

PEST RISK ANALYSIS
FOR
SOUTH AMERICAN LEAF BLIGHT (SALB)
OF RUBBER (*HEVEA*)

July 2007

CONTENTS

	Page
EXECUTIVE SUMMARY	13
1.0 INTRODUCTION	16
1.1 Background	17
1.2 Compliance with international rights and obligations	17
1.3 The PRA area	18
1.4 Previous risk assessments	19
2.0 INITIATION	19
2.1 Initiation event	19
2.2 Conclusion of initiation	21
3.0 PEST RISK ANALYSIS	21
3.1 Pest categorization	21
3.1.1 Pest identity, taxonomy, host and plant parts affected	22
3.1.2 Biology and epidemiology	22
3.1.3 International distribution of SALB	28
3.1.4 Presence or absence of SALB in the PRA area	28
3.1.5 Current regulatory status	29
3.1.6 Entry potential	30
3.1.7 Potential for establishment and spread	30
3.1.8 Potential for economic consequences	31
3.1.9 Conclusion of pest categorization	32
3.2 Assessment of the probability of introduction and spread	32
3.2.1 Probability of entry	32
3.2.1.1 Probability of being associated with host pathways	32
3.2.1.2 Probability of being associated with non-host pathways	33
3.2.1.3 Probability of surviving during transportation	34
3.2.1.4 Probability of surviving existing management procedures	34
3.2.1.5 Probability of transfer to a suitable host	35
3.2.1.6 Conclusions of the assessment of the probability of entry	36
3.2.2 Probability of establishment	36
3.2.2.1 Availability, quantity and distribution of host in the PRA areas	37
3.2.2.2 Environmental suitability in the PRA areas	37
3.2.2.3 Potential adaptation of the pathogen	37
3.2.2.4 Reproductive strategy of the pathogen	37
3.2.2.5 Method of survival of the pathogen	37
3.2.2.6 Effectiveness of existing control programmes	37
3.2.2.7 Conclusion of the assessment of the probability of establishment	37
3.2.3 Probability of spread after establishment	38
3.2.3.1 Suitability of the natural environment	38
3.2.3.2 Presence of natural barriers	38
3.2.3.3 Potential of dispersal with commodities or conveyances	38
3.2.3.4 Intended use of the commodity	38
3.2.3.5 Potential of natural enemies	39

3.2.3.6	Conclusion of the assessment of the probability of spread	38
3.3	Assessment of economic consequences	39
3.3.1	Direct effects of SALB	39
3.3.2	Indirect effects of SALB	41
3.3.3	Conclusion of the assessment of economic consequences	41
3.4	Endangered areas	41
3.5	Conclusions of the risk assessment	42
4.0	RISK MANAGEMENT	42
4.1	Management options for viable host material	43
4.1.1	Plants for planting	43
4.1.1.1	Budded stumps or budwood	43
4.1.1.2	Plants <i>in-vitro</i>	45
4.1.2	Seeds, flowers and fruit	45
4.2	Management options for non-viable host material	45
4.2.1	Cargo pathway	46
4.2.2	Passenger pathway	46
4.3	Residual risk after management	46
5.0	REFERENCES	47
Annex 1	Article IV of the APPPC	50
Annex 2	Appendix B or APPPC: Measures to exclude South American Leaf Blight of <i>Hevea</i> from the region	51
Annex 3	Identified information gaps and additional areas of research	53
Annex 4	Current regulatory status for SALB in seven rubber producing countries within the PRA area	54

EXECUTIVE SUMMARY

Introduction

This pest risk analysis (PRA) was prepared by rubber (*Hevea brasiliensis*) growing member countries of the Asia Pacific Plant Protection Commission (APPPC); namely Thailand, Indonesia, Malaysia, India, China, Vietnam and Sri Lanka. The PRA is expected to provide the scientific justification for standards that will be developed by the APPPC and member countries to manage the trade-related phytosanitary risks of South American leaf blight (SALB). Associated standards on diagnostics, surveillance, import regulation, control and eradication would provide guidelines to further assist countries efforts to safeguard against the incursion of SALB into the PRA area.

Summary of the risk assessment

Vector	Probability of Entry	Probability of Establishment	Probability of Spread	Likely Impact	Level of Risk
Host material (<i>Hevea</i> species)					
Budded stumps or budwood	High	High	High	High	High
Foliage (stem and leaf material not for planting)	Low	High	High	High	Moderate
Flowers, fruit and seeds	Low	High	High	High	Low
Plants <i>in-vitro</i>	Negligible	N/A	N/A	N/A	Negligible
Non-host material					
Inanimate goods or non-host organic material	Negligible	N/A	N/A	N/A	Negligible
Inanimate goods or non-host organic material contaminated by host plant material	Low (if < 1cm ²)	High	High	High	Low (if < 1cm ²)

Summary of recommended risk management options

Viable or non-viable SALB host material (susceptible *Hevea* species) can either be imported from areas considered free of SALB or meet the following phytosanitary requirements:

Budded stumps or budwood

a. Pre-export inspection and treatment

- Mother plants should be inspected by suitably qualified plant pathologist for signs of SALB infection and deemed to be free of SALB infection. Inspections should take place immediately before the harvesting of budded stumps or budwood and during a period considered optimal for disease expression;
- Harvesting of budded stumps and budwood should only occur when the bark has been hardened (brown in colour) and during the low-disease season (e.g. dry weather). Budded stumps and budwood should be no longer than 1 metre when exported;
- Budded stumps and budwood should be packaged for export in a manner that limits the likelihood of infestation during transport.
- Budded stumps and budwood should be dipped in an appropriate surface sterilant and a systemic fungicide effective against *M. ulei*;
- Budded stumps should have their roots washed of any attached soil;

b. Measures on arrival (in an appropriately secure facility)

- Budded stumps and budwood should be dipped in an appropriate surface sterilant and a systemic fungicide effective against *M. ulei*;
- All packaging material should be destroyed or appropriately sterilised, and the budded stumps and budwood repackaged after treatment.

c. Post entry quarantine

- Imported budded stumps and budwood should be grown in a suitable post entry quarantine facility for at least one year or after new foliage has been produced at least six times;
- Plants should be inspected for signs of SALB daily by suitable trained facility staff and fortnightly by suitably qualified plant pathologists;
- Should any signs of SALB be detected, plants showing signs should be destroyed and all other *Hevea* plants within the facility should be treated with suitable fungicide (treatment may require six or more applications);
- Prior to release from the facility all plants in the facility should be inspected by a suitable qualified plant pathologist for signs of SALB infection;
- Plants may be released from the post entry quarantine facility only after having all plants in the facility have been free from any signs of SALB for at least one year or after new foliage has been produced at least six times.

d. Intermediate quarantine

Intermediate quarantine offers a further option to mitigate risk. This system can have some logistical, maintenance and financial problems when used for rubber, but it may operate successfully in some specific circumstances.

Plants *in vitro*

Plants *in vitro* should be held in culture and free of any type of contamination for at least three months prior to being released into the PRA area.

Seeds, flowers and fruit

Flowers and fruits should be washed with a surface sterilant such as 200 ppm of sodium hypochlorite (Chee 2006). Only healthy seeds should be selected for export, washed with water and soaked in formalin (5%) for 15 minutes, and then air dried and dressed with thiophanate methyl, benomyl or mancozeb (Chee 1978; Santos and Pereira 1986).

Foliage

Normally, foliage of rubber plants is prohibited and hence not imported.

Non-viable host material on the cargo pathway

Cargo from SALB infested countries or areas should be screened for goods or shipments that are likely to contain or be contaminated by non-viable host material. A profile list should be established that identifies cargo most at risk of containing non-viable host material.

Cargo such as used machinery (cars, logging equipment, chainsaws, cutters etc) that may have been used in rubber plantations should be thoroughly steam cleaned of all organic material larger than 1 cm², and dismantled if there are parts that can not be easily cleaned. Household effects should be inspected for gardening equipment that may be contaminated by organic material.

Any organic material that is thought to be from a susceptible *Hevea* species, is larger than 1 cm², and can not be removed from the goods or can not be destroyed (e.g. herbarium material), should be heat treated for a minimum of 30 continuous minutes at 56°C or greater. Measures may include cleaning, disinfection or destruction.

Non-viable host material on the passenger pathway

Passengers and accompanied luggage arriving within 21 days from areas not known to be free of SALB should be inspected for both viable and non-viable host material. Special care should be taken with such items as camping equipment and hiking boots, farm equipment, and decorative plant material as these are more likely to contain or be contaminated by non-viable host material greater than 1 cm².

Residual risk after measures

While the measures above, if strictly and effectively enforced, should be expected to manage the phytosanitary risks posed by SALB to the PRA area, it should still be considered possible that slippage (undetected risk items) may result in the establishment of SALB in the region. Efforts should be made to manage this residual risk by establishing an effective monitoring system that would be expected to detect an establishment event early enough to allow for an effective eradication programme to be completed.

PEST RISK ANALYSIS FOR SOUTH AMERICAN LEAF BLIGHT (SALB) OF *HEVEA* RUBBER

1.0 INTRODUCTION

This pest risk analysis (PRA) was prepared by rubber (*Hevea brasiliensis*) growing member countries of the Asia Pacific Plant Protection Commission (APPPC); namely Thailand, Indonesia, Malaysia, India, China, Vietnam and Sri Lanka. This PRA was prepared in response to the proposed deletion of Article IV and Appendix B (see Annex 2) on transitional measures for South American leaf blight (SALB) of rubber caused by *Microcyclus ulei* within the new proposed revised text of APPPC Plant Protection Agreement for the Asia and Pacific region. The revision updates the Plant Protection Agreement and brings it into compliance with the Sanitary and Phytosanitary Agreement (SPS Agreement) and the 1997 revised text of the International Plant Protection Convention (IPPC). The APPPC member countries agreed that Article IV and Appendix B of the Agreement as currently in force dealing with SALB should be retained until a PRA on SALB had been completed and an appropriate regional standard agreed to by APPPC.

Subsequently, a Technical Cooperative Programme project (TCP) was approved by FAO in July 2001 (Project Pest Risk Analysis for SALB of rubber -TCP/RAS/0168A) to develop a PRA on SALB. The PRA is expected to provide the scientific justification for standards that will be developed by the APPPC and member countries to manage the trade-related phytosanitary risks of SALB. Associated standards on diagnostics, surveillance, import regulation, control and eradication would provide guidelines to further assist countries efforts to safeguard against the incursion of SALB into the PRA area.

The purpose of this PRA is to:

- i. examine and evaluate the risks of SALB being associated with the relevant commodities / pathways from the SALB endemic countries into the Asia and Pacific region;
- ii. evaluate risks of introduction and spread of SALB into the region;
- iii. evaluate the economic consequences that may result from the establishment of SALB in the region; and
- iv. evaluate various management options to mitigate the identified phytosanitary risks.

This PRA is prepared based on the International Standard for Phytosanitary Measures Guidelines on Pest Risk Analysis (ISPM No. 2) and Pest Risk Analysis for Quarantine Pests, including analysis of environmental risks and living modified organisms (ISPM No. 11 Rev 1).

Other resources utilized include:

- a. Literature on SALB;

- b. Consultation with scientists/experts on SALB;
- c. Asian rubber producing country regulatory agencies and plant pathologists.

Definitions used in this PRA are consistent with ISPM 5: Glossary of Phytosanitary Terms (2005) unless otherwise stated.

