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Improved Control of South American Leaf Blight of *Hevea* in Brazil

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Abstract: South American leaf blight (*Microcyclus ulei*) of *Hevea brasiliensis* has been the main factor limiting the economic cultivation of the crop in Brazil. Research and development aimed at mitigating the effects of the disease have concentrated on : 1) development of clones (RRIC 117, 121, 130) combining high yield and SALB resistance; 2) identification of areas suitable for cultivation but climatically unfavourable for the disease; 3) wider use of the SALB resistant *H. pauciflora* clone PA 31 on high-yielding trunks (IAN 717, FX 3899, 3810), 4) use of chemical defoliants (merphos, thidiazuron) which allow uniform refoliation and reduce the number of fungicide applications; 5) use of effective fungicides (chlorothalonil, benomyl, triadimefon) in organised large-scale aerial spraying supplemented by thermal fogging; 6) improvements in mechanization and application technology. An increase of rubber yield from 250 kg/ha in 1974 to 700 kg/ha in 1982 had been achieved in Bahia by the judicious application of fungicides.

Keywords: South American leaf blight, Hevea rubber, Brazil, control.

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INTRODUCTION

Brazil is the natural home of Para rubber (*Hevea brasiliensis* Muell Arg.), but although man attempted to domesticate it there early in this century, he had to contend with a serious plant disease—South American leaf blight (SALB) caused by *Microcyclus ulei* Arx.

About 80% of the presently cultivated rubber in Brazil is located in the south of the state of Bahia, with an annual rainfall of 1900 to 2300 mm without a distinct dry season. As a result SALB and Phytophthora leaf diseases assume epidemic proportions annually during refoliation, and severely retard the growth and productivity of the trees.

In order to rehabilitate the rubber devastated by SALB, SUDHEVEA (Superintendẽncia da Borracha of the Ministry of Industry and Commerce) in 1974 started a programme known as PROMASE (Programma Especial de Controle do MaL-DAS-Folhas de Seringueira) in which fungicides were applied to the trees at the time of the annual refoliation. Certain conditions are laid down for participation in PROMASE: trees must be tapping or coming into tapping shortly, the field must be within 10 min flying distance from where the aircraft takes off, at least 10 ha have to be sprayed, aerial spraying is supplemented with spraying from the ground of clones with irregular wintering habit, and a contribution to the cost of spraying is made (10, 20, and 40% for farms of 10–30 ha, 30-100 ha and above 100 ha respectively). Of the 6200 ha (out of 25000 ha) sprayed in 1982, 85% belonged to small growers and 15% to large estates. The cost of PROMASE is escalating each year, from Cr$ 500/ha in 1974 to Cr $155,000/ha in 1983.

In Bahia, increases in yield from 250 kg/ha in 1974 to 700 kg/ha in 1982 have been realised among the more progressive plantations. Encouraged by past results and confident in future research now undertaken by EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária of the Ministry of Agriculture), the Government-aided rubber cultivation programme PROBOR (Programma de Incentivo a Producão da Borracha Natural) is continuing. Acreage under PROBOR I (1972–1977) was 30,000 ha, PROBOR II (1978–1982) was 120,000 ha and PROBOR III (1982–1987) 250,000 ha.

This paper describes measures taken to improve the control and prevention of SALB in Brazil.

METHODS OF CONTROL

Breeding for Resistance

Breeding clones for high yield and SALB resistance has been carried out in Brazil, Malaysia and Sri Lanka. New selections were tested for SALB resistance in the Unit of The Rubber Research Institute in Trinidad (1966–1980). Promising materials from Malaysia have yet to be cloned; among those from Sri Lanka, RRIC 117, RRIC 121 and RRIC 130 represent the most high yielding resistant clones (Fernando and Liyanage, 1980). Clones RRIC 117 and RRIC 121 have as one of their parents, IAN 873 (PB 86 × FA 1717), and RRIC 130, IAN 710 (PB 86 × F 409). IAN 873, resistant to SALB in tests in Trinidad, is yielding as much as PB 86 in Malaysia, and it is recommended for small-scale planting in that country.

