei*. I. *In vitro* production of toxin. II. Differential clones of *Hevea* for identifying races of the fungus. *Ph.D. Thesis University of Florida*, 19 pp.

M. ulei produced toxin in culture medium. Inoculation of leaflets with culture filtrate or mycelial

extract produced small flecks. No flecks developed on leaflets injected with boiled extract or filtrate. A set of differential clones (IAN 717, FX 3925, IAN 710 or IAN 713, MDF 180 and P 122) was used to differentiate four races of *M. ulei*.

237. Miller, J.W. (1966). In vitro production of toxin by *Dothidella ulei*. *Phytogathology,* 56: 718-719.

Fungus-free aqueous extracts and sterile culture filtrates of *D. ulei* caused leaf symptoms in inoculated seedlings similar to those produced by the fungus, indicating the presence of a toxin. Symptoms did not appear when filtrates had been boiled for 1 h or dialysed against water for 96 hr.

238. Miller, J.W. (1966). Differential clones of *Hevea* for identifying races of *Dothidella ulei*. *PIant Disease Reporter*, 50: 187-190.

Races 1, 2, 3 and 4 of *D. ulei* were differentiated using five *Hevea* clones. IAN 717 was highly resistant to races 1 and 4 but susceptible to 2 and 3. FX 3925 was susceptible to race 2 and resistant to race 3. IAN 710 or IAN 713 and P 122 were moderately resistant to races 1, 2 and 3. All clones were resistant to race l.

239. Moncure, R.C. (1946). Agricultural collaboration in Nicaragua. *Agriculture America,* 6: 10-11.

Eastern Nicaragua was one of the few areas in the Western Hemisphere free of SALB then.

240. Moraes, V.H. F., Moraes L.A.C. (2008). Effects of SALB resistant budded crowns on the yield and physiological parameters of *Hevea* latex (may be deleted).

The reported cases of yield reduction had discouraged a more intensive research on the use of SALB resistant budded crowns in Brazil. A strong depressive effect of *H. pauciflora* crowns budded on FX 3899 was found to be related to a lower Mg content affecting the latex regeneration, though an increase of the bursting index and a reduction of the duration of flow were also recorded. In an earlier yield test, the crown/trunk combinations Px/CNS AM 7905, Px/FX 985 and CBA1/FX 985 displayed a relatively high yield. This was due to prolonged flow and latex regeneration, which was correlated to the inorganic phosphorus content. Except for FX 3899 with *H. pauciflora* crowns (low Mg), a normal response to stimulation with etephon was obtained. In both mature (FX 3899) and young trees, *H. pauciflora* budded crowns caused a significant increase of the thiols content. This deserves further studies in connection with resistance to bark dryness. The rise in R-SH did not correspond with increased membrane stability. The effects on sucrose, pH and total solids were discussed.

241. Moraes, V.H. F., Moraes L.A.C. (2008). Performance of rubber tree crown clones resistant to South American leaf blight. *Pesquisa Agropecuaria Brasileira*, 43: 1495-1500.

The performance of 18 South American leaf blight resistant clones used as crowns was evaluated. Eight hybrid clones of *Hevea pauciflora* × *H. rigidifolia* and two clones of *H. pauciflora* were used as crowns on IAN 7905. The crowns of *H. pauciflora* × *H. guaianensis* induced fastest girth increment. *H. rigidifolia* is resistant to *Leptopharsa heveae* and should be investigated as crown. Clones CPAA C01, 06, 13, 15, 16 and 45 are potentially high yielding.

242. Moraes, L.A.C., Moreira, A., Fontes, J.R.A., Cordeiro, E.R. and Moraes, V.H.F. (2011). Assessment of rubber tree panels under crowns resistant to South American leaf blight. *Pesquisa Agropecuaria Brasileira*, 46: 466-473.

The performance of 18 South American leaf blight (SALB) resistant clones (*H. pauciflora* × *H. guaianensis*) used as crowns was evaluated. Within the first three years of evaluation, panel clones IAN 2878, IAN 2903, CNS AM7905, CNS AM 7905P1 and PB 28/59 produced the highest

latex yield. Clones IAN 6158, IAN 6590 and IAN 6515 should not be recommended for crown budding. Higher potassium and copper foliar content in panel clones were associated with higher yield. Crown budding is an effective technology to manage SALB in its endemic areas.

243. Muller, E. and Von Arx, J.A. (1962). Die gattungen der didymosporem Pyrenomyceten. *Beitr. Kryptog. Flora Schweiz*, ll: 373.

The authors transferred the SALB causal fungus *Dothidella* or *Melanopsammopsis* to the genus *Microcyclus* Saccardo.

244. Neto, B.F., Furtado, E.L., Cardoso, R.M.G., Oliveira, D.A. and Roloim, R.R. (1991). Systemic fungicide effects on lifecycle of *Microcyclus ulei*, agent of South American leaf blight. *Summa Phytopatologica*, 17: 238-245.

245. Oliveira, D. De A., Cardoso, R.M.G., Brignane Neto, F., Furtado, E.L. and Rolim, P.R.R. (1986). Sanity index and number of plants by plot in function of *Microcyclus ulei* incidence in nursery of *Hevea brasiliensis*. *Fitopatologia Brasileira*, 11: 847-855.

246. Ong, S.H. (1980). Breeding for disease resistance. *Hevea breeding Course, Lecture notes,* pp. 1-13.

The best yielding progenies produced from crosses between oriental clones (RRIM 600, RRIM 623, Tjir 1, PB 86 and LCB 1320) with introduced South American clones (FX 25, F 351 and FB 3363) were screened against SALB.

247. Ong, S.H., Tan, A.M. and Chee, K.H. (1977). Breeding for resistance against *Hevea* leaf diseases. *Workshop on International Collaboration in Hevea Breeding, Kuala Lumpur*, Mimeograph, 9 pp.

The best yielding progenies of crosses between oriental clones (RRIM 501, RRIM 600, RRIM 623, Tjir 1, PB 5/51, PB 86 and LCB 1320) and resistant materials introduced from South America (FX 25, Ford 351, FB 3363) were screened for resistance to Gloeosporium leaf disease (GLD) and SALB. No clone was resistant to the two diseases. There was no association between resistance to GLD and SALB. A sizeable proportion, classified as moderately susceptible was likely to have field resistance to either GLD or SALB. A useful outcome of this programme was the production of a considerable number of clones which were superior to elite oriental selections in yield and vigour.

248. Ong, S.H., and Tan H. (1987). Utilization of *Hevea* genetic resources in the RRIM. *Malaysian Applied Biology,* 16: 145-155.

As the Wickham introduction has a narrow genetic base, new introductions of rubber from South America were made in 1950s, 1966 and 1981. The 1950s introduction was mainly low yielding. The introduced clones were crossed with local clones. The yield performance of the introduced clones and their progenies was presented.

249. Peralta, A.M., Furtado, E.L., Amorim, L., Menten J.O.M. and Bergamin-Filho, A. (1990). Breeding for resistance to South American leaf blight of *Hevea* rubber tree: review. *Summa Phytopathologica*, 16: 214-224.

Abstract is not available.

250. Pereira, J.L., Rao, B.S. and Ribeiro, J.L. (1980). Role of oil in fungicide formulations in the control of *Microcyclus ulei*. *Seminario Nacional da Seringueira E Simposio Internacional Sobre Borracha, 1980, Manaus, Anais,* Vol. 1, pp. 223-252.

Wettable powder formulations of fungicides used in the control of South American leaf blight of rubber (SALB) had been modified to include mineral oil in tank mix. Suitable water/oil formulations were investigated to obtain a reasonably stable tank mix with a minimum proportion of oil. This was done by first preparing a concentrated emulsion, and then diluted just before use. The role of oil in the technology of spray application and the effect of the water/oil/fungicide mix on disease control was assessed. This preliminary study suggested that oil-mixed sprays may not yield the beneficial effects attributed to them and their use should be urgently re-evaluated, especially in light of the very high cost of mineral oil.

251. Petch, T. (1914). The fungus diseases of *Hevea brasiliensis*. In *International Rubber Congress Batavia, Rubber Record*, 116-129.

The important *Hevea* root, stem and leaf diseases, including SALB were described.

252. Petch, T. (1921). The diseases and pests of the rubber tree. MacMillan, London, 278 p.

Description on symptoms of SALB, life cycle of the causal fungus which has numerous names and the damage on *Hevea* in Surinam, Guiana and Trinidad was presented.

253. Pinheiro, E. (1995). Reducing SALB risks – Cultivating rubber in 'escaped areas'. *Paper presented at a colloquium at the Rubber Research Institute of Malaysia*, 1995, 5 p.

M. ulei was prevalent in the humid areas and more than 50 strains of the fungus had been found. Efforts to control SALB by planting resistant clones and application of fungicides were not very successful. Crown budding may be more suitable. Planting of rubber in 'escaped areas' i.e. areas with 4-5 months of dry period (350 mm year and 60 percent RH). In Matto Grosso 'escaped areas', the clones planted were RRIM 600, RRIM 701, Gt 1, PB 235, PB 260, IAN 717, IAN 873 and IAN 3087. In the 'escaped areas' of Sao Paolo, RRIM 600, RRIM 614, PR 261, AVROS 1518, Gt 1 and PB 235 were planted.

254. Pinheiro, E. and Libonati, V.F. (1971). O emprego do *Hevea pauciflora* M.A. como fonte genetica de resistencia ao mal das folhas. *Polimeros*, 1: 31-39.

The history of breeding for SALB resistance was presented. The programme successfully introduced several promising clones in the IAN series. Unfortunately, the source of resistance was mainly from *H. banthamiana* especially F 4542. When a new race of *M. ulei* developed, most of these progenies were infected. Hybrids of *H. pauciflora* × *H. brasiliensis* were vigorous in growth and do not winter. Although the progenies were resistant to SALB, their yield was poor.

255. Pinheiro, E. and Lion, A. (1976). Perspectivas do emprego da *Hevea pauciflora* na enxertia de copa de seringueira. II. Seminario *Nacional da Seringueire, Rio Bianco, Acre*. Mimeograph, 11 pp.

Clones recommended for large-scale planting differ in their susceptibility to SALB. Crown budding offers a method of disease control. The method is so advanced that it is now used on a large scale. Some clones of *H. pauciflora* are outstanding in that it is disease resistant and when used as crowns improved stem girth. Promising yield was obtained. More research should be directed towards the use of *H. pauciflora* as crown clones and its susceptibility to other leaf and stem diseases.

256. Pita, F.A.D.O., Junqueira, N.T.V., Alfenas, A.C. and Cano, M.A.O. (1992). Phenolic regulation of resistance to *Microcyclus ulei* infection in *Hevea* progenies. *Pesquisa Agropecuaria Brasileira*, 25: 1193-1200.

Three *Hevea* clones (FX 25-moderately susceptible, FX 2804 – highly susceptible and P10 - resistant) with different levels of resistance to *M. ulei* were studied. Phenol, anthocyanin and chlorophyll contents were determined from inoculated and non-inoculated leaflets. Progenies FX 25 and FX 2804 had low phenol content, decreased levels of chlorophyll and heavy damage and sporulation. Progenies P10 had high levels of phenol and chlorophyll, compared to the control. It did not show any damage. The anthocyanin levels decreased in all progenies. *Hevea* resistance to *M. ulei* infection seems to be related to variations of leaf phenol content.

257. Polhamus, L.G. (1962). Rubber. Leonard Hill, London, 448 pp.

Investigation on *Hevea* species other than *H. brasiliensis* and international exchange of breeding material was recommended in the effort to combat SALB.

258. Rands. R.D. (1924). South American leaf disease of Para rubber. *Bulletin United States Department of Agriculture*, 1286, 18 pp.

P. Hennings described the causal fungus of SALB as *Dothidella ulei* from material collected in Acre by E. Ule in 1901-1902. Only the perfect and pycnospore stages were described. In 1910, A.W. Drost drew attention to SALB in Surinam. In 1911, Kuyper described the disease in Surinam and the conidial stage as *Fusicladium macrosporum*. In 1929, V. Cayla collected spores from Para and sent to Griffon and Maublanc who identified the fungus as *D. ulei* and the conidia as *Scolecotrichum*. In 1913, Bancroft reported the conidia as *Passalora heveae* by Massee. In 1914, Petch considered that only one fungus was responsible for these various diseases reported. In 1917, Stahel compared various collections, and concluded that only one fungus was involved and erected the new genus, *Melamnopsammopsis*. In 1917, Rorer thought SALB had been in Trinidad for several years but considered it less serious than in the Guianas because of less favourable weather. Since 1917, SALB had forced the abandonment of rubber in British Guiana and Surinam. The paper also describes the disease symptoms, spread, biologic and climatic factors affecting the disease and control stressing on plant quarantine.

259. Rands, R.D. (1942). *Hevea* rubber culture in Latin America, problems and procedures. *India Rubber World,* 106: 239-243.

A diagrammatic outline on the intergovernmental breeding and selection project for development of SALB resistant superior yielding clones was suggested. This involves crossings between the highly susceptible clones of the East with the most resistant and highest yielding Amazonian selections. For commercial plantings in SALB-free areas, a mixture of three groups of clones was recommended i.e. oriental clones which are tolerant to leaf blight; Latin American clones moderately resistant to leaf blight; and Brazilian Ford clones highly resistant to leaf blight. In areas infected with leaf blight, only the last group should be planted. Closely spaced plantings of a mixture of some half dozen clones from these different groups provide insurance against leaf blight. Alternative procedures were suggested for safe and immediate utilization of the first group of clones. These include top-budding with highly resistant seedling material and a rotational planting scheme.

260. Rands, R.D. (1946). Progress on tropical American rubber planting through disease control. *Phytopathology*, 36: 688 (Abstract).