1.1 Background

Natural rubber is produced by *Hevea brasiliensis*, a tree native to the Amazon region of South America. In the late eighteenth century, rubber was introduced to the Far East, which is now the main rubber-producing region of the world. Currently, the major producers of natural rubber are Thailand, Indonesia, Malaysia, India, China, Vietnam and Sri Lanka. In 2005, the world's production of natural rubber amounted to 8682 million tonnes whereby 7466 million tonnes (approximately 86 percent) originated from these seven countries. In 2005, the world's consumption was over 8742 million tonnes of natural rubber.

The natural rubber industry is a very important component of the agricultural sector and economies of the Asia and Pacific rubber producing countries. The introduction of SALB which has severely damaged the rubber industry in South America (see below), is currently considered to pose a direct threat to the natural rubber industry of these countries. Regional cooperation and phytosanitary action to protect these industries may be necessary to appropriately manage any potential consequences from SALB establishment and spread.

1.2 Compliance with international rights and obligations

The SPS Agreement applies to measures designed to protect human, animal and plant life and health from pests and diseases, or a country from pests, which may directly or indirectly affect international trade. It also recognizes the right of WTO Member countries to determine the level of protection they deem appropriate and to take necessary measures to achieve that protection. Sanitary (human and animal health) and phytosanitary (plant health) measures apply to trade or movement of animal and plant based products within or between countries.

In the SPS Agreement, SPS measures are defined as any measures applied:

- to protect animal or plant health within the territory of the Member from risks arising from entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms.
- to protect human or animal life or health within the territory of Member from risks arising from additives, contaminants, toxins or disease-causing organism in foods, beverages or feedstuffs.
- to protect human or animal life or health within the territory of Member from risks arising from diseases carried by animals, plants or products thereof, or from the entry, establishment or spread of pests.
- to protect or limit other damage within the territory of the Member from the entry, establishment or spread of pests.

As SALB only directly affects plant health, the SPS measures should be developed and implemented in accordance with the principles of the IPPC (ISPM 1 2006). In the context of this risk analysis these principles include:

- **Sovereignty** - Contracting parties have sovereign authority, in accordance with applicable international agreements, to prescribe and adopt phytosanitary measures to protect plant health within their territories and to determine their appropriate level of protection for plant health.
- **Necessity** - Contracting parties may apply phytosanitary measures only where such measures are necessary to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests.
- **Minimal impact** - Contracting parties should apply phytosanitary measures with minimal impact.
- **Transparency** - Contracting parties shall make relevant information available to other contracting parties as set forth in the IPPC.
- **Non-discrimination** - Contracting parties should, in accordance with the IPPC, apply phytosanitary measures without discrimination between contracting parties if contracting parties can demonstrate that they have the same phytosanitary status and apply identical or equivalent phytosanitary measures. Contracting parties should also apply phytosanitary measures without discrimination between comparable domestic and international phytosanitary situations.
- **Technical justification** - Contracting parties shall technically justify phytosanitary measures

1.3 The PRA area

The PRA area for the purpose of this PRA is the Asia and Pacific Region which encompasses the major rubber growing countries of Thailand, Indonesia, Malaysia, India, China, Vietnam and Sri Lanka, as well as the minor rubber growing countries of Cambodia, Bangladesh, Laos, Brunei, Philippines, Myanmar, and Papua New Guinea. These areas are currently considered free from SALB. The area of rubber planted, total production, export value and the number of rubber smallholders for these rubber growing countries are shown in Table 1.

Table 1. Area of rubber planted, production, export value and number of smallholders in Asia and the Pacific Region 2003-2005.

Country	Total area planted (million ha)			Total production ('000 metric tonnes)			Export value (\$USD millions)			No. of smallholders (million)
	2003	2004	2005	2003	2004	2005	2003	2004	2005	
Thailand	2.010	2.019	2.083	2876	2984	2833	2788	3429	3715	6.0
Indonesia	3.290	3.262	4.363	1792	2066	2270	1493	2180	2582	12.10
Malaysia	1.28	1.32	1.237	985	1168	1126	4800	7880	5787	1.6
India	0.574	0.578	0.583	712	750	803	77.08	50.1	91.55	1.0
China	0.661	0.662	0.661	565	570	460	N/A	N/A	N/A	3.0
Vietnam	0.440	0.454	0.480	450	513	697	350	579	1270	0.068
Sri Lanka	0.115	0.116	0.116	92	51	104	39	51	47	0.2
Other Asia and Pacific Countries	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A: Information not available at time of publication

1.4 Previous risk assessments

Ikin and Liyanage (1999) prepared a simplified PRA for SALB of rubber for the APPPC. The analysis and recommendations developed as part of that work have been considered in the development of this PRA.

2.0 INITIATION

2.1 Initiation Event

Rubber is indigenous to South America. Many attempts to start a viable rubber industry in that region have met with failure because of the presence of SALB and the lack of a cost-effective management tools in that region. SALB spreads rapidly causing severe leaf fall and twig dieback. Chemical control that involves repeated fungicide applications to trees of great height has been found to be expensive and impractical. Breeding for disease resistance was continuously frustrated by the concurrent evolution of new physiological races of the pathogen that are capable of breaking down the resistance. No rubber clones can therefore escape infection over the long term. The rubber in Southeast Asia and the PRA area was introduced from South America and it was perhaps fortunate that SALB did not establish during this introduction period.

Foreseeing the potential risks of the disease, regulations, restrictions and prohibitions on imports from South America were introduced and imposed in the 1950's as required by Articles IV in the Pacific Plant Protection Agreement for the Asia and Pacific region. In addition, the Association of Natural Rubber Producing Countries (ANRPC) introduced the ANRPC Agreement on SALB to complement the aforementioned agreement. The International Rubber Research and Development Board (IRRDB) also carried out research and undertook measures to exclude SALB from the region.

SALB is considered to remain a constant threat to the wellbeing of the Southeast Asia rubber industries. This is because of the expansion of international trade links with Central and South American countries wishing to penetrate Asian market. Although the importation of rubber planting material for breeding purposes is considered to pose the greatest danger of disease establishment in the region, other pathways need to be examined and their potential risks determined.

The Plant Protection Agreement for the Asia and Pacific region (APPPC) was revised between 1997 and 1999 to update and align the Agreement with the International Plant Protection Convention (IPPC 1997) and the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement 1995). The agreement contains provisions referring specifically to SALB with a related appendix describing procedures for reducing the risk of introduction of SALB into the region.

The provisions of the APPPC Agreement placed stringent requirement on all contracting parties. These requirements are now seen not to be in compliance with the SPS Agreement or the 1997 revised text of the IPPC since phytosanitary measures imposed under the agreement were not technically justified. This PRA on SALB is a result of the decision to amend the APPPC Agreement.

The main priority of the 1998 – 1999 APPPC work plan was the revision of the SALB Agreement.

- A working group meeting was held on 20 -24 April 1998 to prepare the 1st draft. The working group could not reach an agreement on the deletion of Article IV and Appendix B concerning measures to exclude SALB from the region.
- A further consultation was held on 8 -12 February 1999 and agreed to the restructuring and updating of the Agreement. A compromise was reached on the issue of SALB – measures in the Appendix B would be restricted to rubber producing countries and those with contiguous borders and be recognized as transitional until the Commission had developed an appropriate regional standard.
- At 21st session of APPPC (1999), it was decided that Article IV and Appendix B of the Agreement as currently in force dealing with SALB be retained until such time as a PRA had been completed and an appropriate regional standard agreed to by the Commission. It was noted that Article XIV and the Appendix B set out in the proposed revised Agreement were in contradiction with the requirements of the SPS Agreement and as such could not accept an Agreement that was not compliant with current SPS Agreement.
- October 1999, a working group on SALB was established and focused on the development of a Technical Cooperation Project (TCP) for a PRA for SALB of rubber.
- August 2003 – at the 23rd APPPC meeting, it was decided to rephrase some parts of the TCP to ensure that the PRA is developed by a group of experts from within the region. It is expected that follow up work will be needed to produce supplementary standards to meet the needs of the rubber growing countries in the APPPC.

2.2 Conclusion of Initiation

SALB of rubber is endemic in South America and is currently considered a high risk quarantine pest in the PRA area where 90% of the world's rubber is grown.

Following the decisions at the 21st session of APPPC (1999), a PRA on SALB has been initiated to develop appropriate standards to manage the phytosanitary risks of SALB to the APPPC region.

3.0 PEST RISK ANALYSIS

Given the level of uncertainty surrounding many of the epidemiological characteristics of SALB and the causal organism, the following risk analysis has been undertaken using qualitative rather than quantitative values. Table 2 describes these qualitative values in terms of the descriptors used for estimating likelihoods and consequences in the risk assessment.

Table 2. Rating for qualitative likelihood

<i>Descriptor</i>	Likelihood description	Consequence description
High	The event would be most likely to occur	<ul style="list-style-type: none">• Impact threatens economic viability of a number of industries• A large increase in plant injury or mortality• A large decrease in production• Impacts are not reversible
Moderate	The event would be likely to occur	<ul style="list-style-type: none">• Impact threatens economic viability of an industry• A moderate increase in plant injury or mortality• A moderate decrease in production• Impacts may not be reversible
Low	The event would be less likely to occur	<ul style="list-style-type: none">• Impact does not threaten economic viability of an industry• Only a minor increase in plant injury or mortality• A minor decrease in production• Impact is reversible (if greater than listed)
Negligible	The event would be unlikely to occur	Impact not distinguishable

3.1 Pest Categorization

At the outset, it may not be clear if an identified pest requires a PRA. The categorization process examines for the target pest whether the criteria in the definition for a quarantine pest are satisfied.