The fact that a very low percentage of resistant progeny is obtained from crosses, and the occurrence of physiologic races of *M. ulei* necessitates widening the genetic base with particular reference to SALB resistance. The vast resources of unexploited wild germplasm of *H. brasiliensis* and allied species (found mainly in Brazil) that can be hydridized with it are being utilized for further improvement in yield, quality of rubber and resistance to diseases, especially to SALB. The germplasm bank of *Hevea* has recently been enriched by seeds and budwood collected jointly by IRRDB (International Rubber Research and Development Board) and the Brasilian rubber authorities from the Amazon valley, primarily in Rondonia, Acre and Mato Grosso. The plants are being propagated and evaluated in Brazil, Malaysia and Ivory Coast, and later they will be used in the breeding programme of the member institutes of IRRDB. The number of seedling genotypes in Brazil is 23,000, Malaysia 14,600 and Ivory coast 3,300; in addition, each country has multiplied budwood from 155 mother trees.

New pathotypes of *Microcyclus* are responsible for hitherto resistant clones succumbing to SALB (Simmonds, 1981). Further, the high resistance detected in tests in Trinidad (Chee, 1976) is based on a hypersensitive reaction in which cells surrounding the point of entry of the fungus die, so limiting its spread. This type of resistance, so-called 'vertical resistance', is controlled by one or a few major genes, and is highly vulnerable to adaptation on the part of pathogen. Hypersensitivity, being controlled by major genes, is vulnerable to fungal specialization. Miller's work (1966) on pathotypes of *M. ulei* suggests the presence of vertical resistance and indicates that host resistance is likely to fail due to this reason. In view of this, it is better to look for horizontal or field resistance. The possibility of building up horizontal resistance by breeding has been predicted by Simmonds (1981). Thus, horizontal resistance is being sought among the vigorous, lightly-infected survivors in old American plantations known to have been subjected to regular epidemic SALB attack. An example of such a clone is TP 63 which is resistant to most of the races of *M. ulei* and is yielding over 68g/tree/tapping.

Breeding for SALB resistance goes hand in hand with studies of pathogenic strains and physiologic races of *M. ulei*. Knowledge of the variability of the fungus helps in designing breeding strategy.

Fungus Strains: Field isolates of *M. ulei* exist in at least two pathogenic and morphological forms i.e. smooth and aggregate culture types (Chee, 1978). Conidia produce colonies of three cultural types: fluffy, olivaceous and sooty (Holliday, 1970). How these three laboratory cultures relate to field pathogenicity is not known, but such variations may indicate the ability of the fungus to adapt itself to change of environmental conditions and host genotypes. This assumption is based on the appearance of a second strain of the fungus in Trinidad which differs from the existing one both in morphology and pathogenicity (Chee, 1978). The original strain (smooth) attacked oriental clones. The new strain appeared some years later in 1977, first on IAN 710, then IAN 2664, IAN 713 and IAN 2744. Other South American clones were not affected. The new strain can be readily differentiated in culture by its slower growth rate and significantly heavier sporulation, as well as from morphological differences. It does not constitute a physiologic race since it infected all the 37 clones tested. It is significant, however, that the infection it caused was in all cases more severe than that caused by the original strain (Liyanage and Chee, 1980). In Trinidad over 90% of the rubber clones are highly susceptible oriental material. The few South American clones which are resistant to the original strain may have facilitated the evolution, from the existing population, of the new more aggressive strain.

The smooth and aggregate culture types represent respectively the original and virulent strains, and they seem to have been noted also elsewhere (Langdon, 1966). Differences in severity of infection on the same clones in different areas may be associated with different strains of the pathogen, which may vary in virulence from one district to another.

Physiologic Races: South American clones were originally bred for resistance to SALB. But today, after a few decades, many of these clones are no longer resistant to the disease, although some are less severely attacked than others and as mentioned above there are differences in the severity of attack on the same clone in different localities. Physiologic races of the fungus are implicated in such situations. There is some evidence concerning the existence of 4 physiologic races of *M. ulei* (Langdon, 1965; Miller, 1966). A detailed study of the race structure carried out in our laboratory in Bahia, has demonstrated the presence of five races in our Experimental Station variously attacking different clones planted (Chee and Darmono, in press). It is significant that clones such as FX 2261, MDX 42 and MDX 96 are attacked by only one of the five races. These clones therefore do possess a broad spectrum of resistance to SALB. Strains of different virulence as those occurring in Trinidad have not been detected in Bahia.