Control of SALB by spraying or crown budding enabled the use of the high yielding oriental clones in tropical America. In 1944 more than 28 000 acres of high-yielding rubber had been planted. Further, breeding programmes produced thousand of first and second generation hybrids, some of which indicated superior yield and blight resistance.

261. Rands, R.O. and Brandes, E.W. (1945). Plants and plant science in Latin America. *Chronica Botanica Co., Waltham, Mass.*, 37: 182-201.

The use of selected clones resistant to *Dothidella ulei* and crossing of high yielding, susceptible eastern clones with resistant Amazon selections was recommended. The clones recommended for breeding purposes was listed.

262. Rao, B.S. (1972). Regional cooperation in measures against introduction and spread of South American leaf blight. *IRRBB Meeting, Medan* 1972, 7 pp.

Measures recommended against the introduction of SALB include strengthening plant quarantine, prompt action on disease eradication and establishment of country and regional committees entrusted with the duty to prevent the introduction and spread of SALB.

263. Rao, B.S. (1973a). Potential threat of South American leaf blight to the plantation rubber industry in the Southeast Asia and Pacific region. *FAO Plant Protection Bulletin*, 21: 107-113.

The symptoms of SALB, the possibility of introduction into South East Asia and Pacific region and the likely behaviour in the region were presented. SALB was predicted to be very destructive if it occurs in the region. Quarantine measures against the introduction and spread of SALB presented. An effective phytosanitary barrier is the only means to prevent introduction of SALB to the region. From its first appearance in a country, its spread to neighbouring territories would be rapid. Measures for its exclusion and preparedness are joint responsibility of rubber-growing countries.

264. Rao, B.S. (1973b). Some observations on South American leaf blight in South America. *Planter, Kuala Lumpur*, 49: 2-90.

All the commercially planted clones differ in their resistance to SALB in different locations in Brazil and Trinidad. Thus, disease screening should be carried out in many climatic regions and against diverse races of the fungus.

265. Rao, B.S. (1973c). South American leaf blight: chances of introduction and likely behaviour in Asia. *Quarterly Journal Rubber Research Institute Sri Lanka,* 50: 216-222.

The mechanism of dissemination of *Microcyclus ulei* was described with a view to assess the possibility of its spread outside tropical America. Should SALB be introduced to Asia, its importance in different localities was likely to vary, depending upon the intensity and distribution of rainfall. The epidemiology of the fungus suggests that it could behave more like *Colletotrichum gloeosporioides* leaf disease.

266. Rao, B.S., Ribeiro, J.O., Bezerra, J.L. and Ribeiro do Vale, F.X. (1980). New approaches to control of the major leaf diseases of rubber in Bahia. *III Seminario Nacional De Seringueira, 1980, Manaus, Brazil,* 15 pp.

Considerable effort and expenditure were incurred each year for spraying fungicides to obtain some measure of control of the most destructive leaf diseases caused by *Microcyclus ulei* and *Phytophthora palmivora*. Fungicides that were effective against both diseases were screened. The possibility of adopting simpler and cheaper disease control techniques i.e. by disease avoidance following artificial defoliation, improving tree vigour by manuring, and integration with limited fungicidal application was discussed. More flexible alternatives to the aerial spraying were considered for chemical control.

267. Rivano, F. (1992). South American Leaf Blight; Study in natural and controlled conditions of the partial resistance components to *Microcyclus ulei*. *Ph.D. Thesis, Universite de Paris-Sud, Orsay (France)*, 257 pp.

Abstract is not available

268. Rivano, F. (1997). La maladie sud-americaine des feuilles de l'*heveae* I. Variabilite du pouvoir pathogene de *Microcyclus ulei*. *Plantations, recherche, developpement,* Mai-Juin, pp. 104-110.

South American leaf blight caused by *Microcyclus ulei* remains the main obstacle to the development of rubber, cultivations in Latin America. As early as 1960, *M. ulei* overcame the resistance derived from inter-specific crosses. Studies of variability in clonal responses to SALB were conducted in French Guiana using 10 different clones and 16 *M. ulei* isolates. This study revealed the existence of seven virulence factors and 12 races of *M. ulei*.

269. Rivano, F. (1997). La maladie sud-americaine des feuilles de L'hevea II. Evaluation precoce de la resistance des clones. *Plantation, recherche, developpement,* 4: 187-194.

The resistance to SALB of 31 *Hevea* clones from Asia, Africa and Latin America was evaluated in a small scale trial in French Guiana. Several components of general resistance were evaluated. The tests revealed that the clones could be divided into three groups according to their SALB resistance and origin. Some clones were selected for a breeding programme for improving resistance, and also for further testing in a SALB zone. A methodology for early evaluation of *Hevea* resistance to leaf diseases, particularly *M. ulei*, was proposed.

270. Rivano, F. (2004). Rubber growing in Latin America: a new challenge. *IRRDB/Michelin/CIRAD International Workshop on SALB*, 2004, Bahia, Brazil, Mimeograph, 6 pp.

Rubber cultivation in Latin American countries (Mexico, Guatemala, Colombia, Ecuador, Peru) was reviewed with respect to SALB. In these countries, rubber was mainly cultivated by smallholders and production was below national demand. The major disease management strategies in these countries were planting resistant clones and planting in disease escaped areas.

271. Rivano, F., Malena, M., Victor, C. and Christian, C. (2010). Assessing resistance of rubber tree clones to *Microcyclus ulei* in large scale clone trial in Ecuador: a less time consuming field methods. *European Journal of Plant Pathology*, 126: 541-552.

The resistance of eight rubber clones was evaluated. Three months after planting, the plants were observed for 12 months to assess disease severity, sporulation intensity on young leaves and severity and density of stroma on mature leaves. These variables were correlated. Sporulation density on young leaves and stroma density on mature leaves is sufficient to score resistance level of clones.

272. Rivano, F., Mattos, C.R.R., LeGuen, V., Guyot, J. and Garcia, D. (2010). Is the production of rubber from *Hevea* really threatened?. *Workshop on the Future of Natural Rubber, 14-15 October, 2010.*

273. Rivano, F., Soto, S. and Sanchez J. (1996). *L'heveaculture au Guatemala. Plantations, recherche, developpement*, Novembre-Decembre, 1996, pp. 389-393.

In Guatemala, the rubber areas of about 35 000 ha were mainly in the Pacific zone. There was mild occurrence of SALB on the Pacific Coast due to the suitable climate. In the Southern region and along the Atlantic Coast, SALB was severe throughout the year. Oriental clones were severely infected by SALB in these regions.

274. Rocha, H.M., Aitken, W.M. and Vasconcelos, A.P. (1975). Control of South American leaf bllight (*Microcyclus ulei*) of the rubber tree in Bahia: Aerial spraying of fungicides in the region of Itubera. *Revista Theobroma,* 5: 3-11.

A trial on fungicidal control of *M. ulei* on clone IAN 873 in a rubber plantation was described. The fungicide was sprayed from the air using a Piper 235 fixed wing aircraft during the refoliation

period following wintering. Six sprayings at weekly intervals were given at a rate per spraying of about 2 kg/ha of mancozeb in 15 l spray emulsion. In view of the strongly sloping topography of the area concerned, the use of a more powerful aircraft or a helicopter might have improved the overall efficiency of the treatment.

275. Rocha, A.C.S., Garcia, D., Vetanabaro, A.P.T., Carneiro, R.T.O., Araujo, I.S., Mattos, C.R.R. and Goes-Netto, A. (2011). Foliar endophytic fungi from *Hevea brasiliensis* and their antagonism on *Microcyclus ulei*. *Fungal Diversity,* 47: 75-84.

Endophytic fungi were isolated from three rubber clones. Extracts of these fungi were tested for inhibition of germination of *M. ulei* conidia. Thirteen fungi were inhibitory to *M. ulei*. The inhibitory fungi were *Fusarium* sp., *Gibberella* sp., *Glomerella cingulata*, *Microsphaeropsis*, *Myrothecium* sp. and *Pestalotiopsis*.

276. Rocha, H.M., Medeiros, A.G. and Vasconcelos, A.P. (1973). Selecao de fungicidas para o controle de 'mal-das-folhas' *(Microcyclus ulei*) en condicoes de viveiro. *CEPEC Informe Tecnico 1972 and 1973*, p. 54.

Five fungicides (Benlate-0.07 percent a.i., Cercobin – 0.1 percent a.i., Dithane M 45 – 0.3 percent a.i., Tecto 60 – 0.1 percent a.i. and Kasumin - 0.1 percent a.i.) were tested in nursery for control of SALB. They were applied by a fogging machine at weekly at fortnightly or monthly intervals. Better control was obtained with Benlate, Cercobin and Dithane M 45. Benlate. Cercobin controlled the disease even with fortnightly or monthly applications.

277. Rocha, H.M., Medeiros, A.G. and Vasconcelos, A.P. (1978a). Comparacao de fungicidas para controle do 'mal-das'folhas' de seringueira. *Fitopatologia Brasiliera*, 31: 163-167.

Abstract is not available.

278. Rocha, H.M. and Vasconcelos Filho (1978). Epidemiology of the South American leaf blight of rubber in the region of Itubera, Bahia, Brazil. *Turrialba*, 28: 325-327.

The epidemiology of SALB was studied at Itubera region, Bahia, Brazil. Based on weekly counts of premature leaf fall, SALB may occur every month of the year with the highest incidence in September and October i.e. during the annual refoliation. Dispersion of conidia occurred between 07.00 hours and 14.00 hours, with a peak at noon. The highest number of conidia was collected from spore traps installed at one meter above the ground with south and west exposure during the period from September to December that coincided with the greatest density of new leaves on the trees. It was found that the highest areal spore count and premature leaf fall was highest at bottom of hills.

279. Rodrigues-Machado, R.F., Sena-Gomes, A.R., Rocha, H.M. and Vasconcelos, A.P. (1974). Programa especial de pulverizacao aerea de seringais na Bahia. *CEPLAC/SUDHEVEA*, Mimeograph, 18 pp.

The article reports on an aerial spraying programme on 61 plantations covering 3 992 ha in seven municipalities of Bahia. Dithane M 45 was applied to 1 858 ha by helicopter and to 631 ha by fixed-wing aircraft. Benlate was sprayed to 631 ha by helicopter. Disease control resulting from helicopter and aeroplane fungicide applications was similar. Benlate was more effective than Dithane M 45. In general, about 63 percent control was obtained. The cost of the operation was given.

280. Rogers, T.H. and Peterson, A.L. (1976). Control of South American leaf blight on a plantation scale in Brazil. *Proceedings International Rubber Conference,* 1975, Kuala Lumpur, Malaysia, 3: 266-277.

Preliminary results suggest that weekly aerial applications of Dithane M 45 at 2 kg/ha for six consecutive weeks during refoliation controlled the disease. Benlate was slightly less effective but this could be due to a longer interval (10 days) between sprays and the lower concentrations used (0.15-0.3 kg/ ha). Artificial defoliation prior to spraying fungicides was not beneficial. Improvement of canopy by manuring in conjunction with the spray was not apparent. Both fungicides increased flower production.

281. Romero, I.A.G., Aristizabal, F.A. and Castano, D.M. (2006). A review of *Microcyclus ulei* fungus, causal agent of South American leaf blight of rubber. *Revue Colombia Biotechnologia*, VIII: 50-59.

SALB is an important disease of rubber in Latin America and it was responsible for great economic loss. The fungus has wide variability suggesting great adaptability. Resistance is not well understood especially on its mechanism

282. Rossetti, Victoria (1959). Doencas da seringueira. *O. Biologico*, 25: 233-243.

Hevea diseases, including SALB were described under causal organism, symptoms and control.

283. Russell, J.A. (1942). Fordlandia and Belterra rubber plantations on the Tapajoz river, Brazil. *Economic Geoqraphy*, 18: 125-143.

Abstract is not available.

284. Rutgers, A.A.L. (1960). Bladziekte en kanker bij de *Hevea*. *Indische Mercuur, jaarg.,* 39: 1120.

The pathogen of SALB was named as *Melanopsammopsis heveae*.

285. Sambugaro, R. (2003). Caracterizacao anatomica foliar de clones de seringueira visando resistancia ao *Microcyclus ulei*. Thesis M.Sc., Universidade Estadual Paulista, 61 pp.

South American leaf blight is the main reason for a complete failure of rubber cultivation in Northern Brazil. The disease caused successive defoliation, reduced latex production and plant death. The histological development of the pathogen in different clones was presented. On PB 314, complete asexual and sexual stages developed while only conidia without ascospore stages occurred on MDF 180. On FX 2784, the thick abaxial epidermis conferred resistance.

286. Sambugaro, R. (2007). Estagios foliares, fenologia da seringueira e interacao com *Microcyclus ulei*. Thesis Ph.D., Universidade Estadual Paulista, 94 pp.

The relationship between tree phenology and weather patterns with SALB was studied. Uniform annual leaf changed reduced SALB. Weather conditions influenced the start of leaf change. A mathematical model on leaf change and SALB severity was presented

287. Sanier, C., Berger, P., Coupe, M., Macheix, J.J., Petat, J.M., Rivano, F., Sainst-Blanquat, A. de and D'Auzac, J. (1992). Relationship between Resistance to *Microcyclus ulei* and clonal foliar phenolics of rubber trees. *Journal of Natural Rubber Research*, 7: 38-59.

The relationship between resistance of *H. brasiliensis* to *M. ulei* and to certain foliar phenolics was studied. No qualitative differences were observed between the foliar phenolics of various clones of *H. brasiliensis* and *Hevea* hybrids. Except for clones PB 235 and PB 260, the total quantity of phenols and the proportion of flavans appeared to be related to resistance to *M. ulei* expressed as percentage of abscission. Some compounds seemed to be closely related to the percentage of abscission whereas others appeared to be correlated with resistance (kaempferol-3-rutinoside, 3'p-coumaroylquinic acid). Some phenols were present in resistant clones and others

were found in susceptible clones. Likewise, the hydroxycinnamic derivatives (HDC)/flavonols ratio, the percentage of rutin in relation to total flavonols and the ratios of certain phenols (kaempferol-3-rutinoside: kaempferol-galactoside, rutin: kaempferol-galactoside) appeared in particular to be related to clonal resistance.