3.1.1 Pest identity, taxonomy, hosts and plant parts affected

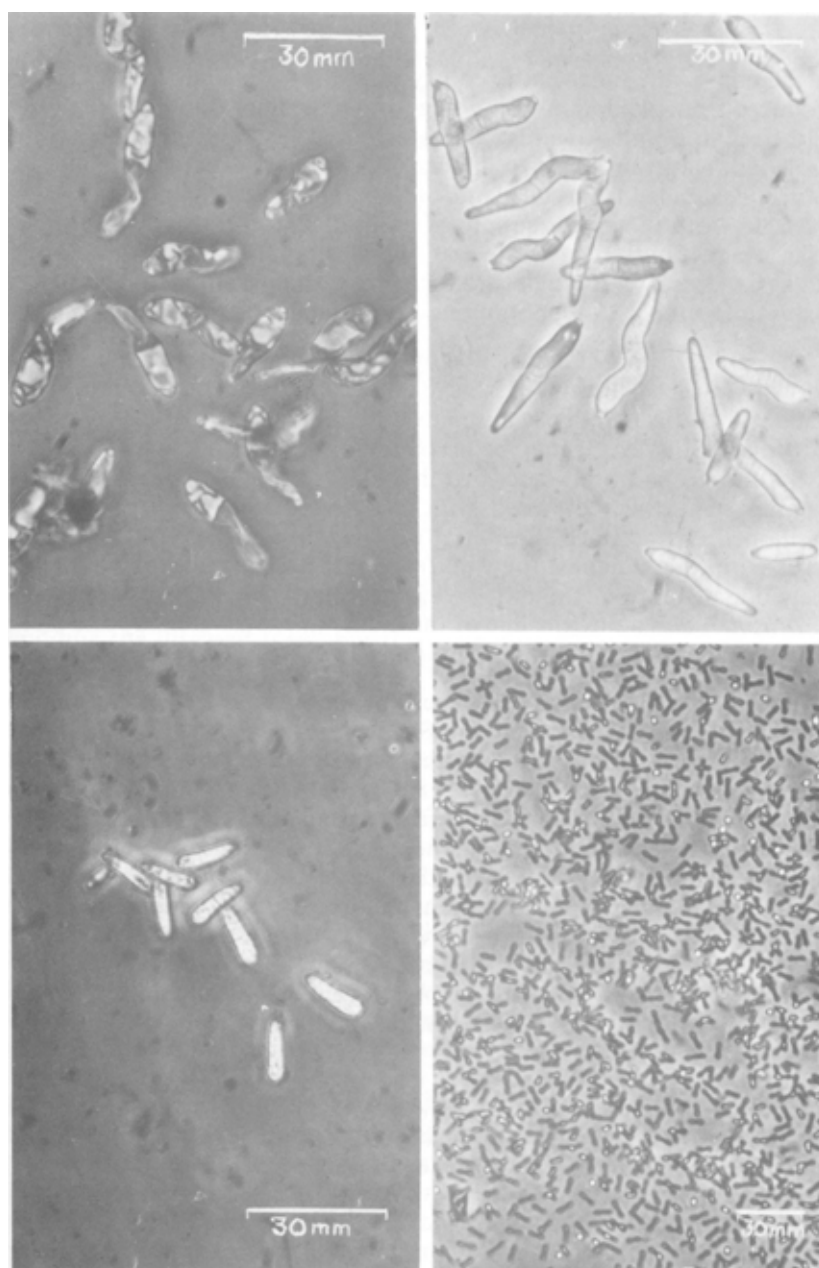
- Pathogen:** *Microcyclus ulei* (P. Henn.) v. Arx
- Order:** Ascomycetes
- Family:** Dothideales
- Synonyms:** *Dothidella ulei* (Henn. 1904)
Melanopsammopsis ulei (Henn.) Stahel 1917
Aposphaeria ulei Henn 1904
(conidial state: *Fusicladium macrosporum* Kuyper 1912)
- Common name:** South American leaf blight (SALB)
- Host species:** *Hevea brasiliensis* Muell. Arg. (Commercial species)
Hevea benthamiana Muell. Arg.
Hevea guianensis Aubl.
Hevea spruceana (Benth.) Muell. Arg.
- Part of plants affected:** Young leaves severely affected. The young tissue of petioles, stems, inflorescences and fruit pods is less affected.

3.1.2 Biology and epidemiology

Spore Production, Germination and Infection

The causal pathogen *Microcyclus ulei* is known to only infect species within the genus *Hevea*. It produces three types of spores; conidia on immature leaves; pycnosporos on newly matured leaves; and ascospores on fully matured leaves. The main propagules are conidia and ascospores (Plate 1b,d). Pycnosporos do not appear to germinate and do not therefore constitute an effective agent of disease dissemination (Plate 1c).

Plate 1. Conidia, pycnospores and ascospores (from Chee & Holliday 1986)

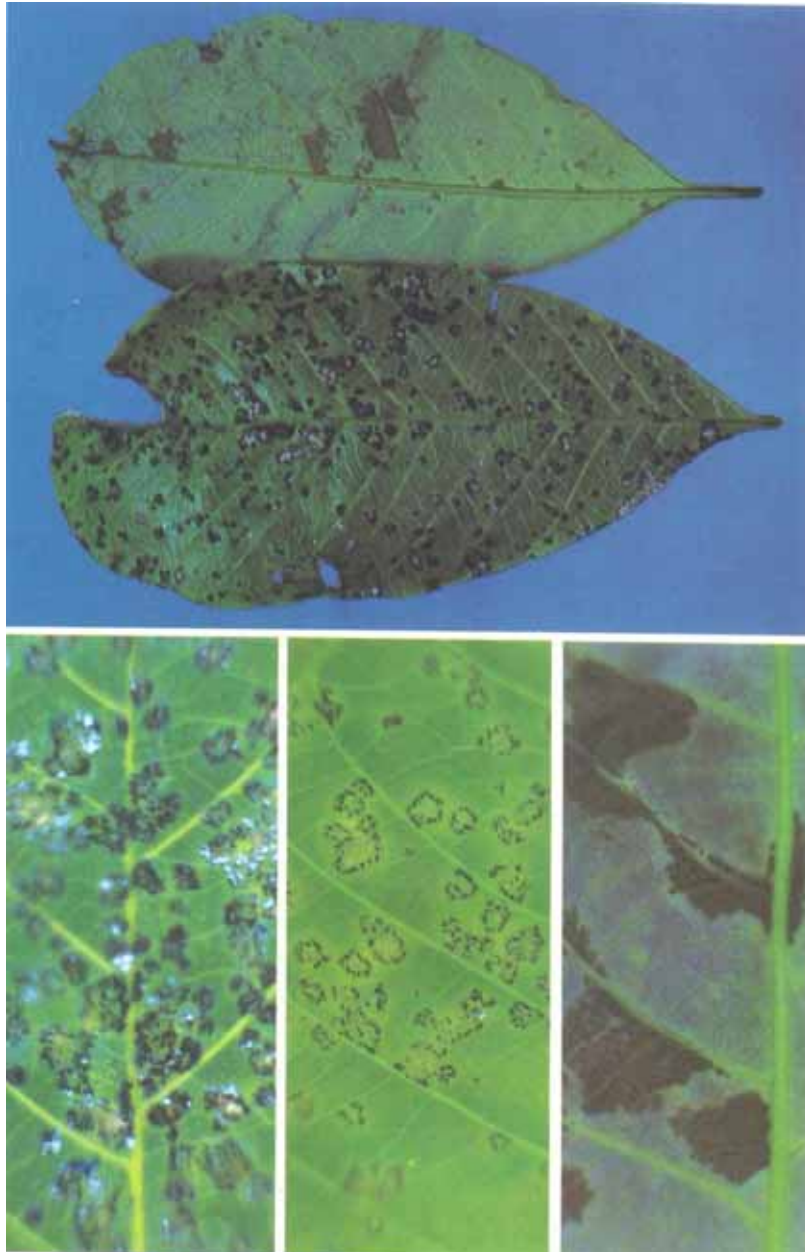


Clockwise: a) Dry, collapsed conidia; b) Turgid conidia; c) Pycnospores; d) Ascospores.

The conidia and ascospores infect the young developing leaves causing distortion followed by necrosis of the lamina (Plate 2). Affected leaves will abscise if infection is severe. Repeated defoliations and twig dieback weaken the tree and may sometimes cause its death (Plate 3) (Chee and Holiday 1986).

The primary stage of the disease on young leaves is characterized by the appearance of lesions covered by dark grey powdery masses of conidia on the abaxial leaf surface. Sporulation lasts for 2 to 3 weeks, later it becomes sparse and eventually no more conidia are produced. The conidia are disseminated by wind, vectors and water.

Plate 2. Foliar signs of SALB (from Chee & Holliday 1986)



Clockwise: a) Conidial lesions and ascostromata on leaf surfaces; b) close up of conidial lesions; c) and d) pycnidia and ascostromata on mature and old leaves respectively.

Plate 3. Plants infected with SALB

Immature rubber plant infected with SALB



Matured rubber trees infected with SALB



The ascospores play an important role in the survival of the fungus from one season to the next. The viability of detached conidia and ascospores is affected by moisture and temperature. The optimum temperature for growth, sporulation and infection is 24°C. Conidia and ascospores germinate in 3-4 hours at 24°C. The optimum temperature range for ascospore germination is 19°C to 25°C, but none germinate at 26-32°C. Water, in the form of dew or rain for about 8 hours, is considered necessary for germination, the formation of an aspersorium, infection hypha and penetration. Penetration is direct and through the leaf cuticle. Conidia begin to form within a week of infection and the perfect state mature about 8-9 weeks later. In infected rubber plantations ascospores are present throughout the year with peak concentrations occurring during the wet seasons. The wet season also marks the period of maximum production and dispersal of conidia (Chee 1976a,c).

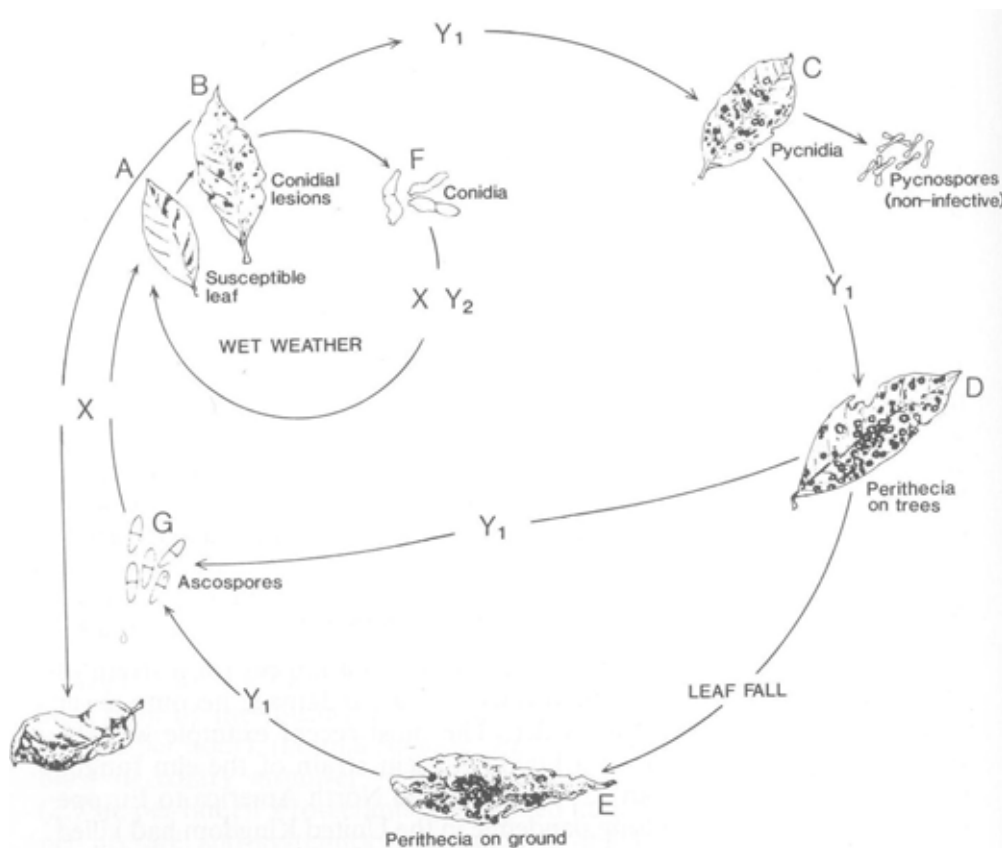
The optimum temperature for germination of conidia is about 24°C (Holliday 1970; Chee 1976a; Kajornchaiyakul *et al.* 1984; Gasparotto *et al.* 1989a). Sporulation was found by Kajornchaiyakul *et al.* (1984) to be totally inhibited at 20°C. However, some isolates of *M. ulei* are able to infect and produce spores at 16°C (Gasparotto and Junqueira 1994). These differences seem to reflect physiological differences between isolates from different ecological regions.