PLANTING RECOMMENDATIONS

Planting in Disease Escape Area

The natural habitat of rubber is in the humid tropics, but it is sufficiently adaptable to have been successfully cultivated in sub-tropical São Paulo in Brazil and in southern China. It can be grown under an annual water deficit of 200 mm (Batos and Diniz, 1975), but it has also been found in locations in the Amazon where the water deficit is 300 mm (Pereira and Rodrigues, 1971). In an area in the state of Maranhão in Brazil, rubber is virtually free of SALB and the water deficit is registered at 335 mm. In São Paulo, SALB occurs only when refoliation is coinciding with heavy rainfall. But in the highlands (400–700 m) the mean temperature during refoliation is below 20 °C, the trees are free of infection. In Guarapari in the state of Espirito Santo in Brazil, the four months dry season largely enables the trees to escape infection. Disease escape also operates in areas where the leaves do not remain wet for long. Areas close to the sea or large rivers also escape serious infection because less dew is formed in wind locations.

In Brazil, using data of annual net evapotranspiration, mean temperature of the coldest month, annual water deficit, annual moisture index, Ortolani *et al.* (1982) have mapped the rubber growing regions in the country according to agro-climatic data and indicated region by region whether it is favourable or marginal for the crop and presumably whether or not SALB will be a limiting factor.

The degree of susceptibility to SALB of different clones differs from place to place, for example, clones FX 2261 and FX 3864 which are fairly resistant in Bahia are very susceptible in Belem in the state of Para. The local climatic conditions and the physiologic races of *Microcyclus* present have a profound effect on the performance of the clones. Whilst these effects are under investigation, national clonal competition trials have been established in different regions.

Crown Budding

Since breeding for horizontal resistance is a lengthy process, and vertical resistance cannot be relied upon as a permanent solution, Leong and Robinson (1982) emphasised the importance of crown budding as a more practical approach to SALB control. A crown of *H. pauciflora* is preferred to that of *H. brasiliensis*, since *H. pauciflora* is immune to *M. ulei* and is less likely to induce the development of new virulent races. Insufficient data are available concerning the crown/trunk combinations, but in general the crown depresses the yield of the trunk. However, *H. pauciflora* PA 31 and an unnumbered PX clone (also *H. pauciflora*) when crown budded on *H. brasiliensis* or *H. bethaminia* IAN 717, FX 3899, FX 3810 or GA 1518, has given a mean yield of 40 g/t/ha (Sena Gomes *et al.*, 1982). Using the technique of green budding instead of brown budding, and raising the three-part-tree in the nursery as advanced planting material may shorten its time to reach maturity.

Crown budding is being tried on a large scale in different localities in Brazil to identify crowns that are immune to SALB and at the same time combine well with the yield component of the panel clones.

DISEASE CONTROL

Artificial Defoliation

One of the parents of clones IAN 717 and FX 3899 is *H. benthaminia*, a non deciduous species, which sheds its leaves several times a year. As a result, leaves of different stage of development are present on different branches and on different trees at the same time. Fungicide protection of the young susceptible foliage becomes necessary for a major part of the year. The technique of artificial defoliation was adopted in that chemical defoliants were applied to the leaves before the natural wintering to obtain uniform defoliation so as to reduce the frequencies of protective fungicide sprays.

The technique of artificial defoliation aims at hastening refoliation while the weather is still dry so as to enable the trees to escape infection from the otherwise wet weather when natural refoliation occurs (Rao, 1972). The technique was adopted in Bahia in 1973 and 1974. Between 1980 and 1982, two defoliants Folex (merphos 2.2 kg/ha) and Dropp (thidiazuron 0.6 kg/ha) were tested by aerial application. Near complete defoliation of the old leaves resulted 2-4 weeks after spraying. In 1981, thidiazuron was applied by fogging, for this chemical has a low mammalian toxicity. It was fogged at 1.2 kg/ha to compensate for heat degradation of the product. Rapid defoliation was achieved in one estate but not in the other (Romano *et al.*, 1982). The herbicide Daconate (MSMA 43 %) was also an effective defoliant of rubber when applied at 4 *l*/ha to shorter trees, using a tractor mounted mist blower. Unfortunately, Daconate is easily washed off by rain.