288. Santos, A.F. dos and Pereira, J.C.R. (1985). Efficiency of fungicides in the control of *Microcyclus ulei in vitro* and *in vivo*. *Revista Theobroma*, 15: 185-190.

The efficiency of fungicides on *M. ulei* was presented. The protective fungicides, clorotalonil and mancozeb, were effective in inhibiting germination of conidia. Tests in rubber nursery showed that *M. ulei* was controled efficiently with triadimefon (0.015 percent), clorotalonil (0.3 percent), mancozeb (0.32 percent), triforine (0.0285 and 0.038 percent), bitertanol (0.015 and 0.03 percent) and fenarimol (0.0011 and 0.0023 percent).

289. Santos, A.F. dos and Pereira, J.C.R. (1986a). Evaluation of systemic fungicides in the control of *Microcyclus ulei*. *Fitopatologia Brasileira*, 11: 171-176.

The efficiency of some systemic fungicides in the control of South American leaf blight of rubber was determined on clone FX 3899. Several fungicides (triadimephon, triforine, methyl thiophanate, benomyl, carbendazim, tridemorph and fenarimol) at a concentration below 0.2 percent were applied at seven or 14 days intervals in a clonal nursery at Una, Bahia. The more effective fungicides were triadimephon and triforine as they reduced the number of lesions and stroma.

290. Santos, A.F. dos and Pereira, J.C.R. (1986b). Evaluation of protective and systemic fungicides and their mixtures in the control of *Microcyclus ulei*. *Revista Theobroma*, 16: 141-147.

The effectiveness of systemic (triadimephon, triphorine, benomyl and methyl thiophanate) and protective (mancozeb and clorothalonil) fungicides for the control of SALB was determined in a nursery. The fungicides were applied weekly, alone or in mixtures, using a knapsack compression sprayer. Triadimephon, triphorine, mancozeb and clorothalonil, applied alone or mixtures, controlled *M. ulei* efficiently even in dosages smaller than the conventional.

291. Schultes, R.E. (1956)/0. The Amazon Indian and evolution in *Hevea* and related genera. *Journal Arnold Arboretum*, 37: 125-148.

The morphological and physiological characteristics of the various *Hevea* species were described. Information on *Hevea* resistant to SALB presented.

292. Schultes. R.E. and Uribe, H.A. (1974). The future of rubber growing in Colombia. *Agriculture America*, 8: 127-130.

The *Hevea* population highly resistant to SALB known in the Amazon was discovered in the Leticia area in Colombia. In Peru, clones selected based on high yield in the forest could still be improved by breeding.

293. Seibert, R.J. (1947). A study of *Hevea* (with its economic aspects) in the Republic of Peru. *Ann. Mo. bot. Gdn*, 34: 261-352.

It was noted that SALB resistant strains of *H. brasiliensis* were found in the Acre territory of Brazil, in the Leticia region of Columbia on the Peruvian border and in the north-eastern region of Madre de Dios of Peru. A number of clones from these areas have inherent characteristics of combined superior yield and high resistance.

294. Silva, L.G.C. (2007). Zoneamento do risco de occurrencia do mal das folhas da seringueira com base em sistemas de informacoes geograficas (Mapping risk of occurrence of SALB of rubber using GIS). Thesis M. Sc., Universidade Federal de Vicosa, Brazil, 38 pp.

Although disease avoidance is effective in reducing yield loss, its effectiveness depends on the ability to map low risk areas. Two GIS systems (CLIMEX and ArcView) were used to map areas with SALB risks. According to CLIMEX, the potential SALB areas occur in all continents within 24 N to 25 S. Areas in Asia, Africa, Northern Australia and several Pacific islands are suitable for SALB. The GISs are also useful in identifying low risk areas for SALB.

295. Silva, L.G., Moraes, W.B., Jesus Junior, W.C. and Souza, A.F. (2009). Effects of climatic conditions on the development of South American leaf blight in the south region of the Espirito Santo state. *Proceedings VI Congresso Brasileiro de Agroecologia, Curitiba, Brazil*, 2009, p. 470-473.

The study involved 18 clones and the factors determined were number of infected leaves and disease severity. The susceptible clones showed highest correlation with climatic variables especially average temperature and maximum and minimum temperature and relative humidity. Temperature of 23-28 ºC and relative humidity above 80 percent were favourable for enhancement of disease.

296. Simmonds, N.W. (1982). Some ideas on botanical research on rubber. *Tropical Agriculture (Trinidad),* 59: 2-8.

Several ideas related to rubber yield as an aspect of growth and partition, relation between tapping cost and yield, and the predictive capacity of variety trials were presented. In addition, vertical and horizontal resistance to airborne fungal diseases was briefly reviewed. The former (roughly equivalent to major-gene resistance) is unreliable and the latter much to be preferred. Some horizontal resistance to SALB was known to be present.

297. Simmonds, N.W. (1990). Breeding horizontal resistance to South American leaf blight of rubber. *Journal Natural Rubber Research*, 5: 102-113.

A scheme to breed polygenic (horizontal) resistance to SALB of rubber was proposed. It was based on biometrical genetic principles and analogy with successful HR to diverse diseases in other crops. There was already some experimental evidence of the existence of low level of HR to SALB in rubber and fairly rapid response per generation could be expected. The objectives should be concentrated on breeding resistant crown clones and the work must be done in SALB areas.

298. Sinulingga (1996). Pesticide application for control of *Microcyclus ulei* in rubber plant. *Warta Pusat Penilitian Karet*, 15: 40-47.

South American leaf blight caused by *Microcyclus ulei* is a disease causing great hindrance to rubber cultivation. Infection caused leaf defoliation and sometimes death of trees. Disease management was by application of fungicides or artificial defoliation. Effective fungicides were thiophanate methyl, benomyl, chlorothalonil, mancozeb, triadimefon, triforine and bitertanol. Many spraying applicators can be used, however, aerial spraying or fogging are most appropriate due to fast spread of the disease.

299. Situmorang, A. Boerhendhy, I. and Lasminingsih, M. (1996). Physiological races of *Microcyclus ulei* and developments for their control. *Warta Pusat Penilitian Karet*, 15: 29-39.

Microcyclus ulei, the causal agent for South American leaf blight, had developed nine physiological races that could overcome resistance of all clones except MDX 96, *H. benthamiana* and *H. pauciflora*. Some races are postulated to be adaptable to Indonesian conditions. Some methods to reduce the occurrence of new races of *M. ulei* were suggested.

300. Soepadmo, E. (1975). *Microcyclus ulei* – Bahaya laten bagi industri karet alam di Indonesia. *Menara Perkebunan*, 43: 303-304.

The article reviews the symptoms of disease, disease spread and lists quarantine measures and other actions to address the problem of SALB. These actions include monitoring of international air travel, breeding for resistant clones and disease eradication.

301. Sorensen, H.C. (1942). Crown budding for healthy *Hevea*. *Agriculture America*, 2: 191-193.

The method of bud grafting disease-resistant crowns to the high yielding trunks was described. The crown budded trees could resist SALB.

302. Sorensen, H.G. (1945). Colombia's plantation rubber programme. *Agriculture America,* 5: 106-108.

Resistant material could be obtained from the Amazon Valley (Acre Territory) but usually a certain percentage of the seedlings were infected. The seedlings from Leticia, Colombia were resistant as not a single plant lost its leaves due to SALB. Seedlings of *Hevea spruceana* obtained from Manaus did not make a good rootstock. Some of the buddings were dormant for months before they began to sprout. In the Far East, hybrids of *H. spruceana* and *H. brasiliensis* produced 15 to 32 percent more yield than *H. brasiliensis*.

303. Spaulding, P. (1961). Foreign diseases of forests of the world. *Agriculture Handbook U.S. Department Agric*. 197, 361 p.

The *Hevea* species attacked by SALB in the various South and Central American countries were listed.

304. Stahel, G. (1915). De *Hevea*-bladziekte van Zuid-Amerika. *Meded. Dep. Landb. Suriname* 1, 3 p.

The perfect stage of the SALB causal fungus was named *Melanopsammopsis heveae*.

305. Stahel, G. (1916). Control of the South American *Hevea* leaf disease. *Tropical Agriculture*, 47: 369-370.

Abstract is not available.

306. Stahel, G. (1917). De Zuid-Amerikaansche hevea-bladziekte veroorzaakt door *Melanopsammopsis ulei* nov. gen. Meded. *Dep. Landb. Suriname*, 34, 111 pp.

This publication describes in detail the causal fungus of SALB and the histology of the infected tissue. The factors affecting spore germination, geographical distribution of SALB and methods of control by artificial defoliation (disease escape) and by 'smoking' to reduce the period of leaf wetness were presented.

307. Stahel, G. (1927). The South American *Hevea* leaf disease in Surinam. *India Rubber World*, 76: 251-252.

A brief account of the destruction caused by SALB in the rubber plantations of Dutch Guiana was presented. From 1915 onwards infection was so heavy that branches and trunks of five to eight years old trees were destroyed, while occasionally the whole tree succumbed to the disease. The disease was most serious in the interior of the country where rainfall was very much heavier than near the coast. The conidia of the pathogen required 10 to 12 hours moisture on the leaves for to effect penetration of the tissues.

308. Stevenson, J.A. (1935). The South American leaf disease of Para rubber invades Central America. *Plant Disease Reporter*, 19: 308.

A specimen of *Hevea* rubber received from Costa Rica showed typical symptoms of both the conidial and pycnidial stages of *Dothidella ulei*, apparently not previously recorded from the country.

309. Subramaniam, S. (1969). Performance of recent introductions of *Hevea* in Malaysia. *Journal Rubber Research Institute Malaysia*, 21: 11-18.

A few *Hevea* collections from Brazil were introduced into Malaysia. Illegitimate progeny of FX 25 was the best population for yield and vigour. *H. benthamiana* from Rio Negro and *H. brasiliensis* from Madre de Dios gave low yields compared with modern oriental selections. However, they were better than the original Wickham material. Nevertheless they provide good sources of genes for resistance to *Dothidella*.

310. Subramaniam, S. (1970). Performance of *Dothidella*-resistant *Hevea* clones in Malaysia. *Journal Rubber Research Institute Malaysia*, 23: 39-46.

All the *Dothidella*-resistant clones imported into Malaysia were bred in South America. The performance of the primary and secondary clones tested in Malaya was reported. Clones F 351, FX 25 and FX 2784 were found to be promising as parents in a breeding programme aimed at combining high yield with resistance to *Dothidella*.

311. Subramaniam, S. (1972). Breeding for disease resistance against SALB in *Hevea*. *Symposium on International Corporation in Hevea Breeding, 1972, Kuala Lumpur*, Preprint 10, 4 pp.

Material from Madre de Dios and Rio Negro were resistant to SALB. These and other resistant Brazilian clones had been crossed with high yielding susceptible oriental clones. International cooperation in *Hevea* breeding and testing for SALB resistance was proposed.

312. Tavares, E.T., Tigano, M.S., Sueli, C.M.M., Martins, I. and Cordeiro, C.M.T. (2003). Molecular characterization of Brazilian *Dicyma pulvinata* isolates. *Fitopatologia Brasileira,* 29: 148-154.

Forty nine isolates of *D. pulvinata* were compared by morphological traits using RFLP, RAPD and AFLP analyses. Isolates from *M. ulei* were closely related. Among isolates of *D. pulvinata* from *M. ulei*, a significant pair wise distance was obtained for all markers between isolates from different SALB regions.

313. Thurston, D.H. (1973). Threatening plant diseases. *Annual Revue Phytopathology*, 11: 27-52.

An account of plant diseases that have potential international importance but were limited to a few countries or a continent was presented. SALB was considered under ‘highly threatening plant diseases’. The earlier effort to reduce the introduction of SALB into Asia was lauded.

314. Tollenaar, D. (1954). *Dothidella ulei* en de rubberculture op het westelijk halfrond en in Z.O. Azei *Bergcultures*, 23: 55-93.

After visiting all the major rubber plantations in Latin America except Brazil, it was concluded that rubber cannot be profitably grown in these countries due to SALB. The devastating effect of SALB in the countries visited was confirmed. In Trinidad, an estate close to the sea was relatively free of infection. In Costa Rica, breeding for resistance to SALB and *Phytophthora* together with trial on crown budding were carried out. Clones recommended for crowns were FX 25, FX 645, FX 516, IAN 45-717 and IAN 45-443, the last two being also resistant to *Phytophthora*. Preventive measures against possible introduction of SALB to S.E. Asia require international cooperation in exchange of resistant planting material.

315. Tollenaar, D. (1959). Rubber growing in Brazil in view of the difficulties caused by South American leaf blight (*Dothidella ulei*). *Netherlands Journal of Agriculture,* 7: 173-189.

As a measure to combat SALB, Brazil should plant three categories of clones i.e. highly resistant clones such as FX 25, FX 3844, IAN 710 and IAN 873; tolerant but high yielding eastern clones such as PB 86 and AVROS 1301; and seedlings of selfed PB 86 and AVROS 1301, which showed some measure of resistance. Crown budding was not recommended because of its depressing effect on yield. The biology of the fungus in relation to the host and climatic conditions was discussed.

316. Townsend, C.H.T. (1960). Progress in developing superior *Hevea* clones in Brazil. *Economic Botany*, 14: 189-196.

The Ford Motor Company's *Hevea* breeding programme attempted to combine high yield with SALB resistance characters. It describes the geographical distribution of *Hevea* spp., sources of SALB resistance, life history of *Dothidella ulei*, chemical control and methods in *Hevea* breeding and selection.