Dry conidia need to be wetted and require 6-8 hours of high relative humidity after deposition for infection. Gasparotto and Junqueira (1994) found that one isolate of the pathogen did not need more than 3 hours of leaf wetness for infection and other isolates could infect within 4 hours. It is assumed that the different periods of leaf wetness required for infection are related to the virulence of the isolates and the

susceptibility of the clones used. Optimum temperature for infection ranges from 19 - 25°C, but little infection occur at 26-29°C and none at 30-32°C. After inoculation high disease intensity was observed on plants incubated at 19-22°C or 23-25°C. Lesions developed best at 23-25°C. Conidial sporulation occurred at 19-28°C and was increased by high humidity especially at 23-25°C (Kajornchaiyakul *et al.* 1984). Ascospores are released in rapid succession when leaves are wetted at sub-ambient temperature (14°C). Leaves which fall during wintering discharge ascospores readily after rain (Chee 1976a,b). During wet weather secondary infections from leaf diseases such as *Collectotrichum* and *Oidium* can occur causing secondary leaf fall (Chee 1990).

Ascospores are released from dark green leaves throughout the dry season (Chee 1976c; 1980a). Under moist conditions at 24°C, perithecia on green leaves lose their viability after 12 days and after 9 days for perithecia on fallen brown leaves. In Brazil, epidemics of the disease occur when daily temperatures are under 22°C for longer than 13 hours, relative humidity is over 85% for a period of over 10 hours, and rainfall exceeds 1 mm per day the preceding 7 days (Rocha and Vasconcelos 1978).

Plate 4. Disease cycle of SALB (from Chee & Holliday 1986)



Spore survival and adaptability

The detached conidia stored at 24°C between 65-85% relative humidity remained viable after 3 weeks. The conidia still attached on leaf lesions when stored under desiccation, 9% of the conidia still germinated after 16 weeks. Fresh conidia produced under optimum conditions can survive over a week on leaves, clothes, polyethylene, artificial leather, glass, mature *Hevea* leaves, metal, paper as well as soil (Zhang *et al.* 1986). Conidia recovered from these materials were tested for viability by their ability to germinate. These recovered single conidia were transferred to leaf discs in laboratory infection tests to determine their ability to infect host material. No infection occurred (Darmono and Chee 1985; Chee pers. com. 2007).

Plant infection requirements

Junqueira *et al.* (1986) determined that the optimum inoculum concentration was 2×10^5 conidia/ml, with higher concentrations inhibiting conidial germination and reducing the diameter of lesions. Outdoor (natural) light reduced viability more quickly than reduced-light (indoor) or no-light conditions. It is expected that for successful infection, with an inoculum concentration similar to that noted above, a spore loading equivalent to that generated from perithecia on a leaf segment at least 1 cm² would be required. This in effect means that for the purposes of this risk analysis it will be assumed that leaf segments of less than 1 cm² would not lead to successful infection under normal circumstances. This technical estimation is supported by the general experience of a number of workers (Chee, pers comm.).

Population variation

Isolates of *M. ulei* grown on agar culture exhibit morphological differences and also differ in the rate of sporulation. Numerous strains have been observed. Over the years clones resistant to SALB succumbed to infection one after another and this was found to be due to evolution of new physiological races breaking down the resistance. Eight races were found initially (Chee *et al.* 1986), and four more have been added (Rivano 1997). Additionally geographical strains have been noted in Brazil (Chee pers. com. 2007)

Propagation of commercial rubber plants (Hevea brasiliensis)¹

Hevea brasiliensis, also known as the Para rubber tree after the Brazilian port of Para, is a quick growing, fairly sturdy, perennial tree of a height of 25 to 30 metres. It has a straight trunk and thick, somewhat soft, light brownish gray bark. The young plant shows characteristic growth pattern of alternating period of rapid elongation and consolidated development. The leaves are trifoliate with long stalks. Once older than about 6 years the tree is deciduous in habit and refoliation is quick with copious flowering following. Flowers are small but appear in large clusters. Fruits are three lobed, each holding three seeds, much like castor seeds in appearance but much larger in size. The seeds are oil bearing.

¹ This section has been extracted from text on the Indian Rubber Board, Ministry of Commerce and Administration, Government of India web site (<http://rubberboard.org.in>)

The rubber tree may live for a hundred or more years, however its economic life period in plantations is only around 32 years – 7 years of immature phase and 25 years of productive phase.

The main form of propagation is budding, which involves the replacement of the shoot system of a plant with that of another more desirable plant. In this process, a patch of bark of the seedling plant (stock) is replaced by a patch of bark with a dormant bud (bud patch) taken from the clone to be multiplied. The bud patch gets attached to the stock permanently and becomes a part of it. The stock is then cut off above the budded portion and the grafted bud develops into a shoot (scion) exhibiting the characters of the plant from which it was taken. The new tree thus formed is a two-part tree, comprising a root system belonging to the stock plant and a shoot system contributed by the donor of the bud.

Depending on the colour and age of the buds as well as the age of the stock plants used, three types of buddings are mainly recognized. These are brown (conventional) budding, green budding and young budding. In the first method, older buds having brown colour are used while in the other two, green tender buds are utilised. Depending on the part of the stock where budding is carried out, buddings are classified into four types: base budding, crown budding, over budding and high budding. Base budding is carried out at the base of the stock plant and includes brown budding, green budding and young budding.

After harvesting, the brown budwood is cut into pieces of one metre length for the convenience of handling. The immature top portion, which may be green or partially brown, is discarded. For longer storage and transporting, the cut ends are sealed with melted wax, each piece covered with wet sacking or equivalent, and then tied into bundles of a convenient size. By this method, viability could be retained up to three days. For storing up to 14 days and carrying over very long distances each piece is first wrapped with perforated polythene and then packed in boxes with a moist substrate.

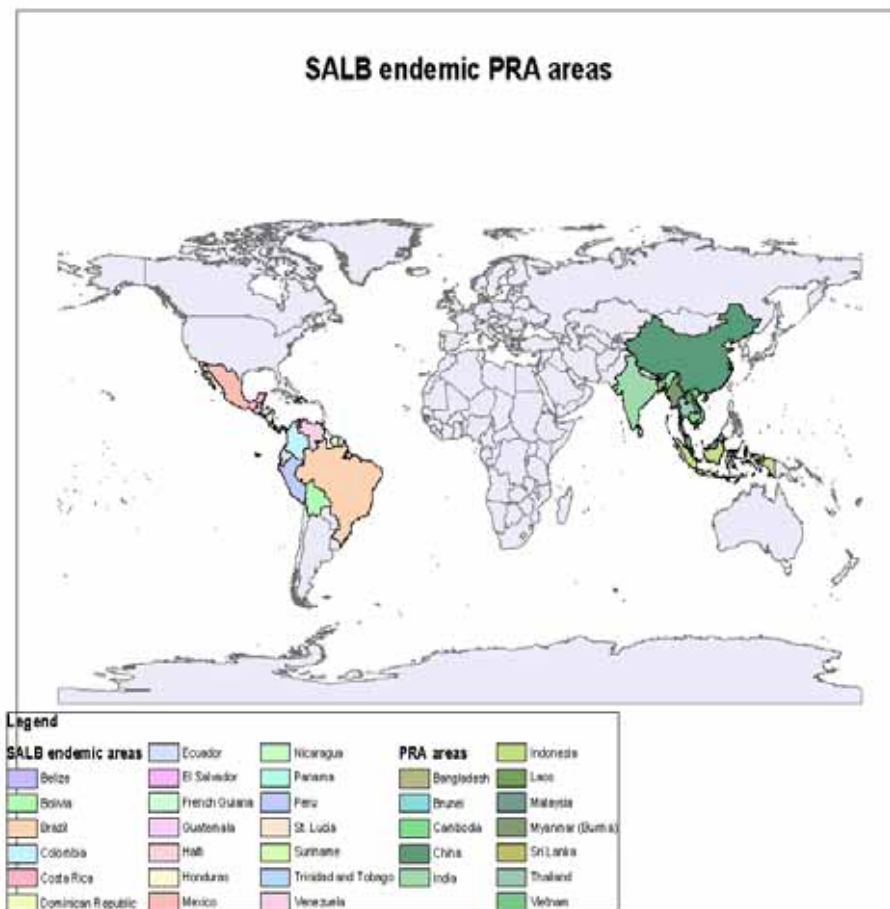
3.1.3 International distribution of SALB

SALB is present in all countries in Central and South America where rubber are present, whether cultivated or wild. In 2003 Brazil's total rubber planted area was 108,373 ha, of which Sao Paulo state had 33,477 ha, Bahia 29,314 ha and Mato Grosso 25,536 ha. The area under production was 103,586 ha; dry rubber production was 156,318 tonnes. Brazil's own production for 2003 was 94,000 tonnes; and in 2004 was 100,000 tonnes. In the second largest rubber planting state Bahia, despite ravages by SALB and low rubber yield (estate: 1000 - 1200 kg/ha/yr; smallholder: 500 - 600 kg/ha/yr), rubber cultivation is still being attempted. Commercial rubber area in the northern states is negligible. Although indigenous wild populations exist, Amazonas' 540 ha of rubber in 1995 has dwindled to 28 ha today.

3.1.4 Presence or absence of SALB in PRA area

SALB has not been recorded from any of the Asia and Pacific rubber producing countries (the PRA area). A map showing areas where SALB is endemic and the PRA area for this analysis is provided in Plate 5.

Plate 5. Map showing areas where SALB is endemic, and the PRA area



3.1.5 Current regulatory status

At present, all the Asian rubber growing countries have legislation, regulations and requirements to exclude SALB. Some countries may have more stringent measures than others due to the availability of appropriate infrastructure, facilities and resources (see Annex 4 for more details).

3.1.6 Entry potential

The pathogen *M. ulei* is specific to the plant genus *Hevea* and almost all aerial parts of the host plant, leaves, petioles, stems inflorescence and fruit pods, can be affected though they become infected only when the tissues are young. Fresh conidia produced under optimum conditions can survive for over a week on inorganic or inanimate objects such as clothes, polyethylene, artificial leather, glass, metal, paper and soil (Zhang *et al.* 1986). Pathways for the entry of *M. ulei* into the PRA area can therefore be separated into host and non-host material.