Chemical Control

Although South American clones are bred for resistance to SALB, without chemical protection the trees would rapidly succumb to infection. The problem is aggravated by the fact that the rainfall in Bahia is over 2000 mm per annum, distributed over a period of nine months; thus many clones, such as IAN 717 and FX 3899, have an extended period of refoliation. As a result, chemical control is absolutely essential. At times, up to 16 rounds of fogging is necessary to protect the continuously flushing young leaves. In one plantation, the management spends US $50,000 annually to control SALB in its 300 ha of IAN 717. Many fungicides (Table 1) have been found to be effective against SALB: benomyl, triadimefon, thiophanate methyl, chlorothalonil and mancozeb (Chee, 1978; 1980; Rocha *et al.*, 1978; Gasparotto and Trindade, 1983).

Aerial spraying: The major problem faced by the control of leaf diseases of rubber is adequate coverage of the canopy by the chemical. This is because the trees are 20–30 m in height, and in South Bahia the terrain is undulating and hilly, making both aerial and especially ground-based equipment difficult to use.

Aerial spraying was first initiated in Bahia in 1971 when 150 ha in five estates were sprayed with mancozeb six times at weekly intervals. The aircraft used was a Piper 260. The results were encouraging and spraying was repeated the second year and thereafter.

Table 1. Effectiveness of fungicides recommended for SALB control

Fungicide (% A.I.)	Control in nursery	Laboratory test				
		Fungicidal Fungistatic	Vapor action	Persistency	Curative property	Antisporulation Conidia Ascospores
Chlorothalonil (0.20%)	Very good	Yes No	No	Very good	No	No No
Mancozeb (0.35%)	Good	Yes No	Yes	Good	No	No No
Benomyl (0.05%)	Good	No Yes	No	Fair	No	Yes No
Triadimefon (0.05%)	Very good	Yes No	No	Good	Some	No No
Thiophanate methyl (0.14%)	Fair	No Yes	No	Good	No	No Yes

To increase rubber production in the state of Bahia, where SALB has been most devastating, SUDHEVEA initiated in 1974, the PROMASE programme. This covered 4000 ha in 61 estates by aerial spraying, involving an organisation of considerable magnitude both at technical and financial levels. Spraying was carried out by two fixed wing aircraft, equipped with Micronair nozzles, and one helicopter mounted with horizontal bars with 32 conventional nozzles. The fungicides used were mancozeb (1,640 g/ha and benomyl (100 g/ha) applied four to six times at seven to ten days intervals. In 1975 the area sprayed was increased to 5000 ha; only benomyl was used and the six applications were made at 12 days intervals. In 1976, 5500 ha were sprayed. In 1977 however, benomyl was replaced by thiophanate methyl at 200 g/ha. The intervals of spraying remained at 12 days but the number of rounds was increased to seven. In spraying 5000 ha in 1978, three fungicides were used: mancozeb, benomyl and thiophanate methyl. The fungicides were protective as well as antisporulant: benomyl against conidia and thiophanate methyl against ascospores (Chee, 1978). Three applications of benomyl, followed by four applications of mancozeb and finally three applications of thiophanate methyl were applied at weekly intervals. In 1979, 1980 and 1981 the same three fungicides were used but their sequence was changed or the fungicides were alternated at each spraying.

The helicopter (Hughes 500 fitted with Micronair equipment) was found to be more suitable than fixed wing aircraft because of the hilly terrain. Today, only helicopters are used by both PROMASE and large growers. The helicopter flies at 5 m above the tree tops at 60 knots, covering a swath of 28 m and carrying 300 kg. The area sprayed increased to 6000 ha in 1982 and 1983, but only 2000 ha were sprayed by helicopter whilst the remaining 4000 ha were covered by fogging machines.