317. Tysdale, H.M. and Rands, R.D. (1953). Breeding for disease resistance and higher rubber yield in *Hevea*, guayule and kok-saghyz. *Agronomy J*ournal, 45: 234-243.

Eastern clones of *H. brasiliensis* cannot be used in South and Central America, their natural home, because of their susceptibility to SALB. The U.S. Department of Agriculture cooperated with 11 Latin-American Republics to produce disease-resistant, high yielding rubber clones. The disease was controlled by the use of the three-component tree. The most disease resistant selections were from crosses between *H. brasiliensis and H. benthamiana*, the latter being a species of low rubber production. Back crossing of the resistant segregates to high-yielding *H. brasiliensis* produced clones with disease resistance and improved yield.

318. Ule, E. (1950). Kautschukgewinnung und Kantschukhendel am Amazonen strome. *Tropenpflanzer, Beihefte*, 6: 1-71.

Thirteen *Hevea* species were described and fungi associated with them listed. Ule was the first collector of specimens of SALB.

319. Valois, A.C.C. (1983). Character expression in rubber trees and obtainment of clones with production and resistance to South American leaf blight. *Pesquisa Agropecuaria Brasileira*, 18: 1015-1020.

Abstract is not available.

320. Van Heusden, W.C. (1953). De Zuid-Amerikaanse bladziekte van *Hevea brasiliensis, Dothidella ulei* P. Hennings. *Bergcultures*, 22: 236.

A description of the primary and secondary stages of infection of SALB was presented.

321. Van Heusden, W.C. (1963). De Zuid-Amerikaanse bladziekte (*Dothidella ulei*) een brendende kwestie. *Bergcultures*, 22: 171-177.

The chances of SALB establishing in South East Asia are ever present. Defence measures worked out in Malaya and Ceylon were the enforcement of plant quarantine, early detection of the disease, establishment of eradication procedures and breeding for SALB resistance. All these measures should be implemented on an international level.

322. Vincens, F. (1920). *Hevea* seed – the Surinam leaf disease. *Planters' Chronicle,* 15: 277-278.

Hevea seed from South America should be excluded on account of the prevalence of leaf disease.

323. Wastie, R.L. (1975). Disease of rubber and their control. *PANS,* 21: 268-289.

324. Wastie, R.L. (1986). Disease resistance in rubber. *Plant Protection Bulletin,* 34: 193-99.

Breeding work conducted in Central and South America against SALB had relied on vertical resistance (VR) and not horizontal resistance (HR). This resulted with serious breakdown of resistance. By better knowing the race structure of the pathogen, and using HR instead of VR, further progress in breeding is possible.

325. Waite, S.H. and Dunlap, V.C. (1952). South American leaf blight on *Hevea* rubber. *Plant Disease Reporter,* 36: 368.

The article is the first record of the occurrence of SALB in Honduras. The disease later appeared in Guatemala. Later SALB occurred in all the commercial rubber growing areas in Central America.

326. Weir, J.R. (1926). A pathological survey of the Para rubber tree *(Hevea brasiliensis*) in the Amazon Valley. *Bulletin United States Department of Agriculture,* 1380, 129 pp.

Part of this book deals with SALB under the following headings: histological development, hosts, life history of the fungus, control, protection, exclusion, eradication, immunization and the disease in the forest.

327. Weir, J.R. (1929). The South American leaf blight and disease resistant rubber. *Journal Rubber Research Institute of Malaysia,* 1: 91-97.

Suitable environmental conditions as well as the contiguous rubber areas are conducive for the spread of SALB in the country. The most important strategy of disease control is breeding for disease resistance.

328. Whalley, W.G. (1946). Rubber, heritage of the American tropics. *Scientific Monthly,* 62: 21-31.

Rubber cultivation in Brazil, particularly the effort of Ford Motor Company in 1928, was hampered by SALB. The disease could be held in check by spraying with copper and grafting with resistant clones.

329. Wijewantha, R.T. (1965). Some breeding problems in *Hevea brasiliensis*. *Journal Rubber Research Institute Ceylon,* 41: 12-22.

No major genes for resistance occurred in 116 clones resistant to *Dothidella ulei*. Several *Dothidella* resistant clones were also resistant to *Phytophthora palmivora*.

330. Wirjomidjojo, R. (1962). First report on performance of *Dothidella ulei* resistant clones in Experimental Garden, Tjiomas. *Menara Perkebunan*, 31: 181-185.

Dothidella-resistant clones (F, FB and FX) were imported from abroad in 1955 by the Research Institute for Estate Crops in Bogor. They were planted out as a collection in the Experimental Garden Tjiomas for breeding and crown-budding purposes. The imported clones when used as crowns had negative impact on growth and yield of the eastern clones.

331. Wycherley, P.R. (1968). Breeding of *Hevea*. *Planters' Bulletin Rubber Research Institute Malaysia,* 99: 159-170.

Resistance to leaf diseases is rapidly decreasing in *Hevea* in S.E. Asia due to genetical erosion. This can be corrected by imports of *Hevea* species from the neotropics. Some SALB resistant clones had been imported and should be used in the breeding programme to upgrade low yielding material.

332. Wycherley, P.R. (1968). Introduction of *Hevea* to the Orient. *Planter, Kuala Lumpur*, 44: 1-11.

The introduction of *Hevea* rubber to the orient by Henry Wickham and the early history of establishment of the crop in Malaya were documented. Introductions after Wickham contained rubber progenies resistant to SALB.

333. Wycherley, P.R. (1977). Motivation of *Hevea* germplasm collection and conservation. *Workshop on International Collaboration in Hevea Breeding, Kuala Lumpur*, Mimeograph, 5 pp.

The loss of genetic reserves in the wild was recognised. Motives for genetic conservation by breeders of *Hevea* were classified as specific, general and innovative. Priorities may be allocated according to these categories or according to the threats to the wild resource. An example of limited specific objective of breeding for resistance to SALB was that collection should concentrate on known sources of resistance to the disease and in areas climatically favourable to the virulent expression of SALB in nature.

334. Zhang, K.M. and Chee, K.H. (1985). Distinguishing *Hevea* clones resistant to races of *Microcyclus ulei* by means of leaf diffusate. *Journal Rubber Research Institute Malaysia*, 33: 105-108.

Leaves of *Hevea* clones were induced to produce diffusate by inoculating them with *Colletotrichum gloeosporioides* and *Phytophthora sp*. The diffusate exerted different degrees of inhibition of conidial germination of four physiologic races of *Microcyclus ulei*. Resistance or susceptibility of the test clones to SALB was segregated based on the degree of inhibition.

335. Zhang, K.M., Chee, K.H. and Darmono, T.W. (1986). Survival of South American leaf blight on different substances and recommendations on phytosanitary measures. *Planter, Kuala Lumpur*, 62: 128-133.

Spores of *Microcyclus ulei*, the causative agent of South American leaf blight of *Hevea* rubber survived best on infected leaves and cloth, less so on polyethylene, artificial leather and glass, and least germination was from conidia deposited on metal and paper in tests over seven days. The spores placed in soil for ten days remained viable. The gaseous phase of formalin at 91 ml/ cu cm or a 35 percent solution) inhibited ascospore release, and also killed the conidia after 15 minutes exposure. Conidia still germinated (5-10 percent) after 15 minutes ultra violet (254 nm) irradiation, but not when simultaneously exposed to 0.5 ml per cu cm of formalin. Conidia did not germinate in 40 mg per litre of soap powder solution. They were killed after 30 minutes exposure at 75 ºC or at 55 ºC in a moist enclosure. Air travellers were advised to bathe and launder their used clothes with soap powder during an intermediate stopover in a temperate SALB free country. At the point of entry into Southeast Asia, personal effects would need to be exposed to heat (75 ºC) or moist heat (55 ºC and 100 percent RH), or to ultra violet irradiation in combination with 'fumigation' with formalin in order to kill all conidia.

336. Zhang, K.M. and Chee, K.H. (1986). Differential sensitivities of physiologic races of *Microcyclus ulei* to fungicides. *Journal Natural Rubber Research,* 1: 25-29.

The effectiveness of benomyl, thiophanate methyl, chlorothalonil to Races 4, 6, 7, and 8 of *Microcyclus ulei* were evaluated by measuring inhibition of conidial germination, infection of leaf disks and field spraying. Races 6 and 8 were less sensitive to benomyl and thiophanate methyl than Races 4 and 7. Spraying benomyl (25 mg and 50 mg per litre) in the nursery gave satisfactory control of South American leaf blight on clones FX 2261 and FX 985 infected by Races 4 and 7 respectively, but not FX 3864 and FX 2804 infected by Races 6 and 8 respectively.

SECTION 2

TRAINING PROGRAMME FOR PROTECTION AGAINST SOUTH AMERICAN LEAF BLIGHT OF RUBBER IN ASIA AND THE PACIFIC REGION

TRAINING PROGRAMME FOR
PROTECTION AGAINST SOUTH AMERICAN LEAF BLIGHT OF RUBBER
IN ASIA AND THE PACIFIC REGION

CONTENT

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Contents *(continued)*

1. BACKGROUND

South American leaf bight (SALB) is the most serious disease of *Hevea* rubber. The disease is confined to Central and South America. SALB threatens the rubber growing industry in Asia and Pacific region. In 1956, the Asia and Pacific Plant Protection Commission (APPPC) was established and the body established the APPPC Agreement and protection of the rubber growing countries in the Asia and the Pacific region was included in the agreement. Various phytosanitary measures were introduced to reduce the risk of introducing SALB. The success of these measures is dependent on knowledgeable and competent personnel. The purpose of this training programme is to ensure the availability of competent and knowledgeable personnel to implement the various phytosanitary measures.

2. INTRODUCTION TO THE TRAINING PROGRAMME

The Training Programme consists of lectures, demonstrations and laboratory sessions. The programme is divided into three modules. Module 1 is on the biology of the host plant *Hevea* rubber, the biology and economics of SALB and *M. ulei* and other diseases of rubber plant. Module 2 will cover on the risks of SALB and the quarantine measures to reduce the risks of introduction of SALB. Module 3 covers measures to eradicate an outbreak of SALB.

3. TRAINING PROGRAMMES

3.1 Module 1: The biology of *Hevea* and South American leaf blight (SALB) and the causal pathogen, *Microcyclus ulei.*

3.1.1 Participants: Plant pathologists, quarantine officers, quarantine inspectors, crop protection officers and extension officers. The relevancy of each topic/lecture to a particular participant is indicated in Appendix 1.

3.1.2 Duration: 7 days

3.1.3 Lecture topics

(i) Lecture 1: The economics importance of rubber and South American leaf blight (SALB).

- The history of the introduction of rubber from Brazil into Asia by Wickham and other subsequent introductions;
- The importance of natural rubber to human kind;
- Rubber production by rubber producing countries and the importance of rubber to the economy of these countries;
- The importance of rubber to the income of the major growers of rubber i.e. the smallholders;
- The destruction of earlier plantations in South America by SALB;
- SALB endemic countries;
- SALB is still the main hindrance to a vibrant rubber growing industry in Brazil and other Central and South American countries;
- The effects of SALB on the tree and latex production.

(ii) Lecture 2: The biology of rubber plant, its cultivation and propagation methods.

- Species of *Hevea*;
- Common clones cultivated in different countries;
- Propagation methods by seeds, budded stumps and stump buddings;

- Preparation of planting material;
- Rubber planting systems;
- Improving tree productivity by breeding and selection;
- The need for new genetic resources to improve productivity and secondary characteristics;
- The importance of germplasm.

(iii) Lecture 3: Identification of *M. ulei*

- Methods for isolation and culturing.
  - Isolation methods;
  - Sterilisation methods;
  - Media: isolation media, growth media and media for spore production;
  - Induction of spore production.
- Diagnosis
  - Morphology of spores;
  - Molecular methods;

(iv) Lecture 4: The biology and epidemiology of SALB and *M. ulei*.

- The symptoms of SALB;
- The lifecycle of SALB: asexual and sexual stages;
- Morphology of spores;
- Physiological races of *M. ulei* and how to differentiate them;
- Spore dispersal: agents and relative to rainfall;
- Effect of weather conditions on disease severity;
- Viability of spores under different conditions;
- Suitability of weather condition in Asia and the Pacific region for SALB.

(v) Lecture 5: Management of SALB of rubber

- Chemical control: effective fungicides, application methods, costs, occurrence of fungicide resistant strains;
- Resistant clones: horizontal resistance vs vertical resistance, mechanism of disease resistance;
- Crown budding;
- Biological and integrated control;
- Polyploidy.

(vi) Lecture 6: Important diseases of *Hevea* rubber.

- Leaf diseases: Colletotrichum leaf fall, Oidium leaf fall, Phytophthora abnormal leaf fall, Corynespora leaf fall, Fusicoccum leaf blight, Birds eye spot;
- Stem diseases: pink disease, Ustulina rot;
- Panel diseases: Black stripe, Mouldy rot;
- Root diseases: White root disease, red root disease, brown root disease;
- The symptoms, biology and methods to control these diseases will be covered;

(vii) Lecture 7: Other quarantine pests and diseases of *Hevea*.

- Catacauma leaf blight, target leaf spot, mandarova (*Erinyis ello*), white moth (mosca do renda) of rubber.

3.1.4 Demonstration, laboratory sessions and site visit.

(i) Species of *Hevea* and various planting materials (seeds, budded stumps and budwood) and budding techniques;

(ii) Observation of preserved specimen of SALB and *M. ulei* spores;

(iii) Isolation and culturing of common *Hevea* diseases of rubber;

(iv) Symptoms of other diseases of rubber plant;

(v) Demonstration on pesticide application techniques.

3.2 Module 2: Risks of introduction of SALB into the APPPC region and risk management measures.

3.2.1 Lecture topics

(i) Lecture 1: The historical development on quarantine of South American leaf blight.

