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INTEGRATED DISEASE CONTROL IN RUBBER PLANTATIONS IN SOUTH AMERICA

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Summary

Rubber tree cultivation in South America is threatened by a lot of pests and diseases. The most important factor retarding a succesful development of natural rubber industry in South America is rubber tree leaf blight, caused by the ascomycete Microcyclus ulei. Due to application problems, this disease cannot be controlled by chemicals. This paper reports on studies carried out to find tolerant plant material, biological control procedures and plant management systems which allow rubber tree plantation establishment with economic succes.

Introduction

Hevea brasiliensis (Willd. ex Adr. de Juss.) Muell. Arg. is the only source of natural rubber with economic importance. The plant's original habitat is tropical South America, but plantation development has prospered only outside South America, especially in the Far East. Since the onset of the 20th century various ambitious programs for the development of South American rubber plantations have been carried out, but all of them failed to be succesful (Table 1), due to a highly destructive rubber tree leaf blight (South American leaf blight, SALB) caused by the ascomycete Microcyclus ulei (P. Henn.)Arx.

Due to the biology of the rubber tree and to the high adaptive potential of its fungal pathogen up till now it has not been possible to control this disease by chemicals. 10 years ago, in order to develop a new basis for South American rubber cultivation, a German-Brazilian program of collaboration was initiated, with the aim of analizing the elements of inherent plant resistance and of elucidating of the pathogen's race structure. Based on these findings the rational "design" of adapted plant material for rubber

Table 1: Influence of rubber tree leaf blight on rubber tree cultivation in South America

Surinam	1911	40,000 trees planted
	1918	plantations destroyed, first known epidemy caused by Microcyclus ulei
Brazil	1927	3,200 ha, 200,000 trees, Fordlandia established
	1933	plantation destroyed by rubber tree leaf blight
Brazil	1936	6,478 ha, Belterra, Ford
	1943	plantation destroyed by rubber tree leaf blight
Panama	1935	Goodyear plantation established
	1941	plantation destroyed
Columbia	1941	epidemic occurrence of rubber tree leaf blight
Costa Rica	1942	epidemic occurrence of rubber tree leaf blight
Brazil	1967	Sudhevea founded, three program steps for rubber plantation development 1972 - 1975 PROBOR I 1978 - 1982 PROBOR II 1982 - 1994 PROBOR III
	1986	program stopped, 150.000 ha had been established, more than 100,000 ha suffer severely from rubber tree leaf blight
Brazil	1986	new efforts in integrated plant management, especially developed in the Brazilian National Rubber Research Center, Manaus.

plantations was carried out. In addition to this, plant management procedures have been modified to improve the nutritional base for rubber plantation culture. Besides this fungal leaf disease which is of overwhelming importance, additional pests and diseases also adversely affect rubber plantation culture in South America.

Materials and Methods

Rubber tree clones of pure Hevea brasiliensis (Euphorbiaceae) or of defined hybrids were grown under natural ambient conditions in the Brazilian rubber germplasm centre in Manaus, Amazonas, Brazil. For detailed laboratory experiments budded stumps were sent to Germany, where they were cultivated in greenhouses under 85 to 90 % relative humidity and under artificial illumination (14 hrs light : 10 hrs dark) provided by HQI lamps, 1000 µE $m^{-2}s^{-1}$ at the top of the plants.

The fungal isolates of M. ulei, those of the fungal hyperparasite Hansfordia pulvinata and of Sporothrix insectorum, a hyperparasite on Leptopharsia heveae, a parasitic fly, were cultivated on potato sucrose agar (0.5 %) pH 5.0 at 23° C with a light phase of 3 x 30 min light per day, in order to stimulate spore production (Lieberei et al. 1983).

The fungal strains of M. ulei were isolated by Junqueira et al. (1984). Production of mycorrhizal inoculum was carried out using the expanded clay technique of Dehne and Backhaus (1986). Lesion types were evaluated according to Junqueira et al. (1986) and methods of determining various biochemical leaf parameters were performed as described by Lieberei (1984).

Results

Biology of the host plant

Perennial woody crop plants pose other problems of plant management than do annual crops. According to morphological criteria rubber tree development can conveniently be divided into three stages: seedling, juvenile tree, and mature tree. With the production of the first regular trifoliate leaves the juvenile tree stage begins. The juvenile tree is characterized by the production of leaf flushes which occur in a rhythmic growth pattern, as described in detail by Hallé and Martin (1968). During this growth phase, which lasts about 7 years, the tree produces new flushes every 6 to 8 weeks, combined with extensive internodial stem elongation. Thus the tree continuously provides young susceptible leaves to a lot of pathogens throughout the whole year, during which time it rapidly grows by about 2 meters or more. After about 7 years this rhythmic growth pattern ceases and by a process of intensive ramification crown formation takes place. The mature trees are characterized by an annual leaf fall: the new leaves are produced with the onset of the rainy season and defoliation occurs 10 to 11 months later.

Tree growth and leaf fall patterns vary between different Hevea clones and are important factors in the selection of resistant and tolerant plant varieties.