3.1.7 Potential for establishment and spread

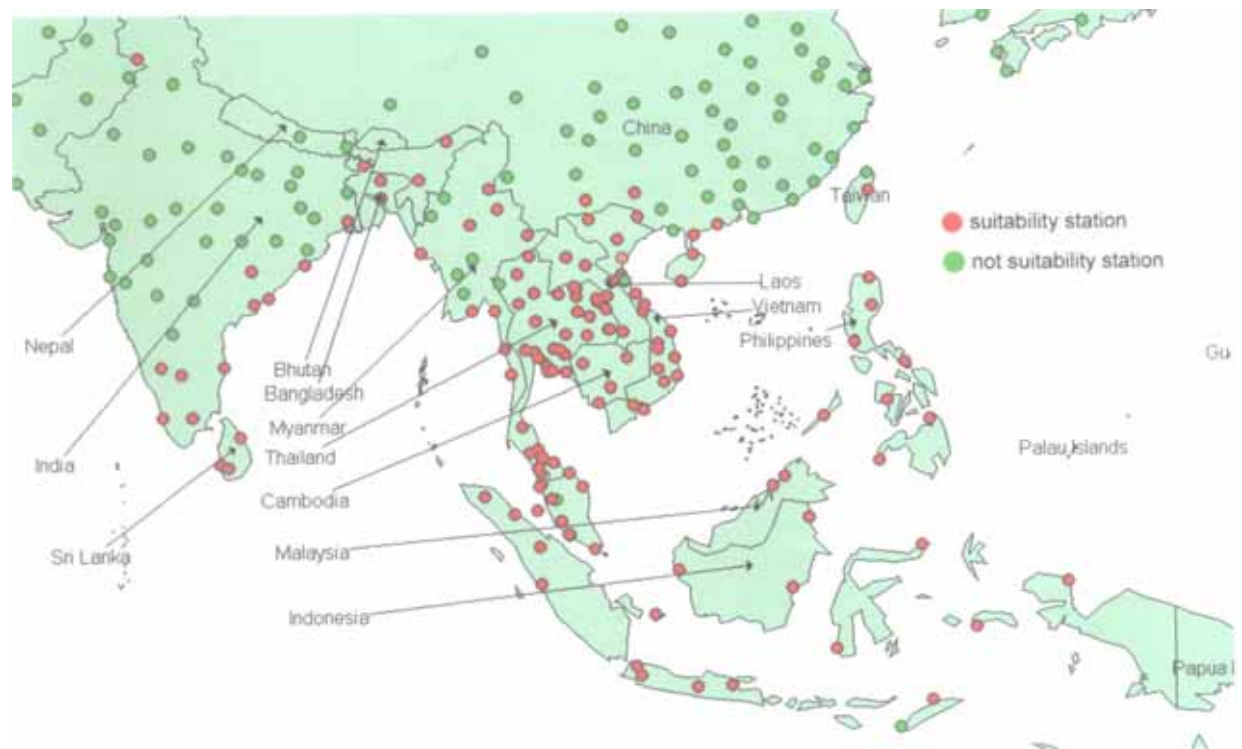
Infection and establishment of SALB requires the presence of susceptible young foliage, wet weather and suitable temperature (22°C–28°C). Depending on the local climatic conditions, after the annual wintering, rubber trees re-leaf from February to April. There are abundant rubber plantations throughout the PRA area, and host plants (*Hevea* species) can be found in urban plantings and forest areas.

In South American countries the initial spread is believed to have originated from wild rubber trees, but spread to Trinidad and Central American and to Bahia and Sao Paulo areas of Brazil was presumably through infected material when attempts were made to grow rubber in these regions. The spread of disease to Haiti is speculated to be through the spores brought over by wind and rain from Guyana or Trinidad and Tobago. Spread of the disease from Amazon basin to the surrounding areas was possibly caused by long distance dissemination by wind and rain and deposition of spores from infected plants in the field (Holliday, 1970).

Climatic conditions especially rainfall in Asian countries are similar with SALB endemic regions of the Amazon. SALB occurs in epidemic proportions in the months which have 18 days of high relative humidity (exceeding 85%) for 10 hours. The climatic condition in many parts of Asian countries is similar to SALB endemic region in Brazil (Chee 1980b). Lin (2006), using Geographic Information System (GIS) analysis to compare the climatic records of 12 rubber growing countries in the PRA area, including Thailand, Indonesia and Malaysia, with SALB endemic regions, confirmed the climatic suitability of SALB to these countries. The criteria used in the analysis were:

1. Average temperature of March, April and May (refoliation in Northern Hemisphere) is higher than 18.5°C; the average temperature of September, October and November (refoliation in Southern Hemisphere) is higher than 18.5°C.
2. Annual rainfall is higher than 760 mm.
3. There is no more than 6 consecutive months with less than 42 mm per month of rainfall.

Plate 6. Map showing climates suitable for SALB development within the PRA area (from Lin 2006)



3.1.8 Potential for economic consequences

Natural rubber is one of the most important commercial commodities in Asia, particularly Southeast Asia. Presently, the rubber areas in Asia are free from SALB. If SALB were to establish and spread in the PRA areas the potential consequences would be expected to include:-

- 1. Increased cost of production with lower productivity**
 - additional disease and weed control costs
 - shortage of raw material for rubber and rubber wood based industries
 - poor stand and wood quality when infected trees suffer dieback

- 2. Adverse financial effects**
 - reduction in country's revenue from rubber and rubber wood exports including effects on growers and rubber manufacturing sectors
 - loss of income due to unemployment of rubber smallholders
 - escalating rubber wood prices because of low supply

3.1.9 Conclusion of pest categorization

There are abundant rubber plantations throughout the PRA area. Currently SALB is absent from the PRA area. If SALB were to be introduced into the PRA area, it has the potential to establish, spread and cause unwanted consequences as the PRA area has similar climatic conditions as in the SALB affected area (Lin, 2006). SALB therefore fulfils the criteria for a quarantine pest as defined by IPPC: “A pest of potential economic importance to the area endangered thereby and not yet present there ...”, (ISPM 5 2006).

3.2 Assessment of the probability of introduction and spread

Pest introduction includes both the entry and establishment. As mentioned in section 3.1.6, commodities that can carry *M. ulei* into the PRA area can be separated into host and non-host material. For ease of analysis host material, which includes plant parts from species in the *Hevea* genus, has been classified into the following groups:

1. *Budded stumps or budwood*
2. *Foliage (including stem and leaf material but not for planting)*
3. *Flowers, fruit and seeds*
4. *Plants in-vitro*
5. *Rubber wood*

Non-host material can be classified into two main groups:

1. *Inanimate goods or non-host organic material*
2. *Inanimate goods or non-host organic material contaminated by host plant material*

3.2.1 Probability of entry

The probability of entry describes, in qualitative terms, the likelihood of an organism successfully moving from the place of origin to the PRA area. In this PRA the organism in question is *M. ulei*, the place of origin is the areas in which SALB is endemic, and the PRA area includes the rubber growing member countries of APPPC (see section 1.3).

3.2.1.1 Probability of being associated with host pathways

Budded stumps or budwood: On infected young leaves, conidia are found on the surface of necrotic lesions. On old leaves ascospores are borne within the stromata and are released following wetting and cooling. Conidia are therefore more readily dispersed from this material when infected leaves are present. SALB and therefore *M. ulei* is present in all areas of South America where host material is likely to be sourced. Infection is mainly through young leaves however once plants have SALB all aerial parts can contain the disease. There is no evidence that stems (e.g., budwood) are affected by the pathogen when they are mature brown wood, but these

may carry infections which have occurred when the stems were green. The likelihood that this material would be infected before transport to the PRA area is therefore considered **high**.

Foliage (including stem and leaf material but not for planting): At the height of an epidemic *M. ulei* affects actively growing stems and petioles causing them to curl and twist and occasionally spirally roll. The lesions become suberised and sometimes split (Holliday, 1970). SALB and therefore *M. ulei* is present in all areas of South America where host material is likely to be sourced. Therefore the likelihood that this material would be infected before transport to the PRA area is considered **high**.

Flowers, fruit and seeds: The inflorescences and flowers are infected by the pathogen. The small flowers turn black and drop. Young fruit pods up to 1 cm diameter can be destroyed by the pathogen. Larger fruit pods form swellings, 0.5-2 cm in diameter, on which the fungus fructifies (Holliday, 1970). In Bahia, Brazil, SALB coincides with *Phytophthora*, both occur during the wet season. Fruit pods are highly susceptible to *Phytophthora* thus denying SALB infection. There is no evidence that the pathogen is directly seedborne and seed transmitted (Holliday, 1970), however it is likely that conidia could contaminate seed lots in the same manner that inanimate objects could become contaminated. SALB and therefore *M. ulei* is present in all areas of South America where host material is likely to be sourced. Therefore the likelihood that this material would be infected before transport to the PRA area is considered **moderate**.

Plants in-vitro: Plant parts or callus that has been held in sterile culture for more than 3 continuous months should be considered axenic and pose a **negligible** risk of being associated of *M. ulei*. This material will therefore not be considered further in the risk assessment sections of this analysis.

Wood: Manufactured wood and logs with bark are considered unlikely to transmit the pathogen and thus constitutes a **negligible** risk.

3.2.1.2 Probability of being associated with non-host pathways

Inanimate goods or non-host organic material: Conidia from infected host plants may become associated with this type of material if it is sourced from or passes through SALB infested areas. It is unlikely that the conidia in these circumstances will remain viable given the extended period that may occur between contamination and shipment, and contamination levels are likely to be low. Therefore the likelihood that this material would be contaminated before transport to the PRA area is considered **low** (Zhang et al, 1986).

Inanimate goods or non-host organic material contaminated by host plant material: Goods that contain or become contaminated by host plant material, such as plant cutters, chainsaws, compost, footwear, or plant decorations, could be contaminated with conidia if the host plant material in question is leaf material and of a significant quantity. SALB and therefore *M. ulei* is present in all areas of South America where host material is likely to be sourced. Therefore the likelihood that these goods would be contaminated before transport to the PRA area is considered **moderate**.

3.2.1.3 Probability of surviving during transportation

For the purposes of this PRA methods of transport were categorised into three main groups:

1. *Sea cargo, passengers, and ocean going vessels*
2. *Air freight and aircraft*
3. *Air passengers and accompanied luggage*

Sea cargo, passengers, and ocean going vessels: The most significant aspects of these methods of transport are the duration of travel and the environmental conditions during travel. Transport by sea generally takes three weeks from South America and environmental conditions such as temperature and moisture would not be optimal for spore survival during this period. It is therefore considered that *M. ulei* would not survive the journey via this pathway unless it was infecting host material (Zhang *et al.*, 1986). The likelihood that *M. ulei* would survive transport via this pathway is therefore considered **negligible** unless associated with the appropriate host material. Under these exceptions the likelihood that *M. ulei* would survive transport via this pathway would be considered **high** for appropriately packaged budwood or foliage and **low** for other host material.

Air freight and aircraft: Transport by air takes three days from South America to the PRA area in Southeast Asia. In optimal environmental conditions it is likely that spores of *M. ulei* would survive the journey via this pathway. However the aircraft surfaces and freight held within aircraft holds is exposed to low temperatures at high altitudes that would significantly reduce spore viability. The survival of spores in the aircraft would be **negligible**.

Spores on the outside of an aircraft would be subject to extreme conditions. It is noted that while the spores of *M. ulei* are reported to survive at -28°C and -78°C (LebaiJuri *et al.* 1997) (a method used in preservation of the viability of many micro-organisms), conidia are killed on exposure to ultraviolet irradiation for periods 4-60 minutes or solar radiation for 3 (ascospores) to 6 hours (conidia) (Chee 1985; 2006). Survival of spores on the outside of an aircraft would be **negligible**.

Air passengers and accompanied luggage: Air passengers and accompanied luggage should be considered equivalent to air freight above. Unless spores of *M. ulei* were infecting live or fresh host material, the likelihood that they would survive transport via this pathway is **negligible**. When infected live host material is introduced to this pathway, the likelihood of survival should be considered **high** for budwood or foliage and **moderate** for other host material.

3.2.1.4 Probability of surviving existing pest management procedures

Visual inspection: Unless there are obvious signs of infection in the host material, detecting the presence of *M. ulei* would not be possible by visual examination alone. To confirm the identity of the pathogen by laboratory isolation, a special technique of

isolating *M. ulei* must be used (Holliday 1970; Junqueira *et al.* 1984). Inspections for host material above 1cm² should be considered a relatively effective measure if the material is not otherwise concealed.

No other pest management procedures were considered relevant to this analysis.