- The establishment of the APPPC Agreement in 1955;
- Article IV and Appendix B;
- Revision of the APPPC Agreement;
- ANRPC SALB Agreement;
- Activities of ANRPC and IRRDB on SALB.

(ii) Lecture 2: Pest Risk Analysis (PRA) of *M. ulei* with emphasis on entry pathways and import requirements.

- What is PRA?
- ISPMs
- The need for a pest risk analysis of SALB;
- The pathways and vectors of SALB,
- The probability of entry, establishment, spread and the level of risks associated with various pathways;
- Recommended risk management options.

(iii) Lecture 3: Guidelines for importation of *Hevea* planting materials from SALB endemic countries.

- Import requirement for host and non host materials;
- Point of entry inspection system: procedures for inspection, procedures for clearance, inspection of documents, disinfection or destruction procedures;
- Field and laboratory diagnostic systems: recognizing the symptoms of SALB and the spores of *M. ulei*;
- SALB surveillance system: detection survey, delimiting survey, and monitoring survey;
- Eradication and quarantine programme.

3.2.2 Demonstration and field visit

(i) Disinfection treatments of rubber planting materials

(ii) Quarantine inspection at entry points

3.3 Module 3: Surveillance and eradication programme

Lecture 1: Contingency plan

Lecture 2: Detection surveys, delimiting surveys, monitoring surveys

Lecture 3: Eradication procedures

3.4 Module 4: Workshop on SALB in Brazil

Objectives:

- To ensure the availability of SALB diagnostician
- To familiarize participants on SALB
- To train the trainers

Participants:

Pathologists, NPPO officials, plant breeders

Duration:

>4 days (actual training time)

Programme Leader:

Malaysia (leader of working group on SALB)

Role of Programme Leader:

- To liaise with NPPO Brazil and other relevant authorities (IRRDB)
- To coordinate sources of funding
- To draft training programmes
- To prepare criteria for participating countries to identify and select participants to be funded by FAO (Appendix)
- Each country can nominate participants under their own expenses.

Note: Lecturers and logistic arrangements to be provided by NPPO Brazil

TENTATIVE PROGRAMME:

LECTURES:

- Welcoming address By Organizer.
- Research activities on SALB in Brazil.
- Distribution, economic and significance of SALB.
- Rubber breeding programme against SALB by Institute Agronomy Campinas.
- The pathogen and the disease, SALB of *Hevea*.
- Variability and physiological races of *M. ulei*.
- Field visit to rubber nursery and Germplasm garden.
- The epidemiology of SALB.
- Management of SALB – Integrated control of SALB.
- Production and Evaluation of SALB Resistant Clones.
- Importance of Plant Quarantine and its Role in Preventing the SALB of Rubber.
- Plant Protection Agreement for Asia & Pacific Region.
- Pest Risk Analysis on SALB.
- Genetics of resistance.
- Country Report on Prevention of SALB by member Countries (Presentation).

LABORATORY SESSIONS

(a) Disease symptoms

- Observe using naked eye and under the binocular microscope:
  - The conidial lesions on young leaves
  - The pycnidial stage
  - The perithecial stage
  - Spore morphology

(b) Pathogenicity

- Inoculation of young leaves in Petri dishes
- Inoculation *in vivo* of young leaves on plants
- Observe symptoms and evaluate different parameters of infection (latent period, incubation period, lesion diameter, sporulation intensity).

(c) Culturing of *M. ulei*

- Isolation using an agar block
- Isolation using a wet needle
- Observation of cultures of *M. ulei*

(d) Spore survival period

- Different temperatures
- On different substances

(e) Effectiveness of fungicides

(f) Plant protection equipment

FIELD VISITS

(a) Rubber Nursery

- Observe symptoms of SALB on young leaves of various ages from bud burst (purple red), 7-day-old leaves (copper brown), and 14-day-old leaves (pale green). Examine both upper and lower leaf surfaces of the lesions
- Observe the necrotic lesions and black powdery conidia
- Observe if other organisms (mycoparasites) are growing on the lesions of *M. ulei*.Take note the size of lesions on different rubber clones
- Examine the newly mature green leaves; observe both the upper and lower leaf surfaces. Observe the pycnidia which produce the pycnospores. Note the location of the pycnidia on the upper leaf surface with respective to the location of the lesion on the lower leaf surface
- Examine the hardened old dark green leaves. Feel the protruding black masses i.e. the stromata on the upper surface of the leaves. Stroma contains perithecia, which borne in them asci and each ascus contains eight ascospores

(b) Mature rubber area

- Observe the canopy density and the health state of the trees. Note for the low density of the canopy and the occurrence of dead branches and trees
- Examine fallen leaves, note the lesions and the fruiting bodies on the leaves

- Note the age and the size of the trees. Enquire about the latex productivity of various clones
- Note various canopy densities of various clones (resistant and tolerant clones and species)
- Visit a crown budded rubber area
- Observe differences of canopy density and disease severity between the top and the bottom of a hill planted with FX 3864
- Demonstration of spray equipment

4. RESOURCES

a. Personnel

b. Reference materials

   i. Poster
   ii. A note on South American leaf blight
   iii. Bibliography
   iv. Leaflet on South American leaf blight
   v. Pamphlet on South American leaf blight
   vi. PowerPoint presentations

APPENDIX 1

CRITERIA FOR SELECTION OF PARTICIPANTS FOR TRAINING IN BRAZIL

– The selected participants will be responsible for training others in the country or region.
– The selected participants must have knowledge on relevant ISPM
– The selected participants must be willing to work together with NPPO
– The selected participants must take photographs to be deposited with the programme leader for distribution to member countries
– The selected participants have to come up with a report on their return

1. Pathologists

- Must have at least 5 years working experience
- Must be a practicing pathologist

Training table Relevance

Relevance of training topics to target groups

Module	**Module and Relevant Topics**				
	1	**2**	**3**	**4**	**5**
Topics / **Target group**	**Plant Quarantine Officers, Plant Pathologists, Crop Protection Officers**	**Extension Officers**	**Quarantine Officers at entry point**	**Technical/ diagnostic officers, Lab Technicians**	**Officers from other agency**
Topic 1: The biology of *Hevea* and South American leaf blight (SALB) and the causal pathogen, *Microcyclus ulei*. **Lecture topics:**					
(i) Lecture 1: The economic importance of rubber and South American leaf blight (SALB).	/	/	/	/	/
(ii) Lecture 2: The biology of rubber plant and its cultivation and propagation methods.	/	/	/	–	–
(iii) Lecture 3: South American leaf blight: The symptoms of SALB, the spores of *M. ulei*, distribution, dispersal and epidemiology.	/	/	/	/	/ (basic – not detail)
(iv) Lecture 3: Management of SALB of rubber.	/	/	/	–	–
(v) Lecture 4: Methods for isolation and culturing of *M. ulei*.	/	–	–	/	–
(vi) Lecture 5: Other quarantine pest and diseases of *Hevea*.	/	/	/	–	–
Demonstration and laboratory sessions					
(i) Species of *Hevea* and various planting materials (seeds, budded stumps and budwood) and budding techniques	/	/	/	–	–
(ii) Observation of preserved specimen of SALB and *M. ulei* spores	/	/	/	/	–

Module	Module and Relevant Topics				
	1	**2**	**3**	**4**	**5**
Topics / **Target group**	**Plant Quarantine Officers, Plant Pathologists, Crop Protection Officers**	**Extension Officers**	**Quarantine Officers at entry point**	**Technical/ diagnostic officers, Lab Technicians**	**Officers from other agency**
(iii) Isolation and culturing of common *Hevea* diseases of rubber	/	–	–	/	–
(iv) Symptoms of other diseases of rubber plant	/	/	/	/	–
(v) Demonstration on pesticide application techniques	/	/	–	–	–
Topic 2: Risks of introduction of SALB into the APPPC region and risk management measures. **Lecture topics:**					
(i) Lecture 1: The historical development on quarantine of South American leaf blight	/	/	/	–	–
(ii) Lecture 2: Pest Risk Analysis (PRA) of *M. ulei* with emphasis on entry pathways and import requirements	/	–	/	–	–
(iii) Lecture 3: Procedures for importation of *Hevea* planting materials from SALB endemic countries	/	–	/	–	–
(iv) Lecture 4: Procedures for inspection, diagnostics and disinfection of planting materials.	/	–	/	/	–
Topic 3: Surveillance and eradication programme. **Lecture topics:**					
(i) Contingency plan: Detection surveys and eradication procedures.	/	/	/	–	–
(ii) Public relation: Creation of public awareness	/	/	/	–	/

SECTION 3

OPERATIONAL GUIDELINES FOR IMPORTATION OF *HEVEA* PLANTS FOR PLANTING TO PROTECT AGAINST SOUTH AMERICAN LEAF BLIGHT

CONTENTS

Contents *(continued)*

Page

OPERATIONAL GUIDELINES FOR IMPORTATION OF *HEVEA* PLANTS FOR PLANTING TO PROTECT AGAINST SOUTH AMERICAN LEAF BLIGHT

1. PURPOSE

The purpose of the Operational Guidelines for Importation of *Hevea* Plants for Planting to Protect against South American Leaf Blight (SALB) is to establish an effective uniform quarantine procedures relating to the protection from SALB. The main objective of the operational guidelines is to reduce the risk of entry and spread of SALB in the APPPC region. The operational guidelines is for Competent Authority (CA) (PQ officers, PQ inspectors, plant pathologists) and other related personnel in the Asia and Pacific Plant Protection Commission (APPPC) rubber growing countries to deal with importation of rubber planting materials from SALB endemic countries.

2. SCOPE

The SOP documents the various certification and measures to be followed by Competent Authority during importation of planting materials from SALB endemic areas. The SOP is divided into several major sections:

- References, glossary, definitions, references;
- Resources;
- Quarantine procedures:
  - Registration and Processing application for importation;
  - Quarantine procedure for pre import requirements;
  - Set/establish requirements and approve PEQ facilities;
  - Inspection of document and consignment at point of entry;
  - Transportation;
  - Handling and Quarantine of planting materials;
  - Surveillance;
- Appendices.

3. REFERENCES

Protection against South American Leaf Blight (2011), RAP Publication 2011/7, FAO of the United Nations, APPPC, Bangkok.

Glossary of Phytosanitary Terms, ISPM No. 5 (2010), FAO, Rome.

Guidelines for Inspection, ISPM No. 23 (2005), FAO, Rome.

Guidelines for a phytosanitary import regulatory system, ISPM No. 20 (2004), FAO, Rome.

Guidelines for surveillance, ISPM No. 6 (1998), FAO, Rome.

Training requirement for plant quarantine inspectors, 2004, APPPC RSPM No. 2, RAP Publication 2004/24, FAO, Bangkok.

Design and operation of post-entry quarantine stations for plants, ISPM No. 34 (2010), FAO, Rome.

4. GLOSSARY OF ACRONYMS AND DEFINITIONS

4.1 Acronyms

APPPC	Asia and Pacific Plant Protection Commission
CA	Competent Authority
IPPC	International Plant Protection Commission
NPPO	National Plant Protection Organization
PQ	Plant quarantine
PEQ	Post entry quarantine
PRA	Pest Risk Analysis
SALB	South American leaf blight

4.2 Definitions

Budded stumps	Planting material produced by grafting bud from a selected scion onto rootstocks.
Bud-grafting/budding	The process of inserting a slice of bark with bud obtained from a scion onto an insertion made on a rootstock to a budded plant.
Buffer zone	An area in which a specific pest does not occur or occurs at low level and is officially controlled, that either encloses or is adjacent to an infested area.
Certificate	An official document which attests to the phytosanitary status of a consignment affected by phytosanitary regulations
Clearance of a consignment	Verification of compliance with phytosanitary regulations
Competent Authority	The national authority with the officially approved responsibility and competency and is responsible to ensure and supervise the implementation importation of planting materials and quarantine measures
Consignment	A quantity of plants, plant products and/or other articles being moved from one country to another and covered when required by a single phytosanitary certificate.
Country of origin	Country where the plants were grown
Detection survey	Survey conducted in an area to determine if pests are present.
Enclosed quarantine facility	Facilities of the station may include glasshouse constructed of breakage-resistant glass or twin-walled polycarbonate, or a laboratory.
Import Permit	An official document authorizing importation of a commodity in accordance with specified phytosanitary import requirements
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present and/or to determine compliance with phytosanitary regulations.
Intermediate quarantine	Quarantine in a country other than country of origin or destination.
Monitoring survey	Ongoing survey to verify the characteristics of a pest population.
National Plant Protection Organization (NPPO)	Official service established by a government to discharge the functions of the IPPC

Open field quarantine facility	A suitable site, field or nursery where imported consignment released from enclosed PEQ facility are grown and subjected to post entry quarantine measures.
Pest Risk Analysis (PRA)	The process of evaluating biological or other specific or economic evidence to determine whether a pest should be regulated and the strength of any regulatory measures to be taken against it.
Phytosanitary Certification	Use of phytosanitary procedures leading to the issue of a phytosanitary certificate
Phytosanitary Import Requirements	Specific phytosanitary measures established by an importing country concerning consignment moving into that country.
Plants	Living plants and parts thereof, including **seeds** and **germplasm** [FAO, 1990; revised IPPC, 1997]
Plants for Planting	**Plants** intended to remain **planted**, to be **planted** or **replanted** [FAO, 1990]
Point of entry	Airport, seaport or land border point officially designated for the importation of consignment.
Post entry quarantine (PEQ)	Quarantine applied to a consignment after entry
Quarantine pest	A pest of potential economic importance to the area endangered and not yet present there or present but not yet widely distributed and being officially controlled.
Regulated pest	A quarantine pest or a regulated non-quarantine pest.
Survey	An official procedure conducted over a defined period of time to detect the characteristics of a pest population or to determine which pest species occur in an area.
Visual examination	The physical examination of plants, plant products or other regulated articles using the unaided eye, lens, or microscopes to detect pests and contaminants without testing or processing.