Diseases and pests

A short overview on diseases and pests is given in Table 2. As already mentioned in the introduction, the most important factor retarding the economical development of rubber plantations in Brazil is "rubber tree leaf blight", therefore our main interest will be focussed on this disease.

This disease starts with the infection of young rubber tree leaves by conidiospores or ascospores of Microcyclus ulei. The spores penetrate the lower leaf surface, develop an intercellular mycelium and, within 5 to 10 days, form conidiophores on the lower leaf surface, from which a new generation of spores is liberated. These new spores represent an effective inoculum of high density in a leaf canopy. Only young leaves are susceptible, while adult leaves are totally resistant to infection by M. ulei and almost all other known fungal rubber leaf diseases. When the infection density is high, M. ulei causes defoliation. Repeated defoliation results in dieback and in death of the tree. Leaves bearing only a few infection sites, on the other hand, do not fall. On these leaves, about 2 months after primary infection, black stromata are formed in which ascospores are produced in pseudothecia. Intensive studies on the fungal race structure have been carried out in the last 5 years.

Table 2: Rubber tree diseases and pests in Brazil

Leaf diseases	
Rubber tree leaf blight	Microcyclus ulei
Target leaf spot	Thanatephorus cucumeris
Anthracnosis, Die back	Colletotrichum gloeosporioides
Abnormal leaf fall and wither	Phytophthora sp.
Black scab	Phyllachora huberi
False black scab	Rosenscheldiella sp.
Periconia blight	Periconia manihoticola
Corynespora leaf spot	Corynespora cassiicola
Rubber tree decline	presumably bacterial origin
Hevea leaf deformation	virosis, potex virus group
Stem and panel diseases	
Pink disease	Corticium salmonicolor
Black stripe	Phytophthora palmivora
Mouldy rot	Ceratocystis fimbriata
Root diseases	
Brown root disease	Phellinus noxius
White root disease	Rigidoporus lignosus
Red root disease	Ganoderma philippii
Pests	
Mandarova	Erinnyis ello
white fly	Aleurodicus sp.
mosca de renda	Leptopharsia heveae

(Chee et al. 1986, Junqueira et al. 1986).

Among the collection of 55 M. ulei isolates, established by Junqueira et al. (1986) at the National Brazilian Rubber Research Institute, two were found to cause a severe leaf deformation and leaf fall of cassava (Manihot esculenta). This should be a warning to us, as it provides evidence for a potential host range amplification of a severe infective agent, and it cannot be ruled out that M. ulei might gain the potential to infect Manihot as a second genus in the family of Euphorbiaceae.

Susceptibility of the host plant

11 Hevea species have been described. All of them originate from the tropical South American rain forest. 5 species are known to be susceptible to M. ulei: H. brasiliensis, H. benthaniana, H. spruceana, H. guianensis (Chee 1976), H. camporum (Junqueira 1988, unpublished).

Only immature, young leaves are susceptible to M. ulei. Once they have reached their mature, hardened state they reveal an almost complete, stage specific resistance to leaf infecting fungi.

Therefore, the speed of leaf maturation is an important factor in biological disease control, as will be shown later (Table 3).

Chemical control

A number of effective fungicides against the fungal pathogen are known, e.g. benomyl, triadimefon, thiophanate methyl, mancozeb, and carbendazin, all of which are useful for controlling the disease in seed orchards and in clone gardens. However, due to application problems it is impossible to control the disease using these chemicals in established plantations. Trees form closed canopies 20 to 30 m in height. The fungus infects the leaves from the lower surface and is therefore protected from direct contact with fungicides by the tightly folded leafets of the threefoliate leaves. Intensive studies of areal spraying and thermonebulization showed that these methods cannot provide any economic control, due to the density and height of the canopies. A search for new types of fungicides, which can be applied by stem feeding techniques or for new application methods is necessary if effective chemical control is to be achieved.

Other control strategies

During the past 50 years or so a number of rubber plants tolerant to leaf blight have been discovered in Brazil and used for resistance breeding, but as there were no detailed data on resistance factors, breeding was a laborious and purely empirical occupation. Inherited resistance had to be evaluated in field trials which were very time consuming and costly and the outcome of which was not very succesful.

A very promising technique applied in the last 20 years was crown budding. A scion with good resistance characteristics was budded on a trunk clone with good productivity. Especially crowns of Hevea pauciflora were used, but these, unfortunately, turned out to be highly susceptible to the fungal parasite Thanatephorus cucumeris, which is a prominent pathogen in the amazon basin; it causes target leaf spot.

Another approach aimed at reducing the life span of the susceptible leaves in Hevea plants is artificial defoliation, but the costs of this method proved to be very high and the control of leaf blight was not complete. Furthermore, the ecological drawbacks of this method have not yet been fully evaluated.

Escape areas for rubber tree cultivation which are unfavorable for pathogen growth are known, but the aim of the national Brazilian programs is to establish a rubber cultivation zone in the amazon basin, which is the natural genetic center of origin of the rubber tree - but also of rubber tree diseases.