3.2.1.5 Probability of transfer to a suitable host

Rubber is widely planted in smallholdings scattered over the PRA area, and can be found in urban areas within parks and peoples dwellings.

Infected host material: Any propagable host material that is infected with *M. ulei* would be expected to act as both a vector of the disease into a region and as a host once the material has been planted into the environment. The likelihood that *M. ulei* would transfer to a suitable host would only be limited by the nature of the imported host material itself. This material has therefore been separated into the following sub-groups for analysis:

1. *Budded stumps or budwood:* This type of imported material would be expected to act as both a vector and host. The likelihood that *M. ulei* would transfer to a suitable host on budded stumps or budwood is considered **high**.
2. *Seeds:* While seeds could also act as a vector, the likelihood that the infecting agent, in this case surface spores, could survive until the seed has germinated and young leaves have developed, and subsequently infect these young leaves is considered highly unlikely. In the absence of conclusive research data demonstrating the potential or not for vector transfer in this manner, the likelihood should be considered **low** (rather than negligible).

Infected fresh non-viable host material: While this type of material could act as a vector for *M. ulei* into a region, this material will not or can not be propagated. Therefore any contaminating infection agent such as spores must find their way onto a suitable host in the PRA area. As a suitable host in this instance is the young leaf material of a susceptible *Hevea* species, and the spore load for achieving infection must be relatively high, the conceivable mechanism for successful transfer to a suitable host would be via the development of conidia (on immature leaves) or ascospores (on fully matured leaves) and the dissemination of subsequent spores. The host material must therefore be suitable for conidia or ascospore production and of a size sufficient to produce the required volume of airborne or water washed spores.

The likelihood, therefore, that small sizes (< 1cm²) of infected fresh non-viable host material could result in the transfer of *M. ulei* to a suitable host in a new region should be considered **negligible**. The likelihood that larger sizes (> 1cm²) of infected fresh non-viable host material could result in the transfer of *M. ulei* to a suitable host in a new region should be considered **low**.

3.2.1.6 Conclusions of the assessment of the probability of entry

Table 3 provides a summary of the different aspects of the entry pathway discussed in the previous sub-sections (3.2.1.1 – 3.2.1.5) and provides a final probability of entry for each category of potential vector.

Table 3. Summary of the assessment of entry

Vector	Probability of association	Probability of transit by Sea/Air	Probability of transfer to a suitable host	Conclusion of Probability of Entry
Host material (<i>Hevea</i> species)				
Budded stumps or budwood	High	High High	High	High
Foliage (stem and leaf material not for planting)	High	High High	Low (< 1cm ²)	Low (< 1cm ²)
Flowers, fruit and seeds	Moderate	Low Moderate	Low	Low
Plants <i>in-vitro</i>	Negligible	N/A N/A	N/A	Negligible
Wood	Negligible	Negligible Negligible	Negligible	Negligible
Non-host material				
Inanimate goods or non-host organic material	Low	Negligible Negligible	N/A	Negligible
Inanimate goods or non-host organic material contaminated by host plant material	Moderate	Low Moderate	Low (< 1cm ²)	Low (< 1cm ²)

3.2.2 Probability of establishment

The definition of establishment provided in ISPM 5: Glossary of Phytosanitary Terms (2005) is:

The perpetuation, for the foreseeable future, of a pest within an area after entry [ISPM 5 2006]

ISPM 11 considers the following factors should be taken into consideration when determining the probability of an organism establishing in a PRA area.

3.2.2.1 Availability, quantity and distribution of host in the PRA area

There are 8.7 million ha of rubber in the PRA area and all the clones planted are susceptible to SALB. Initial signs of SALB are similar to other rubber leaf diseases already occurring in PRA area. Therefore, early detection of the occurrence of SALB is difficult.

3.2.2.2 Environmental suitability in the PRA area

The climatic conditions in SALB endemic area are characterized by high rainfall and temperatures from 26°C to 28°C. Similar environmental conditions exist in the PRA area. Temperatures in the west of Malaysia may be slightly above the optimum for development of the disease, but the rainfall regime appears to be extremely favourable (Holliday 1969). However the north-west region of Malaysia may be sufficiently dry when the rubber trees undergo withering and therefore could escape serious disease development (Wycherley 1967).

3.2.2.3 Potential adaptation of the pathogen

Morphological, ecological and physiological strains of *M. ulei* have evolved suggesting that the pathogen is adaptable to the new environment in the PRA area.

3.2.2.4 Reproductive strategy of the pathogen

The pathogen produces abundant conidia during refoliation. If the infected leaves escape severe infection and do not fall ascospores are produced on the dark green harden leaves. Sporulation therefore follows from one spore stage to another. When conidia production is tailing off ascospores begin to produce. Ascospores are therefore present through the year but low in concentration during wintering when old leaves are shed. Infection can be due to conidia or ascospores or both depending the time of the year.

3.2.2.5 Method of survival of the pathogen

In plantations, the pathogen survives on old leaves by producing the secondary stage of stromata. The stromata are alive on the leaves that are on the trees or have fallen to the ground, and will continue to eject ascospores from the perithecia contained in the stromata.

3.2.2.6 Effectiveness of existing control programmes

Cultural practice has little value in control measures. Fungicide spraying is effective to certain extent, but the cost of chemical control is high and method of application is difficult because of uneven terrain and tree height.

3.2.2.7 Conclusion of the assessment of the probability of establishment

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.

3.2.3 Probability of spread after establishment

The definition of spread provided in ISPM 5: Glossary of Phytosanitary Terms (2005) is:

Expansion of the geographical distribution of a pest within an area [ISPM 5 2006]

ISPM 11 considers the following factors should be taken into consideration when determining the probability of an organism spreading in a PRA area.

3.2.3.1 Suitability of the natural environment

The natural environment is suitable for natural spread of the disease. Given the temperatures between 16°C - 32°C the pathogen will establish on the susceptible host and spread unabated. Little information is known on the relative humidity over the region in relation to SALB.

3.2.3.2 Presence of natural barriers

Spores of SALB are spread by wind and splashing rain. Natural barriers such as desert, arid area, mountains, ranges and seas may limit the spread to some areas over the short term, but SALB would be expected to spread to all areas over time.

3.2.3.3 Potential of dispersal with commodities or conveyances

There is currently free movement of commodities, planting materials, conveyances and people within and between countries in the PRA area. As many of these areas have relatively uncontrolled land borders, effective limitations on dispersal with commodities or conveyances are not considered possible.

3.2.3.4 Intended use of commodity

Rubber is a processed product and should not be considered a pathway for SALB. Rubber wood may act as a pathway for a short period immediately after harvesting, but natural drying and use in manufacturing would remove any viable infection.

3.2.3.5 Potential of natural enemies

There is no known natural enemy or other biological control agent for SALB. Work with *Dicyma pulvinata* does not appear to have produced successful results (Chee pers com).

3.2.3.6 Conclusion of the assessment of the probability of spread

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.

3.3 Assessment of economic consequences

SALB is known to cause severe economic losses in the agriculture system and until today it remains as the main obstacle for the viable natural rubber industry in South America. Severely affected plantations had been abandoned (Holliday 1970). Rubber cultivation in Brazil has moved from its traditional state of Bahia to Sao Paulo and Mato Grosso where refoitation occurs during the dry season escaping *M. ulei* infection. Rubber growers in Bahia are therefore denied of an income while land in Sao Paulo is escalating in price. According to Michelin Plantation in Itubera, in Bahia SALB causes, conservatively, rubber yield reduction of about 30 %.

3.3.1 Direct effects of SALB

SALB would directly affect the yield of latex and rubber wood, shortage of raw material for downstream rubber industry, loss in employment and effect on environment. The direct effects of the disease on the host were evaluated with these considerations using factors listed in Table 4.

Table 4. Direct consequences of SALB

Event	Rationale	Consequence
1. Rubber plant mortality	The pathogen causes defoliation and dieback, weakens the plants and kills the tree. All clones are susceptible. Within a few years, all standing stock within the PRA area is expected to be infected.	High Almost all rubber plants affected; 8.7 million ha.
2. Reduction in latex yield	Infected trees are bare of leaves or having poor canopy and twig dieback. It causes a reduction of rubber yield and indirectly affecting the down stream rubber industry. Estimate 30% - 50 % yield reduction in rubber production (Chee K.H, pers. com.)	High Estimated loss 4.4 million tonnes.
3. Reduction of rubber wood production	Affected trees experience retarded growth. Estimated 40% reduction in rubber wood availability. Affect manufacturing and industrial sector.	Moderate Estimated loss of 1.1 million m ³ .
4. Investment in eradication	Should SALB be detected within an isolated area early in the infection cycle, eradication may be possible. For the period of the eradication programme tree mortality due to eradication measures would exceed expected disease mortality.	Moderate Eradication exercises to be carried out of a minimum area of 1000 ha within a radius of 3km of infected trees.
5. Increases in production costs	Costs of production would increase due to increased need for disease control, weed control and stock replanting or replacement.	Moderate
6. Loss of income and employment within affected regions	Rubber industry supports millions of families, mainly smallholders.	High Loss of income for the country due to closing down-stream rubber industries/factories. Loss of income for employment in rubber industry.
7. Environmental impact	Chemical control of rubber leaf diseases is not normally practiced. In the event of SALB eradication and prophylactic treatment, large scale fungicide application will be implemented. Loss of rubber stands equivalent to deforestation with subsequent habitat degradation.	High Environmental pollution and health hazards to human and animals, soil erosion.
8. Loss in aesthetic value	Rubber trees contribute to the agro ecosystem beauty and tourism from its unique form and attraction.	Low
9. Loss in foreign exchange	Loss of revenue due to reduction in export of rubber and rubber products. Increase production costs are thus not competitive in global export market. Loss of foreign exchange in importation of pesticides.	High

3.3.2 Indirect effects of SALB

The indirect consequences of SALB would be a shift in consumer demand and domestic social dislocation. The indirect SALB effect is evaluated using factors listed in Table 5.

Table 5. Indirect consequences of SALB

Event	Rationale	Consequence
1. Loss of market opportunity (International trade)	Depressed supply of rubber and rubber wood would be expected to lead to loss of market share	High
2. Intensified research and development	Increase research and development costs for disease management	Moderate
3. Social dislocation	Urbanization and migration of rubber labour force	High
4. Decline in the standard of living of people involved in rubber industries, especially small holders	Smallholders and workers in the rubber downstream industry will be denied of decent income affecting food and education expenditure	High

3.3.3 Conclusion of the assessment of economic consequences

Both the direct and indirect SALB effects are high. Control measures for a relatively widely spread infestation would involve great costs and would not be economical sustainable. Without treatment, vast areas of rubber would eventually be lost, directly affecting the livelihood of rubber smallholders and indirectly the rubber wood furniture industry and rubber goods manufacturing sector, in particular rubber gloves and tyres. The combined economic consequences are a loss of revenue in the region of USD 10 billion a year. This would have a significant impact on the gross domestic product of the highest volume rubber-producing countries.

The economic consequences of SALB are **high** as rubber is a significant economic crop in ANRPC countries. It provides employment to many people and brings in foreign exchange earnings as a result of export of the raw material or processed products.

3.4 Endangered areas

The endangered area is where rubber is grown in the Asia and Pacific countries i.e. Thailand, Indonesia, Vietnam, Sri Lanka, Malaysia, southern part of India, tropical part of China, part of Laos, Myanmar, Bangladesh, Brunei, Cambodia, the Philippines and Papua New Guinea.