5. BACKGROUND

South American leaf blight (SALB) is the most serious disease of rubber. The pathogen of SALB is the fungus *Microcyclus ulei* (P. Henn) v. Arx. The disease had destroyed many early plantations and it is still the main hindrance to the expansion of a viable natural rubber growing industry in Central and South America. SALB prolongs the immaturity period of the rubber plant and reduces latex yield resulting from repeated and prolong defoliation. Several scientists predict that the natural rubber industry in Asia and Pacific region would be decimated within five years on the entry of SALB (references?). The early rubber planters had the vision to introduce the Plant Protection Agreement for the Asia and Pacific region (the Agreement) in 1956. The Article IV and Appendix B of the Agreement that dealt specifically with SALB prohibited the import of: plants or seed of the genus *Hevea* from outside the region; plant material of genus *Hevea* not capable of further growth or propagation (such as fresh or dried herbarium specimens); and any plants of other than genus *Hevea* from SALB endemic areas into their countries unless except for research purposes.

The Agreement was revised in 1999 to bring it in line with the WTO Agreement on the Application of Sanitary and Phytosanitary Measures. Consequently, a pest risk analysis (PRA) on SALB was done and adopted by the APPPC in 2007. The PRA identified the pathways and vectors, and categorized their risks. Budded stumps and budwood were given high probability of entry high level of risks. The other vectors i.e. the foliage, seeds, fruits and flowers were given low probability of entry and low to moderate level of risk. The SALB PRA recommends general measures for importation of rubber planting materials from SALB endemic countries into Asia and the Pacific region. The measures are detailed in the APPPC RSPM No. 7 – Guidelines for Protection against South American leaf blight that includes:

- Strict phytosanitary import requirements;
- An inspection system at point of entry;
- A laboratory diagnostic system;
- An efficient surveillance system.

The procedures to implement the above measures are detailed in the current publication.

6. FLOW CHART

This flow chart should be read in conjunction with the work plan of the importation of the budded stump or budwood of *Hevea* sp.

Description	Responsibilities
1. Prepare and submits application a. Propose PEQ facilities	Importers
2. CA Quarantine Facility a. Receive and acknowledge application; b. Register application; c. Process application; d. Investigate pre-export condition; e. Assess proposed PEQ facilities; f. Decide on status of application; g. Inform importer on status of application or for clarification; h. Issue Import Permit and any other relevant documents.	CA
3. Inspect, harvest and treat planting materials in exporting country and transport to importing country. a. NPPO of the exporting countries certifies the planting materials which meet the import requirements	Importer, exporter & NPPO of the exporting and importing countries (need based)
4. Intermediate Quarantine Station (optional) a. Intermediate country must be a non-rubber growing country b. NPPO of the importing country approved the intermediate country c. Same procedures as in point of 5 and 6. d. NPPO of the intermediate country issue a PC	NPPO of the importing country and NPPO of intermediate country
5. Point of Entry a. Inspect outside of the consignment and verify documents at the point of entry b. For non-compliance consignments, the options include destruction, deportation, seeking further clarification or other remedial action c. Transfer the consignment to approved post entry quarantine facility	NPPO

6. For importation from intermediate quarantine country a. Only budwood to be imported b. Quarantine period in enclose post entry quarantine facility for minimum of 3 months or until the first flushing of leaves.	NPPO
7. Post-entry Quarantine Facility a. Inspect consignment b. Destroy packaging materials and unwanted seeds c. Treat seed and budwood d. Germinate seed in seedbeds and transplant seedlings into polybags or carry out bud grafting for budwood e. Inspect seedlings or budded plants for disease symptoms f. Quarantine plants for at least 12 months g. Destroy plants infected with SALB and other quarantine pests h. Plant shall undergo an initial quarantine period in an enclosed quarantine facility until after the second flush of growth then maybe transfer to open quarantine facility for the remainder of quarantine period.	NPPO
8. Surveillance around the PEQ facility for the sign of SALB.	NPPO of importing country

7. LEGAL AUTHORITY

The laws and regulations pertaining to the importation of rubber planting materials from SALB endemic countries shall be established. The regulations must comply and satisfy the international and national requirements. The personnel involved shall have legal mandate and administrative authority to perform the required activities. The Competent Authority (CA) and its personnel will have legal power for their activities and actions taken.

8. MANAGEMENT RESPONSIBILITY

The NPPO will identify a specific Plant quarantine unit and personnel at national and regional levels that will deal with importation of rubber planting materials from SALB endemic countries. The line of command and the duties and functions of an officer at various national and regional levels will be established. The NPPO shall plan and execute measures on importations of rubber planting materials from SALB endemic countries. The NPPO to assess other potential pest of *Hevea* that may be of quarantine concern.

9. RESOURCES

9.1 Trained and qualified personnel

The NPPO shall ensure that adequate, trained and competent personnel to undertake various related activities are available. In addition, a list of local and foreign pathologists well versed on SALB and related subjects shall be kept for consultation and assistance on diagnostic and advisory purposes (if necessary).

9.2 General facilities

The Plant Quarantine Department will be provided with ample office space and relevant facility and equipment for secretarial, data storage, communication and training (Appendix 1).

9.3 Specific Facilities and Equipments

9.3.1 Diagnostic Laboratory

A laboratory to carry out pathological and diagnostic activities will be made available. The laboratory will be equipped with adequate equipment, chemicals and consumables needed to effectively carry out these functions (Appendix 1). Apart for general pathological functions, the laboratory will also have rooms and equipment for serological (ELISA) and molecular diagnostic (PCR) methodologies. The laboratory will also be allocated with a suitable insect proof glasshouse. Laboratory, glasshouse and other facilities should follow the guideline as specified in plant containment facilities requirement (Appendix 9).

(Note: Appendix 9: in draft – Safety in the laboratory code of practice part 3: Bio containment and biosafety in microbiological facility)

9.3.2 Post entry quarantine facilities (Enclosed and open field facilities)

Post entry quarantine (PEQ) facilities will be established in accordance with **Appendix 1 of ISPM No. 34 – Requirement for PEQ Station for Pests** that are highly mobile or easily dispersed (e.g. rust fungi, airborne bacteria).

The enclosed PEQ facility shall be designed and constructed to ensure it is insect-proof and is large enough for carrying out quarantine treatments and maintaining the rubber plants for the quarantine period. The open field PEQ facility (rubber nursery) shall be located in an area at least 3 km away from any rubber plant. The open field PEQ facility shall be secured by a fence.

9.3.3 Intermediate Quarantine

Importation of planting materials that are considered as high risk may undergo intermediate quarantine in non-rubber growing country where SALB is not present.

For importation from intermediate quarantine country:

a. Only budwood to be imported
b. Quarantine period in enclose post entry quarantine facility for minimum of 3 months or until the first flushing of leaves.

The quarantine in the intermediate country must fulfill the following conditions:

Point of Entry

- Inspect outside of the consignment and verify documents at the point of entry
- For non-compliance consignments, the options include destruction, deportation, seeking further clarification or other remedial action
- Transfer the consignment to an approved post entry quarantine facility

Post-entry Quarantine Facility

- Inspect consignment
- Destroy packaging materials and unwanted seeds
- Treat seed and budwood

- Germinate seed in seedbeds and transplant seedlings into polybags or carry out bud grafting for budwood
- Inspect seedlings or budded plants for disease symptoms
- Quarantine plants for at least 12 months in an enclosed quarantine facility
- Destroy plants infected with SALB and other quarantine pests

9.4 SALB Database

The Plant Quarantine Division shall be equipped with equipments and software for data storage and online communication and reporting. The Plant Quarantine Authority will establish a SALB database that contains information on South American leaf blight and its causal pathogen *Microcyclus ulei*, available expertise on SALB, diagnostic laboratories, surveillance system and data, documentation on quarantine procedures and linkages. The database will also contain information on pest control companies preferably those with airplanes or helicopters, suppliers of spraying equipment and chemicals effective against *M. ulei*.

10. QUARANTINE PROCEDURES

10.1 Registration and processing of application

Any importation of *Hevea* plants for planting will be subject to the conditions and the laws of the importing countries. Private application to import *Hevea* plants for planting will also be considered in collaboration with the importing country NPPO.

10.1.1 Register application for importation of planting materials from importers

On receipt of the application for importation of rubber planting materials from an importer, the receiving officer is to verify and record the particulars of the applicant including the name of the applicants in a prescribed form containing the information in Annex 1. If necessary, the applicant will provide other relevant particulars and information required for approval of the importation.

10.1.2 Process application and issue relevant certificates

The application shall be processed by relevant personnel and the personnel shall decide whether to approve or reject the application guided by the rules and regulations for importation of rubber planting materials from SALB endemic countries (Appendix 2 and the work plan). Once the decision to permit importation is made, the relevant PQ officer will inform the importer on the status of the application and issue the Import permits.

10.1.3 Record the application

The application shall be acknowledged, recorded and stored in proper places.

10.2 Certify PEQ facilities

The enclosed quarantine facility need to be registered with the NPPO and certified in accordance with ISPM No. 34: Appendix 1. For the facilities that not registered the following procedure will apply

10.2.1 Preparation and Inspection

The imported planting materials (budwood or seeds) shall be processed and treated on arrival in an enclosed PEQ facility. After two growth flushes, the plants will be transferred to an open field PEQ facility to complete the quarantine period. If the PEQ facilities do not exist, they shall be constructed in accordance to ISPM No. 34. Existing facilities shall be inspected, modifications and renovations made if necessary. The suitability of the facilities for the quarantine purposes of the planting materials will be inspected and certified.

Annex 1. Application for Permit to Import Rubber Planting Materials

1. Particulars of applicant	1.1 Name of applicant: 1.2 Name of Organization: 1.3 Contact address: Telephone: Fax: E-mail: 1.4 Contact person:
2. Particulars of planting materials to be imported	2.1 Type of planting materials and quantity: • Seeds (quantity); • Budwood (quantity); 2.2 Detail information on planting materials: • Species: • Clones: • Wild progeny
3. Purpose of importation	3.1 Objectives
4. Source of planting materials	4.1 Country and states: 4.2 Name of plantation or nursery:
5. Exporter	5.1 Name of Organization: 5.2 Contact address: Telephone: Fax: E-mail: 5.3 Contact person:
6. Shipment itinerary	6.1 Point of entry: 6.2 Dates to import/arrival: 6.3 Direct or indirect importation: 6.4 Carrier:
7. Proposed PEQ facility	7.1 Location of facility 7.2 Specification (include e.g. layout, photo of the facility)

10.2.2 Certification

The suitability of the PEQ facilities shall only be given when the following conditions are met:

- *Location:* The enclosed PEQ facility if possible should be near to the entry point. The PEQ facility should be 3 km away from any rubber plant. The open field PEQ should be easily accessible for inspection;
- *Construction:* The enclosed PEQ facility will meet ISPM No. 34 – Appendix 1. The PEQ facility shall be insect proof and equipped with double doors. The height of the roof should be sufficiently high to accommodate the height of the growing rubber plants and made of transparent materials for light transmission. Details as Appendix 9 (to be refer later);
- *Adequate space:* The PEQ facility shall have sufficient space to accommodate the quantity of the imported planting materials for the required period of quarantine and allow sufficient space for maintenance (watering, fertilization, inspection) and permits good growth of plants without suffering from aetiolation;
- *Security:* The PEQ facility is sited in a safe location. The open field PEQ facility should be adequately fenced;

Items	Comments	Approval
Location		
Construction		
Adequate space		
Security		
Soil fertility		
Drainage, irrigation and watering system		
	Name of officer:	Signature:

10.3 Inspection and Examination of documents and consignment

10.3.1 Inspection of consignment

PQ Inspectors shall examine the necessary documents to ensure that consignments comply with export/import requirements (Appendix 3 and the work plan). The documents to be examined are:

- Permit to import consignment issued by the NPPO of importing country;
- Phytosanitary Certificate issued by NPPO of exporting country;
- Report on preparation and treatments of planting materials in exporting country;
- Shipment reports;
- Quarantine Inspectors should conduct visual inspection of the consignment i.e. packaging to ensure that they are in good conditions.

10.3.2 Certify and release of consignment

Consignment with documentation that complies with rules and regulations should be released and immediately moved to the PEQ facility.

10.4 Inspection, treatment, processing and quarantine of planting and packaging materials at PEQ facility

10.4.1 Disposal of waste materials

The packaging and packing materials and debris and wastes derived from the budwood (i.e. the remainder of the budwood after the bud eyes had been removed for budding operation), damaged budwood, poor quality seeds and ungerminated seeds shall be disposed accordingly. They shall be burned, autoclaved or soaked for at least 30 min in 10 percent formaldehyde/sodium hypochlorite.

10.4.2 Inspection of planting materials

The planting materials (budwood or seeds) shall be examined and good quality planting materials shall be selected. Damaged and poor quality budwood and seeds shall be disposed. The budwood is considered damaged when the bud eyes are not viable anymore often due to long storage. Selection for good seeds is based on the appearance and weight as good seeds are shiny and heavy and the micropiles are intact. In addition, good seeds will bounce when thrown onto hard surfaces while poor seeds will not bounce.

10.4.3 Treatment of planting materials

The budwood and the seeds shall be treated as follows:

- Dipped in surface sterilant e.g. formaldehyde or sodium hypoclorite solution and treated with a fungicide in Appendix 7

10.4.4 Germination of seeds

The seed germination shall be carried out as follows:

- The seeds shall be germinated in seedbeds or appropriate containers filled with aged sawdust and fine river sand.
- The germinated seeds with sufficient length of radicles shall then be transplanted to designated polybags filled with soil. The seeds that failed to germinate after a month in the seedbeds shall be collected and disposed according to 14.4.2.