In 1982 the protective effect of thiophanate methyl was found to be less marked and chlorothalonil and triadimefon were introduced instead, because of the good results obtained in nursery trials in Trinidad and Brazil (Chee, 1978; Gasparotto and Trindade, 1983). The dosage used per ha in aerial spraying is: mancozeb 1280 g, benomyl 150 g, thiophanate methyl 630 g, chlorothalonil 750 g and triadimefon 75 g. The carrier is 30 *l* of water per ha. Prior to 1980, an emulsion of 3 *l* of spray oil and 17 *l* of water per ha was used (with surfactant 0.5–1 *l*) but this was not found beneficial. Undiluted spray oil is prohibitively expensive. The cost of the aircraft was 40.5% of the total cost, fungicides 35.0% and the remaining 24.5% was spent on labour and materials.

Thermal fogging: Thermal fogging for leaf disease control is gaining acceptance because of a lack of other suitable means of applying fungicides from the ground to the trees. Fogging is flexible and costs 40% less than aerial spraying. However, tractors and tractor paths have to be provided. The fogging machine can spread a dense fog to a height of 20–30 m and a distance of 80–100 m, and it can cover 15 ha per h. Fogging is done in the morning and evening when the atmosphere is calm.

Thermal fogging was first used on rubber in Brazil in 1974. Experiments in Malaysia have confirmed that fogging gives good control of *Oidium* and other leaf diseases (Lim *et al.*, 1980).

As well as a few Tifa "Tart" machines, SUDHEVEA in 1981 imported 50 Leco 120B machines from the United States. A prototype of a Brazilian fogger is currently being tested. The rate of application by fogging per hectare is: benomyl 150 g, mancozeb 1600 g, chlorothalonil 800 g and triadimefon 75 g. The fungicide is diluted with spray oil at 7 *l*/ha, although the volume of carrier may need to be increased to 10 *l*/ha in order to reduce the viscosity of certain copper fungicides (H.G. Correa, pers. comm.). Cheaper substitutes for spray oil such as a mixture of diesel fuel and palm oil or soya oil (2 *l*:5 *l*/ha) have also been used. The fungicides are not appreciably degraded by the heat of the fogger. In order to obtain a fog width of 80–100 m the flow rate of the Leco should not exceed 3 *l* per min., and the speed of the tractor should be approximately 2.5 km/h when applying 7 *l*/ha or 2 km/ha when using the larger volume of 10 *l*/ha.

To produce a fog, Correa also showed that fogging with palm oil requires a higher temperature than spray oil. The temperature of the fog as it leaves the machine should be approximately 230 °C for spray oil and 260 °C for palm oil.

Exposing agar plates at different positions in the canopy and assessing the fungicide deposit by conidial germination of *M. ulei* demonstrated that the fungicide was usually deposited only on the agar surface facing the sky. Disease development, occurs on the under surface of the leaves. There is still much to be learned about:

- Droplet size in relation to impingement and distance of spread. A larger droplet size than used at present may be desirable since the larger the droplets and the greater the speed at which they approach, the less the directional change that can occur and the greater the amount of impingement.
- Velocity and direction of wind in relation to the dynamic catch of aerosols.
- The problem of upward convection by the turbulent air, which occurs during the day when the air at the surface of the ground is warmer than the overlying levels. The aerosol, travelling downwind, may lose much of its effectiveness by rising to a height greater than that of the leaves on which it is intended to be deposited.

CONCLUSION

All the measures mentioned above, contribute towards the control of SALB. An immediate measure to reduce the adverse effect of SALB on rubber production is chemical control and in this area more information is needed on the technology of application in order that the leaves are adequately covered by the fungicide applied. Planting rubber in areas where the climatic conditions are not favourable to the development of SALB is the most attractive solution for new planting. As to the future, the three-part-tree combining high yield and disease resistance needs to be developed. Whilst breeding for high yield one would endeavour to incorporate disease resistance. No matter how difficult this is, the challenge to the natural rubber industry lies in the multiple disciplines of crop production and crop processing, and genetic improvement to the crop in my view take the first place in such challenges.

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