The major rubber producing countries Thailand, Indonesia and Malaysia will be the most vulnerable since rubber is found throughout the country. Other countries although rubber is scattered, but all the countries in the region are in fact in close

proximity to each other geographically and there is active inter- countries movement of trade and people in the region.

3.5 Conclusions of the risk assessment

Table 6 provides a summary of the conclusions reached in the assessments of introduction, spread and consequences completed in the previous two sections (3.2 and 3.3).

Table 6. Summary of the assessments of introduction, spread and consequences

Vector	Probability of Entry	Probability of Establishment	Probability of Spread	Likely Impact	Level of Risk
Host material (<i>Hevea</i> species)					
Budded stumps or budwood	High	High	High	High	High
Foliage (stem and leaf material not for planting)	Low	High	High	High	Moderate
Flowers, fruit and seeds	Low	High	High	High	Low
Plants <i>in-vitro</i>	Negligible	N/A	N/A	N/A	Negligible
Non-host material					
Inanimate goods or non-host organic material	Negligible	N/A	N/A	N/A	Negligible
Inanimate goods or non-host organic material contaminated by host plant material	Low (if < 1cm ²)	High	High	High	Low (if < 1cm ²)

It should be noted that foliage is normally prohibited and entry would not generally occur. The strict control and treatment of other host material such as budded stumps, budwood or flowers, fruit and seed is discussed in section 4.

4.0 RISK MANAGEMENT

The guiding principle for risk management should be to manage risk to achieve the required degree of safety that can be justified and is feasible within the limits of available options and resources. Pest risk management (in the analytical sense) is the process of identifying ways to react to a perceived risk, evaluating the efficacy of these actions, and identifying the most appropriate options (ISPM 11 2005). The effectiveness of any risk management measures depends on our perception and understanding of the disease and the risk pathways. Phytosanitary measures drawn up on the basis of science and practicality are essentially easy to implement, have minimal economic impact and are discriminating.

Based on the assessment of risks completed in the previous chapters of this risk analysis, risk commodities have been divided into the following groups.

- A. *Viable host material:*
 - 1 *Plants for planting:* Whole plants and cuttings, and plants *in-vitro*;
 - 2 *Seeds, flowers and fruit.*
- B. *Non-viable (inanimate) host material:*
 - 3 *Cargo pathway* (including sea freight, airfreight and mail);
 - 4 *Passenger pathway* (including accompanied luggage).

For goods or passengers originating from an area not known to be free of SALB, the following risk management measures may be applied.

4.1 Management options for viable host material

Viable host material includes any plant parts that are being imported into the region for the purposes of propagation or could be propagated by conventional means.

4.1.1 Plants for planting

The IPPC definition of plants for planting includes whole plants and cuttings, and plants *in-vitro* (ISPM 5 2006). For the purposes of this risk analysis only budded stumps and budwood have been considered for measures as they are the most likely form to be transported between countries for planting.

4.1.1.1 Budded stumps and budwood

Management of the phytosanitary risks associated with the import of budded stumps and budwood for propagation should start in the country of origin. Efforts should be made to ensure that, as far as is reasonable and possible, budded stumps and budwood exported to the PRA area should be free of SALB. The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Plant Protection and Quarantine (PPQ): *Postentry Quarantine Manual for State Inspectors* (2006) states that to achieve an appropriate level of assurance from plant inspections, plants should be inspected over two growing seasons. It is therefore considered appropriate that mother plants of budded stumps and budwood should undergo periods pre-export and post entry inspection for signs of SALB before being distributed in the PRA area.

In the case of SALB and the susceptible *Hevea* species, the period of greatest disease expression is at the time of new foliage growth. Therefore budded stumps and budwood should only be harvested from mother plants that have been recently inspected during a period of optimal disease expression and no signs of SALB were detected. To further lessen the likelihood of contamination, harvesting of budded stumps and budwood should only occur when the bark has been hardened (brown in

colour) and during the low-disease season (e.g. dry weather). Budded stumps and budwood should be no longer than 1 metre when exported, and the material dipped into a suitable surface sterilant followed by a suitable systemic fungicide. All packaging material should be destroyed on arrival in the PRA area.

During the post-entry quarantine inspection period plants should be maintained in an environment that both stimulates SALB expression and limits the ability of SALB to escape the facility and infect surrounding host plants. No fungicides effective against SALB should therefore be applied to plants during the inspection period (new leaf growth) as fungicides may mask disease expression. SALB containment can be achieved either through the use of high security quarantine facilities or by ensuring no host plants are within 3 km of the boundaries of the facility. To ensure any infected plants are removed from the post-entry quarantine facility as possible, plants should be inspected daily by staff trained to detect signs of SALB infection. Suitably qualified plant pathologists should also inspect the plants every two weeks to verify the daily inspections by facility staff.

If SALB is positively identified in the quarantine facility, all host plants in the facility should be treated with an appropriate fungicide, and another inspection period instigated.

Based on the aforementioned recommendations, the following measures should be applied to budded stumps and budwood before export from the SALB affected country or region, during transport to the PRA area, and on arrival in the PRA area.

Pre-export inspection and treatment

- Mother plants should be inspected by suitably qualified plant pathologist for signs of SALB infection and deemed to be free of SALB infection. Inspections should take place immediately before the harvesting of budded stumps or budwood and during a period considered optimal for disease expression;
- Harvesting of budded stumps and budwood should only occur when the bark has been hardened (brown in colour) and during the low-disease season (e.g. dry weather). Budded stumps and budwood should be no longer than 1 metre when exported;
- Budded stumps and budwood should be packaged for export in a manner that limits the likelihood of infestation during transport.
- Budded stumps and budwood should be dipped in an appropriate surface sterilant and a systemic fungicide effective against *M. ulei*;
- Budded stumps should be free from soil.

Measures on arrival (in an appropriately secure facility)

- Budded stumps and budwood should be dipped in an appropriate surface sterilant and a systemic fungicide effective against *M. ulei*;
- All packaging material should be destroyed or appropriately sterilised, and the budded stumps and budwood repackaged after treatment.

Post entry quarantine

- Imported budded stumps and budwood should be grown in a suitable post entry quarantine facility for at least one year or after new foliage has been produced at least six times;
- Plants should be inspected for signs of SALB daily by suitable trained facility staff and fortnightly by suitably qualified plant pathologists;
- Should any signs of SALB be detected, plants showing signs should be destroyed and all other *Hevea* plants within the facility should be treated with suitable fungicide (treatment may require six or more applications);
- Prior to release from the facility all plants in the facility should be inspected by a suitable qualified plant pathologist for signs of SALB infection;
- Plants may be released from the post entry quarantine facility only after having all plants in the facility have been free from any signs of SALB for at least one year or after new foliage has been produced at least six times.

Intermediate quarantine

Intermediate quarantine offers a further option to mitigate risk. This system can have some logistical, maintenance and financial problems when used for rubber, but it may operate successfully in some specific circumstances.

4.1.1.2 Plants *in vitro*

Plants *in vitro* should not be considered a risk pathway for the entry of *M. ulei* if the cultures are axenic. However, at the moment the practice is not commercially used.

4.1.2 Seeds and fruit

As the risk from seeds and fruit material relates to surface contamination only, all such products exported from SALB regions should be surface sterilised immediately prior to export.

Flowers and fruits should be washed with a surface sterilant such as 200 ppm of sodium hypochlorite (Chee 2006). Only healthy seeds should be selected for export, washed with water and soaked in formalin (5%) for 15 minutes, and then air dried and dressed with thiophanate methyl, benomyl or mancozeb (Chee 1978; Santos and Pereira 1986).

4.2 Management options for non-viable host material

Non-viable host material is essentially leaves or other parts of a host plant (susceptible *Hevea* species) that are imported either deliberately or as contaminants into the PRA area from countries or areas not known to be free of SALB. These types of host material are not able to be propagated by normal means.

4.2.1 Cargo pathway

Cargo from SALB infested countries or areas should be screened for goods or shipments that are likely to contain or be contaminated by non-viable host material. A profile list should be established that identifies cargo most at risk of containing non-viable host material.

Cargo such as used machinery (cars, logging equipment, chainsaws, cutters etc) that may have been used in rubber plantations should be thoroughly steam cleaned of all organic material larger than 1 cm², and dismantled if there are parts that can not be easily cleaned. Household effects should be inspected for gardening equipment that may be contaminated by organic material.

Any organic material that is thought to be from a susceptible *Hevea* species, is larger than 1 cm², and can not be removed from the goods or can not be destroyed (e.g. herbarium material), should be heat treated for a minimum of 30 continuous minutes at 56°C or greater.

4.2.2 Passenger pathway

Passengers and accompanied luggage arriving within 21 days from areas not known to be free of SALB should be inspected for both viable and non-viable host material. Special care should be taken with such items as camping equipment and hiking boots, farm equipment, and decorative plant material as these are more likely to contain or be contaminated by non-viable host material greater than 1 cm². Measures may include cleaning, disinfection or destruction.

4.3 Residual risk after measures

While the measures above, if strictly and effectively enforced, should be expected to manage the phytosanitary risks posed by SALB to the PRA area, it should still be considered possible that slippage (undetected risk items) may result in the establishment of SALB in the region. Efforts should be made to manage this residual risk by establishing an effective monitoring system that would be expected to detect an establishment event early enough to allow for an effective eradication programme to be completed.

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ARTICLE IV of the APPPC

Functions of the Commission

1. The function of the Commission shall include:
 - a. the determination of procedures and arrangements necessary for the implementation of the Agreement and the making of recommendations to the Contracting Governments accordingly;
 - b. the review of the state of plant protection in the region and the need for action to prevent the introduction and spread of pests;
 - c. the promotion of appropriate measures to prevent the introduction and spread of pests of plants and plant products, and to control pests, including the use of integrated pest management, as appropriate, eradication and the establishment of Pest free areas and areas of low pest prevalence and the application of phytosanitary measures in relation to genetically modified organisms;
 - d. the development and adoption of Regional Standards, including the development of pest risk analyses, and the identification of pests for common action and recognition of pest free areas and areas of low pest prevalence;
 - e. assistance in the development of International Standards to be adopted within the framework of the International Plant Protection Convention;
 - f. the review of the status of integrated pest management and the promotion of its implementation within the Region;
 - g. the harmonization of pesticide regulation;
 - h. the collection, collation and dissemination of information on plant protection in the region as decided by the Commission;
 - i. the coordination and, as appropriate, the arrangement for training of human resources;
 - j. the promotion and development of multilateral and, as appropriate, bilateral arrangements to further the objectives of this Agreement;
 - k. coordination of the work of the sub-commissions and consideration of matters of regional concern arising from that work; and
 - l. the resolution of technical issues.