10.4.5 Budding

The bud-eyes shall be harvested from budwood and grafted onto rootstock seedlings maintained in the PQ facility for sometimes for acclimatization. The leftover of the budwood shall be disposed as specified in 14.4.2. The budding tapes shall be removed and disposed by autoclaving or sterilized by dipping in formaldehyde/sodium hypochlorite solution.

10.5 Quarantine and inspection

10.5.1 Quarantine period

The plants are to be kept under quarantine for one year or until the plants produce six whorls of leaves.

10.5.2 Inspection and diagnosis of pests and diseases

The plants shall be inspected for disease symptoms as follows:

- The plants shall be examined daily by a trained technician and weekly by a qualified plant pathologist for symptoms of SALB or any quarantine pests and diseases.
- Inspection shall concentrate on the lower surface of the young leaves (reddish in colour) of the plants.
- Record each inspection (dates, pests detected).
- The identification of pests and diseases shall be based on:
  - The characteristic symptoms of SALB on young leaves;
  - The morphology of the spores under a microscope;
  - The diagnostic aids, Appendix 5;
  - In the event of inability to diagnose the disease, a competent authority should be consulted;
- Fungal isolation and culturing may be conducted according to Appendix 6.

10.5.3 Certification and release

At the end of quarantine period the plants shall be released after being certified free of SALB and other quarantine pests and diseases.

- The plant pathologist shall certify that the plants are free of SALB and other quarantine pests;
- If the diseases are not detected during the quarantine period, the plant pathologist shall recommend that the plants are to be released to the importer;
- In the event SALB or any quarantine pests and diseases are detected and confirmed, the infected plants in the PEQ facility shall be destroyed immediately by uprooting and dipping the whole plant in formaldehyde/sodium hypochlorite solution and burned or autoclaved. The other plants that have not shown any disease symptoms should be treated with effective fungicides and continue under quarantine for another 12 months. The importer should be immediately informed;
- The seedlings and budded plants once certified free of SALB and other quarantine pests and diseases will be released.

10.6 Planting and maintenance of plants in open field PEQ

10.6.1 Planting

Plants shall be planted in rows at reasonable distance (3 m × 3 m) to facilitate good plant growth and permits inspection and treatment. The plants will be regularly watered and fertilized.

10.6.2 Inspection

The plants are inspected daily by a trained technician and weekly by a qualified plant pathologist to detect for symptoms of SALB and other quarantine pests and diseases. If the need arises for further confirmation, the leaves or other plant organs with suspected symptoms are sampled, placed in special containers and brought to the laboratory for further diagnosis.

10.7 Disease surveillance

10.7.1 Responsibilities

The NPPO shall appoint a Survey and Monitoring Officer who will be responsible for planning, conducting, monitoring and reporting result of the surveys. The NPPO shall determine that the survey procedures (Appendix 8) are carried out and properly recorded.

10.7.2 Types of surveys

Two types of surveys shall be conducted:

- *Detection survey*. A detection survey shall be initiated following importation of rubber planting materials from SALB endemic countries to determine if SALB occurs for the first time. The survey shall be conducted within 3 km around the point of entry and 3 km around the PEQ facilities. The NPPO shall identify all the rubber plantings (nurseries, estates and smallholdings) within the boundary and the NPPO shall undertake the survey after informing and briefing the stakeholders. The survey should commence one month after arrival of imported plants and shall be continued for one year. The survey will target young leaves. All plants in the nursery shall be inspected fortnightly. For mature rubber, monitoring should be done fortnightly during the leaf change period (wintering) and monthly during normal growth period. The number of sampling points is one point per hectare. In addition, all rubber holding owners and/or operators within the zone shall be supplied with relevant information on SALB. They will inform the NPPO when SALB is suspected.
- *Delimiting survey*. In the event of detection of SALB, the NPPO shall initiate and implement a delimiting survey immediately so as to determine the extent of disease spread.
- *Disease Eradication and quarantine*. The NPPO shall decide and determine the eradication and quarantine measures. The eradication and quarantine measure shall be implemented as soon as possible upon detection of SALB. The procedures for eradication and quarantine of a SALB infected and surrounding area (Appendix 8) shall be adhered.

11. DOCUMENT MANAGEMENT AND RECORD CONTROL

11.1 Document management

The NPPO dealing with importation of rubber planting materials shall adopt these guidelines. The NPPO will document and store relevant information in the database. Any revision and changes made to the guidelines or any other related documents shall be recorded and communicated to relevant personnel and authorities possessing the guidelines. The obsolete documents will be replaced by the revised version. The NPPO will ensure that the documents are easily available to related personnel.

11.2 Record control

The NPPO will maintain the records of relevant activities related to importation of rubber planting materials in special files and folders that includes:

- Particulars on various applications;
- Procedures and treatments undertaken for each importation;
- Records of surveillance activities and technical visits
- Records of pests and diseases intercepted from imported consignments of planting materials or planting materials grown in PEQ facilities that includes diagnostic protocols, and pest and disease identifications (photographs, microscope slides).

The records should be properly compiled and indexed for easy retrieval. The records should be maintained for at least five years.

12. TRAINING

The NPPO will identify personnel entrusted to carry out quarantine activities related to importation of planting materials. The NPPO will review the competency of the personnel, identify the training needs and initiate implementation of training programme that includes funding, target audience, lecturers and training materials, training venues and dates.

Appendix 1

RESOURCES

1. Equipment for secretarial, data storage, communication and training

- Computers and printers;
- Software for data management;
- Reference books;
- Diagnostic and laboratory manuals.

2. General Pathology Equipments

- Major equipments – Autoclaves, incubators, ovens, water distillers, bio-safety cabinets and fume chambers, laminar flow cabinets, refrigerators, weighing balances, microscopes, cameras, pH meters, water baths, shakers, microwave ovens, thermometers, isolation needles, grinders, glassware, hot plates and stirrers, distilled water apparatus, centrifuges.
- PCR and related accessories – Thermocycler, electrophoresis apparatus, gel documentation unit with printer, PCR work station, pipettes, nucleic acid chemicals.
- ELISA and related accessories – Elisa readers
- Disease treatment and disposing equipments – Sprayers, moist heat chambers, dipping tanks, incinerators, pesticides and hot water jet apparatus.
- Chemicals and consumables – Medias (PDA, PSA, MEA etc.), Chemicals for making medias (agar, sucrose, glucose, malt extract, potato extract etc.); Chemicals for sterilization (formalin, mercuric chloride, sodium hypochlorite, alcohols etc.); Glassware (Petri plates, test tubes, flasks, beakers, glass slides and cover slips); Stains (trypan blue or cotton blue, hematoxylin etc.); PCR primers, ELISA antiserum.
- Requirements for sampling and transportation – Cooler boxes, containment boxes.

Appendix 2

IMPORT REQUIREMENTS FOR *HEVEA* PLANTING MATERIALS

(Sourced from "RSPM No. 7: Guidelines for protection against South American leaf blight of rubber")

The NPPO of rubber growing country shall impose or undertake the following import requirements for *M. ulei* host materials:

- Restriction of the quantity of importation (NPPO of importing country to decide)
- Pre-export inspection and treatments in the exporting country by a pathologist;
- Measures applied on arrival at entry point;
- For budwood
  - Restriction of quantity
  - Restricting the length
  - Treating with a surface sterilant and dressing with a systemic fungicide (effective to control *M. ulei*)
- For seeds
  - Restrict the quantities of seeds imported
  - Only healthy seeds to be imported
  - Treating with a surface sterilant and dressing with a systemic fungicide (effective to control *M. ulei*)

Appendix 3

MANAGEMENT OPTIONS FOR VIABLE HOST PLANTS

(Sourced from "Guidelines for protection against South American leaf blight of rubber")

1. Pre-export inspection and treatments:

- Mother plants should be inspected by a suitably qualified pathologist for symptoms of SALB infection. The inspection will be carried out immediately before the harvesting of budwood.
- Only brown budwood should be harvested and the length should not exceed one metre. The budwood should be harvested during low disease season. Budwood should be dipped in a surface sterilant and a fungicide effective against *M. ulei*.
- Budwood should be properly packaged to ensure minimum infestation during export.

2. Intermediate Quarantine

Importation of planting materials that are considered as high risk may undergo intermediate quarantine in non-rubber growing country where SALB is not present.

For importation from intermediate quarantine country:

a. Only budwood to be imported
b. Quarantine period in enclose post entry quarantine facility for minimum of 3 months or until the first flushing of leaves.

3. Measures on arrival:

- The outside of the consignment must be inspected for any unwanted pests.
- *bud*wood and seeds should be dipped in a surface sterilant and a fungicide effective against *M. ulei*.
- The packaging materials and should be destroyed by incinerating them or soaked in a surface sterilant.

4. Post entry quarantine

- The budwood operation using the budwood on preplanted rootstocks shall be carried out in certified PEQ facility.
- The seedlings and budded plants should kept in the PEQ facility for at least a year or until the plants possess six leaf whorls
- Plants should be inspected daily by a trained technician and weekly by a qualified plant pathologist.
- Any plant suspected of being infected by SALB should be immediately destroyed and all the remaining plants should be treated with a fungicide effective against *M. ulei*.

Appendix 4

RESPONSIBILITIES OF NPPO FROM EXPORTING AND IMPORTING COUNTRIES AND THE IMPORTER

(Sourced from "Work plan for the importation of budded stumps or budwood of *Hevea* spp. from (exporting country) into (importing country)")

1. Responsibilities of NPPO of exporting country

- Follow all requirements of the work plan and the import permit issued by the importing country;
- Propagating materials should be harvested from mother plants with no or minimum symptoms of SALB;
- Propagating materials with symptoms of SALB or other diseases will not be exported;
- Supervise harvesting of budwood (brown budwood of less than 1 m long) and budded stumps (without sprouting) during low disease season;
- The nursery where the budded stumps are prepared or where budwood is harvested should be registered;
- Ensure that budded stumps, budwood or seeds are surface sterilized and treated with fungicides effective against *M. ulei*;
- Inspect the requirement and issue a PC certifying that the consignment conforms to the import requirements of the importing country.

2. Responsibilities of NPPO of importing country:

- Issue an import permit specifying the import requirements;
- May elect to send a plant pathologist to the exporting country to inspect the conditions of the planting materials for export and supervise treatments and packing of the planting materials;
- Inspect the consignment on arrivals to ensure they are free of pests and other regulated items;
- Transport the consignment to PEQ facilities in enclosed vehicles;
- Treat planting materials with surface sterilant and fungicides;
- Ensure that the packaging materials and remainder of budwood and non viable seeds are destroyed or sterilized;
- Examine plants for signs of exotic pests and diseases.

3. Responsibilities of Importer:

- The grower will contact the NPPO of exporting country and request them to provide inspection and certification services according to the IP and provide them with the necessary information;
- Abide by all rules and regulations and recommendations of the accredited plant pathologist pertaining to importation;
- Provide details on the source of planting materials and other information required by the NPPO;
- Maintain accurate records of activities and identity and source of planting materials.

INSPECTION AND DIAGNOSTICS

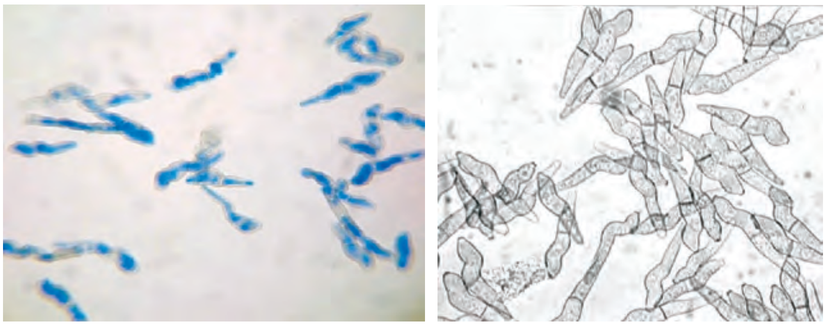
1. Inspection

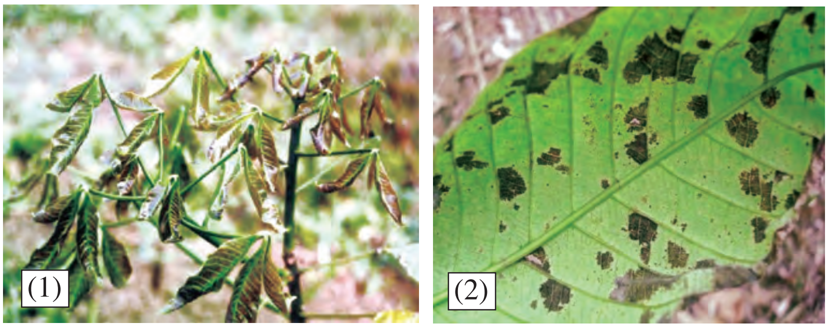
Levels of inspection

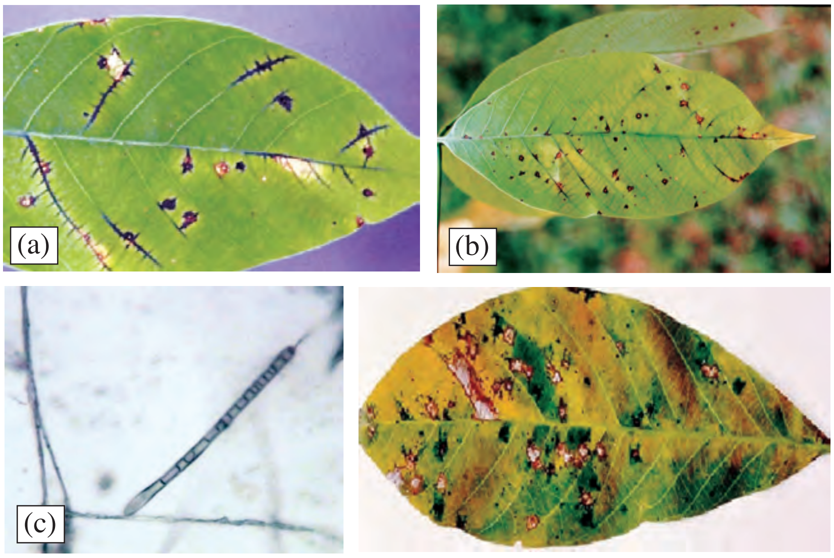
Level	Site	Activity
I	Point of entry	• Inspection of documents; • Visual inspection of imported consignment.
II	Enclosed quarantine facility	• Inspection of seedlings and budded plants for disease and pest symptoms visually or aided by hand lenses, binocular or compound microscopes
III	Open quarantine facility	• Inspection of seedlings for symptoms of diseases and pests visually or aided by hand lenses, binocular or compound microscopes
IV	Laboratory	• Identification of spores • Isolating and culturing of pathogens

Good rubber seeds are shining and reasonably heavy. Good budwood and budded stumps possess viable bud eyes i.e. they are not dead.