APPENDIX B

MEASURES TO EXCLUDE SOUTH AMERICAN LEAF BLIGHT OF HEVEA FROM THE REGION

1. In this Appendix -
 - a. "the American tropics" means those parts of the continent of America, including adjacent islands, which are bounded by the Tropic of Capricorn (latitude 23 1/2°S) and the Tropic of Cancer (latitude 23 1/2°N) and the meridians of longitude 30°W and 120°W, and includes the part of Mexico north of the Tropic of Cancer;
 - b. "Competent Authority" means the officer or Government Department or other agency, which each Contracting Government recognizes as its authority for the purpose of this Appendix.
2. Each Contracting Government shall prohibit by law the importation into its territory or territories of any plant or plants of the genus *Hevea* from outside the Region, unless
 - a. the importation is made for scientific purpose; and
 - b. written permission has been granted for each consignment of plant or plants by the Competent Authority of the importing territory or territories and the importation is in accordance with such special conditions as may be imposed by the Competent Authority in granting such permission; and
 - c. the plant or plants have been disinfected and freed of any original soil in the country of origin in a manner acceptable to the Competent Authority of the importing territory and are free from pests and diseases, and each consignment of plant or plants is accompanied or covered by a certificate to the effect that the above requirements have been fulfilled, and signed by an appropriate authority in the country of origin; and
 - d. each consignment is addressed to and is received by the Competent Authority of the importing territory.
3. Each Contracting Government shall prohibit by law the importation into its territory or territories of any plant or plants of the genus *Hevea* capable of further growth or propagation (excluding seed) from the American tropics or from any other country in which South American leaf blight (*Dothidella ulei*) is present, unless, in addition to the requirements of paragraph 2 of this Appendix, at a place approved by the Competent Authority of the importing territory and situated outside the Region and outside the American tropics and any other country in which South American leaf blight (*Dothidella ulei*) is present, such plant or plants have been grown for an adequate period at a plant quarantine station for *Hevea* and each consignment of such plant or plants is accompanied or covered by a

certificate to the effect that the above requirements have been fulfilled, and signed by the officer-in-charge of such quarantine station.

4. Each Contracting Government shall prohibit by law the importation into its territory or territories of any seed of any plant of the genus *Hevea* from the American tropics or from any other country in which South American leaf blight (*Dothidella ulei*) is present, unless, in addition to the requirements of paragraph 2 of this Appendix, such seed, having been examined and again disinfected at a place approved by the Competent Authority of the importing territory and situated outside the Region and outside the American tropics and any other country in which South American leaf blight (*Dothidella ulei*) is present, has been repacked with new packing materials in new containers, and unless each consignment of such seed is accompanied or covered by a certificate to the effect that the above requirements have been fulfilled, and signed by the officer-in-charge of these operations.
5. Each Contracting Government shall prohibit by law the importation into its territory or territories of any plant or plants of the genus *Hevea* not capable of further growth or propagation (such as fresh or dried herbarium specimens); unless, in addition to the requirements of sub-paragraphs (a), (b) and (d) of paragraph 2 of this Appendix, the Competent Authority of the importing country is satisfied that such plant or plants are required for a legitimate special purpose and that such plant or plants have been sterilized in the country of origin by a method satisfactory to the said Competent Authority.
6. Each Contracting Government shall prohibit by law the importation into its territory or territories of any plant or plants other than the genus *Hevea*, capable of further growth or propagation and originating in the American tropics or in any other country in which South American leaf blight (*Dothidella ulei*) is present, unless written permission has been granted for each consignment of such plant or plants by the Competent Authority of the importing territory or territories and the importation is in accordance with such special conditions as may be imposed by the Competent Authority in granting such permission.
7. The Competent Authority of any territory or territories into which any plant or plants of the genus *Hevea* are imported for further growth or propagation shall ensure that such plant or plants are grown under control for such period as will ensure that such plant or plants are free from all pests and diseases before they are released.

Information Gap and Additional Areas for Research for PRA on SALB

Information Gap (Detection)	Status
Determine whether <i>M. ulei</i> is seed borne.	Available evidence and expert opinion considers that <i>M. ulei</i> is not seedborne. Research to confirm this assumption should be completed when possible.
Develop quick detection methods/procedures.	At present, there is no available method for rapid diagnosis or detection of SALB. Molecular-based techniques may be able to provide an appropriate method. This technology would require capacity building in this aspect.
Determine latent infection period of various races on various ages of leaves (susceptible and moderately susceptible leaf stages), clones and young stems.	Still requires research.
Determine the level of contamination on various related pathways.	Research partially completed

Information Gap (Survival)	Status
In carriers and containers.	Not done
In real situation studies.	Research partially completed

Information Gap (Spread)	Status
Distance of spore travel.	Distance was determined to be 3 km based on available information. Further information is necessary to provide more confidence in this assumption. This information can be obtained through the use of spore-traps.
Dispersal agents – animals.	Bees, flies and birds should be included as potential dispersal agents in future research.

Current regulatory status for SALB in seven rubber producing countries within PRA area.

Thailand

The Plant Quarantine Act (PQ Act) has been established in Thailand in 1964. With the authority of the PQ Act, the Department of Agriculture (DOA) carries on regulatory measures against the introduction of the exotic pests including SALB into Thailand. Recently, the PQ Act has been revised to widen the scope of the Act and to strengthen the phytosanitary measures and the 2nd Edition of the PQ Act came into force in 1999. There are some changes in quarantine regulations and implementation with regard to prevention of introduction of SALB into Thailand as follows.

Plant Quarantine Regulations on Importation of Plant Materials

Hevea plant materials

- Hevea species from every sources as prohibited materials
- Importation authorized by Director General of DOA under specified conditions
- Limitations of amount and for scientific purposes only
- Maximum quantity:
 - seed – 100
 - budwood- 5 meters
 - budded stump – 50 plants
 - tissue culture – 100 plants/clone
- Plants treated with effective fungicides on SALB organism
- Import consignment accompanied by Phytosanitary certificate
- Subject to intermediate quarantine station
- Import via Plant Quarantine Stations in Bangkok
- Subject to Post-Entry Quarantine Station upon arrival

Non Hevea planting material

- Subject to Post-Entry Quarantine Station upon arrival
- Require Import Permit / Phytosanitary Certificate
- Planting materials treated with fungicides

Non Hevea plant products

- Phytosanitary certificate
- Inspection at port of entry
- Passenger from SALB areas (direct flight)
- To fill in Quarantine Declaration Form

Baggage (direct flight)

- Double tagging and separate compartment
- UV irradiation
- Spray with soap solution

Indonesia

- Law No. 12 of 1992 on Crop Cultivation System (Article 19 up to 21)
- Law No. 16 of 1992 on Animal, Fisheries, Plant Quarantine
- Government Decree No. 14 of 2002 on Plant Quarantine
- Ministry of Agricultural Decree No. 38 of 2006 on List of Quarantine Pest.
- Ministry of Agricultural Decree No. 559 of 1985 on Plant Quarantine Requirements for the importation of plant propagating materials of Rubber, Cocoa, Coffee, Tea, Sugarcane, Coconut, Oil Palm, and Tobacco.
- Ministry of Agricultural Decree No. 861 of 1989 on Prevention of the Introduction into Indonesian territory of SALB of Hevea
 - a. Basically, import of propagation material and products of hevea and non-hevea from SALB endemic countries into Indonesia territory is prohibited.
 - b. The exception is made to import of above materials under the following terms and conditions
 - For research purposes which is conducted by government research institution
 - Having import permit from Minister of Agriculture and comply with other terms and condition according to prevailing law and regulation
 - Addressed to the related government research institution
 - Have been treated in its origin country
 - Have been washed or cleaned of any attached soil from its origin country
 - Accompanied by Phytosanitary Certificate explaining that all requirement stated in point d and e above have been fulfilled
 - c. In addition to the compliance to the above stipulation, import of hevea propagation material other than seeds has to comply with the following condition as well:
 - Has been grown in the intermediate quarantine installation of a non- SALB endemic country outside Asia-Pacific region and has been treated
 - Accompanied by recommendation letter from Phytopathologist from the intermediate quarantine installation stating that the above requirement has been fulfilled and the propagation material is free from SALB
 - Subject to post-entry quarantine on arrival in entry point
 - d. In addition to the compliance to above stipulation, import of hevea in the form of seeds has to comply with the following conditions:
 - Subject to treatment in the intermediate quarantine installation in a non-SALB endemic country outside Asia-Pacific region
 - All packaging material, including the containers, from origin country has to be replaced with a new one in the intermediate quarantine installation
 - Accompanied by recommendation letter from Phytopathologist from the intermediate quarantine installation stating that

- Interception of passengers and baggage
- Plant Quarantine Declaration Card
- Announcement in the flight
- Double tagging
- Passengers and Cargo Manifest
- Separate compartment / conveyer for baggage

Treatment for passengers

- Floor mat with Dettol
- Air tunnel
- X-ray machine

Treatment baggage including equipment

- Treated with soap/Dettol
- UV – light chamber

India

Plant Quarantine Order (Regulation of Import into India) Order 2003 effective with effect from 1 January 2004

Hevea planting material

- Prohibited from American continent and West Indies. For remaining countries require Import Permit, Phytosanitary Certificate, Intermediary Quarantine station and Post Entry Quarantine.
- Special permission from export and import committee of Department of Agriculture and Cooperation
- Can only be imported through/by Director of Rubber Institute, Kottayam (Kerela)

Hevea plant product

- Require Import Permit, Phytosanitary Certificate and inspection upon entry

Non-Hevea planting material

- Require Import Permit, Phytosanitary Certificate, inspection upon entry and post-entry quarantined.

Non-Hevea plant products

- Require Import Permit, Phytosanitary Certificate and inspection upon entry

Passengers from SALB area / Container

- No regulation

China

SALB is listed on the Quarantine Pest List (A1)

Hevea planting materials

- Restriction on importation from countries where SALB is known present.

Non Hevea planting materials

- Restriction on importation from the countries where SALB is known present.

Seeds or other Hevea planting materials

- Special import permit required in advance.
- Quarantine treatment required at intermediate quarantine station.

Soil

- Restriction on importation from the countries where SALB is known present.

Passengers

- Should be transited one day at the place of North American or Europe
- Plant Quarantine Declaration Cards

Cargo or posting materials

- Quarantine treatment such as ultraviolet and so on, required.

Vietnam

SALB is listed on the Quarantine Pest List (Group I)

Hevea planting materials

- Import permit required in advance from Plant Protection Department (PPD)
- Phytosanitary certificate (PC) is required
- Inspection at point entry
- Subject to Post Entry Quarantine

Hevea plant product

- PC is required
- Inspection at point of entry

Non Hevea planting materials

- Import Permit required in advance from PPD
- PC is required
- Inspection at point of entry
- Subject to Post-Entry Quarantine

Soil

- Prohibited

Passengers from SALB area/Container

- No regulation

Sri Lanka

Regulatory Position on Importation of Rubber.

- Import of rubber planting material is allowed only for scientific purposes.

- Import permit from Director General of Agriculture (DGA) is necessary.
- Permission from Rubber Controller is necessary.
- DGA will issue the permit only for the Director of The Rubber Research Institute Sri Lanka (RRISL)
- Import conditions specified.
- Soil, packing material of plant origin and planting media are not allowed.
- Phytosanitary certificate required.
- Inspection at port of entry.
- Mandatory PEQ for a considerable period.

Import from SALB Endemic Area.

- All conditions given in previous case will apply.
- Collection of the material preferably by a senior researcher of RRISL.
- Intermediate Plant Quarantine mandatory.
- Phytosanitary certificate for re-export is required.
- Inspection at port of entry.
- Packing material and packaging material should be destroyed.

Other (non Hevea) planting material from SALB endemic area for scientific studies.

- Import permit of DGA is required.
- No soil and plating media.
- Intermediate Plant Quarantine Station.
- Phytosanitary certificate (PC) and PC for re-export are required.
- Inspection at port of entry.
- Mandatory PEQ for a period less than 2 years.
- RRISL should have a contingency plan to combat the disease, in case of accidental entry.