2. Diagnostic aids

Disease (Pathogen)	Symptoms
South American leaf blight (*Microcyclus ulei*)	 The conidia of *M. ulei*. They are septate with two cells; the distal cell is narrower than the proximal cell. Observe for the characteristic twist of the conidia.

Disease (Pathogen)	Symptoms
	 The initial signs of SALB infection are the crinkling and distortion of the young leaflets (1). Later, dark irregular shaped lesions form on the lower surface of leaflets. The lesions are covered with dark colored spores (2).
	 The perithecia appearing as dark raised bodies occur on the upper leaf surface of mature leaflets.
Colletotrichum leaf disease (*Colletotrichum gloeosporioides*)	 The necrotic leaftips of leaflets infected by *C. gloeosporioides* and brown lesions are surrounded by yellow region. The lesions are raised and can be felt when touched.
Oidium leaf disease (*Oidium heveae*)	 White powdery mycelia on upper surface of leaflet

Disease (Pathogen)	Symptoms
Corynespora leaf fall (*Corynespora cassiicola*)	 The leaf spots (a) and herring bone (b) symptoms and the stick-like spore (c). The herring bone is the characteristic symptoms of the disease. On some leaves the symptoms may appear as spots.
Phytophthora abnormal leaf fall (*Phytophthora palmivora*)	 Drops of latex on the darkened lesions on leaf petiole
Fusicoccum leaf blight (*Fusicoccum* sp.)	 Large lesions with concentric rings
Bird's eye spot (*Drechslera heveae*)	 Spots with white centres surrounded by brown region

Appendix 6

ISOLATING AND CULTURING *MICROCYCLUS ULEI*

1. Isolation method

Cultures of *M. ulei* can be obtained by transferring fresh conidia from disease lesions onto growth medium (Chee, 1978; Junqueira *et al*., 1984). The spores should be obtained from young leaves with fresh disease lesions. Contamination is more common if the conidia are obtained from old lesions or from leaves which are harvested on a rainy day. The conidia can be transferred onto the isolation medium in several ways:

(i) Carefully touching the top surface of the lesion with moist tip of an isolating needle and gently placing the conidia onto the surface of the isolation medium agar slants contained in test tubes (Junqueira *et al*., 1984).

(ii) A small piece (2 × 2 mm) of the isolation agar medium is cut and placed on the tip of the isolating needle. The agar block is then gently touched to the top surface of the lesion and transferred onto the surface of the isolation medium (Medeiros, 1973).

(iii) The leaf sections bearing fresh lesions are gently tapped to dislodge the conidia onto the surface of the isolation medium or water agar in Petri plates. With the aid of a stereo microscope, the spores are located and a small piece of agar with the conidia is cut with the aid of a biscuit cutter isolation needle, and transferred onto the surface of the isolation medium. This method is most suitable when fungal culture from a single spore is required. Chee (1978) stated that a good method to isolate *M. ulei* is to deposit fresh conidia on plain water agar and then transfer the spores to potato sucrose medium.

(iv) The culture can also be established from isolation of the ascospores. Leaf section bearing fresh perithecia were stuck to the inner surface of the Petri dish cover. The perithecia are moistened by spraying cold water and the cover is replaced on top of Petri plate containing the isolation medium. The ascospores released onto the medium are identified under a compound microscope and transferred onto the isolation medium using a biscuit cutter isolation needle. Single ascospore culture is obtained using this technique.

(v) The fungus can also be isolated by plating fresh infected leaf tissues on growth medium. Sections of young leaves with fresh lesions are cut into small pieces and surface sterilised in either sodium hypochlorite or mercuric chloride solutions. Holliday (1970) was more successful in isolating the fungus by plating leaf tissues which are cut across the disease lesions than plating leaf sections cut around a disease lesion.

2. Growth Medium

Various media had been used to isolate *M. ulei*. The most commonly used media are water agar, potato dextrose agar and potato sucrose agar. If water agar is used, the culture has to be transferred to richer medium once its growth is visible, usually after three weeks. The main problem usually encountered during the isolation process is the presence of microbial contamination. Bacterial contamination of the culture can be reduced by adding antibiotics e.g. chloroamphenicol at 50 mg/l.

The better medium for culturing *M. ulei* was potato sucrose medium containing 2.5 or 5 percent sucrose. A modified potato sucrose medium amended with multivitamins and minerals was indicated to improve growth of the fungus. The growth of *M. ulei* on artificial medium is very slow. Normally the fungal stroma is visible only after two weeks attaining a diameter of about 2 mm and reaching a diameter of two centimetres in one month.

Sporulation in culture is induced by incubation under alternating light and dark period. Sporulation is also increased by adding vitamins and green coconut water in the medium. For long storage, sporulating colonies of the fungus grown on agar slants in test tubes are submerged in sterile mineral oil, however rejuvenation of these cultures are often very slow. For short term, *M. ulei* can be stored in a medium containing egg yolk. The conidia can also be preserved on infected leaves for several months in dry condition. Some of the conidia remained viable for a few months on leaves stored in a dessicator either at room temperature or in a refrigerator.

FUNGICIDES EFFECTIVE AGAINST *M. ULEI*

Common name
Triadimefon
Benomyl
Thiophanate Methyl
Mancozeb
Chlorothalonil
Fenarimol
Propiconazole
Triforine
Triadimenol

Appendix 8

DISEASE SURVEYS AND ERADICATION PROCEDURES

1. Detection Survey

- The survey will be conducted to determine if the disease is present for the first time;
- Areas – The areas to be surveyed include rubber estates, smallholdings and nurseries especially those exposed to planting materials imported from SALB endemic countries;
- Coverage – Any rubber holdings within 3 km of entry points and PEQ stations;
- Sampling procedure – All trees in the nursery to be inspected. For mature rubber, one sampling point for every 5 ha;
- Frequency – Monthly for nurseries and fortnightly for mature rubber during the annual leaf change refoliation period.
- Farmer based detection survey – Owners or operators of rubber holdings and nurseries shall be supplied with information on SALB. They will be requested to inform the Survey and Monitoring Officer in the event SALB is suspected.

2. Delimiting survey

A delimiting survey shall be implemented immediately after detection of SALB to determine the extent of infection. The survey should cover 3 km radius from the boundaries of the infested area.

3. Eradication and Quarantine Treatment

The responsibility of the NPPO shall include:

- Inform the stakeholders and higher authorities on the outbreak;
- Carry out a feasibility study on disease eradication;
- Establish and undertake an eradication programme;
- Eradicating infected trees and fallen leaves by felling and burning the trees and spraying of fungicides effective against *M. ulei*.
- If a decision is made that eradication is not feasible, then the disease shall be contained
- Quarantine the affected area by restricting human and vehicle movement within and out of the affected area.
- Verify effectiveness of eradication or disease containment.

4. Monitoring surveys

The purpose of the monitoring survey is to verify the effectiveness of the eradication procedures and to determine whether the disease has spread to new areas. The survey shall commence when the eradication procedure is conducted and shall be continued until the disease is eradicated or until a decision is made that eradication is a futile exercise.

SALB diagnostic laboratories

Development of Diagnostic Laboratories for SALB of Rubber(potential)

Country	Laboratory	Containment Level	Test that can be perform	Contact Person
China				
India	Rubber Research Institute of India, Kottayam, Kerala.	Quarantine Level 2	Cultural and Morphological Test Serological Test Molecular Test – PCR Sequencing for DNA	Dr James Jacob Director Rubber Research Institute of India Rubber Board, Kottayam, 686009 Kerala, India Tel: +914812353311 E-mail: james@rubberboard.org.in
Indonesia	Centre for Plant Quarantine Laboratory, Jakarta	Quarantine Level 3	Cultural and Morphological Test Serological Test Molecular Test – PCR Sequencing for DNA	Dr Eliza S. Rusli Deputy Director Plant Quarantine Seed Division Indonesia Agriculture Quarantine Agency Tel/Fax: 6221 781 6482 E-mail: eliza_rusli@yahoo.com
	Crop Protection Laboratory, Medan (North Sumatera)	Quarantine Level 1	Cultural and Morphological TestMolecular Test – PCR	Mr Nurnowo Paridjo Director Estate Plant Protection Ragunan, Jakarta, Indonesia Tel: (Mobile): 08128010778 Fax: 62217815684 E-mail: nurnowa_paridjo@yahoo.com
	Rubber Research Laboratory, Medan (North Sumatera)	Quarantine Level 1	Cultural and Morphological Test Serological Test Molecular Test – PCR	Dr Karyudi Centre for Rubber Research Sei Putih Galang, Deli Serdang, North Sumatera Tel: (Mobile): 08126559566 Fax: 62617980046 E-mail: karyudi@indoset.net.id

Country	Laboratory	Containment Level	Test that can be perform	Contact Person
Malaysia	PEQ Laboratory, Serdang, Selangor	Quarantine Level 2	Cultural and Morphological Test Serological Test Molecular Test – PCR	Mr Yusof Othman Deputy Director Crop Protection and Plant Quarantine Division, Tel: +603-26977180 E-mail: yusofothman@doa.gov.my
	Crop Protection and Plant Quarantine Laboratory Division, Kuala	Quarantine Level 1	Cultural and Morphological Test Serological Test Molecular Test – PCR Sequencing for DNA	
	LumpurMalaysian Rubber Board (LGM), Sungai Buloh, Selangor	Quarantine Level 1	Cultural and Morphological Test Serological Test Molecular Test – PCR Sequencing for DNA	
Philippines	Post Entry Quarantine Station, Los Banos, Laguna	Quarantine Level 3	Cultural and Morphological Test Serological Test Molecular Test – PCR	Mr Clarito M. Barron, Ph.D BPI Director E-mail: cmbarron@ymail.com
	University of the Philippines, Los Banos, Laguna	Quarantine Level 3	Cultural and Morphological Test Serological Test Molecular Test – PCR	
Sri Lanka				
Thailand	Plant Quarantine Research Group Laboratory, Plant Protection Research And Development Office, Bangkok, Thailand	Quarantine Level 2	Cultural and Morphological Test Serological Test Molecular Test – PCR	Mr Surapol Yinassawapan Director Plant Quarantine Research Group Plant Protection Research and Development Office Bangkok 10900 Thailand Tel: +662 940 6670 ext. 109 Fax: +662 579 8516

Country	Laboratory	Containment Level	Test that can be perform	Contact Person
Vietnam	Central Laboratory for Plant Quarantine, 149 Ho Dac Di, Dong Da, Hanoi, Vietnam	Quarantine Level 3	Cultural and Morphological Test Serological Test Molecular Test – PCR Sequencing for DNA	Dr Duong Minh Tu Director Tel: (84) 4 904101090 E-mail: duongminhtu60@gmail.com
	PEQ1 Laboratory, Dong Ngac, Tu Liem, Hanoi, Vietnam	Quarantine Level 2	Cultural and Morphological Test Serological Test Molecular Test – PCR	Dr Nguyen Quy Duong Deputy Director Tel: (84) 4 989589477 E-mail: kdtvsnk1@vnn.vn
	PEQ2 Laboratory, 28 Mac Dinh Chi, District 1, Ho Chi Minh City	Quarantine Level 2	Cultural and Morphological Test Serological Test Molecular Test – PCR	Dr Nguyen Huu Dat Director Tel: (84) 8 903775574 E-mail: kdtvsnk2@vnn.vn
	Rubber Research Institute Laboratory, Ho Chi Minh City	Quarantine Level 2	Cultural and Morphological Test Serological Test Molecular Test – PCR	Mr Phan Thanh Dung Deputy Director Tel: (84) 8 918320888 E-mail: ptdrriv@gmail.com

Country	Laboratory	Containment Level	Test that can be perform	Contact Person
Other Asian and Pacific Countries				
Bangladesh				
Brunei Darussalam				
Cambodia				
Lao PDR				
Myanmar				
Papua New Guinea				

Notes:

- Infectious materials cannot moved between APPPC rubber growing country
- For diagnostic purposes, DNA of *M. ulei* should be extracted in the country of detection and this can be moved to other country which have the facility
- For identification and confirmation of pathogen, the extracted DNA may be sent to laboratories in non rubber growing countries or country endemic to SALB such as CAB International Laboratory or laboratory in a country such as Brazil.
- APPPC should write to NPPO of Brazil seeking their agreement to provide SALB identification services
- Rubber growing countries of APPPC should have close collaboration in the event of an incursion as a formal agreement (to be initiated by APPPC)
- It was noted that minor producing countries of APPPC may need assistance in developing the capacity to manage incursion of SALB especially in the area of diagnostic, surveillance and incursion response
- General awareness workshop should be conducted by APPPC inviting all rubber growing countries with their statistic
- All laboratory handling infectious SALB materials should be at least at quarantine level 2 and preferably at quarantine level 3

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