New approaches to the control of leaf blight

Plant inherent resistance factors have been found which are now put to use in the selection of suitable plant material for new plantations:

1) Lieberei (1986, 1988) demonstrated that all Hevea trees with a high capacity for HCN liberation after tissue destruction are susceptible to M. ulei, which unlike its host is highly tolerant to this cell poison. This factor now serves as a biochemical marker for sorting out potentially susceptible plants and helps to lower the costs in breeding programs.

2) Detailed investigation of leaf maturation pattern and of lesion formation on leaves revealed an inverse relationship between the length of the maturation phase and the time from infection of a leaf to the production of new spores. The longer the leaf maturation phase, the shorter the fungal generation period and vice versa, the shorter the maturation phase, the longer the fungal generation period (Table 3). These factors have also quite recently been introduced as test components to screening trials of newly collected or newly bred plant material.

3) Biological control methods have been worked out using the hyperparasite Hausfordia pulvinata (Berk + Curt Hughes), which grows well on conidial layers as well as on stromatic layers of M. ulei. Under the high humidity conditions of the Amazon area this hyperparasite is able to colonize the leaf pathogen and to spread throughout plantations, Studies in 1986, 1987, and 1988 revealed that in clonal gardens 8 days after application of the hyperparasite about 93 % of all conidial layers of M. ulei were parasitized and up to 86 % of stromatic areas were destroyed.

4) New plant material is produced by plant biotechnological techniques, especially by polyploidization of high yielding clonally defined plants.

Other diseases and pests

In the Brazilian Rubber Research Center (Centro Nacional de Pesquisa de Seringueira e Dende),at Manaus, which was founded in 1975, many new diseases of rubber trees have been described and a number of techniques for their biological control developed. Among the new diseases described are a "false leaf crust disease" caused by Rosenscheldiella sp., a leaf virus disease, presumably caused by a

Table 3: Effect of leaf maturation in rubber trees on the development of Microcyclus ulei.

Hevea clones	susceptible leaf period (days)	fungal generation period(days)	calculated generation number
Fx 3925	16	5.0	3.2
Fx 3864	16	6.0	2.7
IAN 873	16	5.2	3.1
IAN 717	16	5.0	3.2
Fx 3899	14	6.2	2.3
Fx 985	14	6.4	2.2
IAN 6323	12	5.5	2.2
Fx 4098	12	7.2	1.7
IAN 6158	10	7.6	1.3
CNS AM 7665	10	8.0	1.3
CNS AM 7907	10	9.4	1.1

The experiments were done in two growth periods 1985/1986 and 1986/1987, using 24 inoculated leaves per clone/pathogen combination. Inoculation was carried out with 2 x 10^5 spores/ml. Incubation at 24°C under 85 to 92 % r.H. Number of pathogen generations is calculated by dividing SLP by GP.

Table 4: New factors in integrated disease and pest control in rubber plantations in Brazil.

Biological control

controlling agent	organisms controlled
Hansfordia pulvinata	Microcyclus ulei Phyllachora huberi Rosenscheldiella sp.
Cylindrosporium sp.	Phyllachora huberi Rosenscheldiella sp.
Baculovirus (extracts of infected caterpillars)	Erinnyis ello
Aschersonia sp.	Aleurodicus sp.
Sporothrix insectorum	Leptopharsia heveae

Plant breeding and plant selection

Use of cyanogenic capacity of leaves (Lieberei 1988) in screening as a marker for susceptibility to leaf blight.

Introduction of the leaf susceptible period as screening factor.

Enlargement of the germplasm center in Manaus.

Plant management

Artificial inoculation of budded rubber stumps with vesicular-arbuscular mycorrhiza selections.

Study of light stress enhanced susceptibility of young rubber plants.

potex virus, and a rubber decline, whose causal agent so far has not been identified but seems to be a bacterium.

Biological control organisms have been found and tested (Table 4).

Future activities

The present aims of research on integrated control in rubber tree cultivation are as follows:

1) Identification of factors involved in horizontal resistance, in order to help to design tolerant plant material.
2) Search for new biological control agents.
3) Combination of selective fungicides with biological control systems
4) New plant management methods, especially introduction of effective mycorrhiza. A new joint German-Brazil research project on VA-Mycorrhiza has recently begun its work(Feldmann et al. 1989).

Discussion

Rubber plantations in Brazil are threatened by a lot of pests and diseases, but the disease of overriding importance is leaf blight caused by Microcyclus ulei. Over the past 25 years and more the Brazilian efforts to install an effective rubber plantation industry have led to a new infra structure, including a national research center and a germplasm collection. The germplasm collection has been established in Manaus, situated in the central Amazon basin. This area is the original habitat of the rubber tree and, consequently, also the original habitat of all adapted pathogens and pests of this tree. This can easily been shown by looking at the list of new rubber tree diseases described in recent years. The coincidence of gene pool center and disease center surely is a dangerous situation for Brazil and for all rubber growing countries depending on fresh genetic material. Therefore, besides this center, in which research on diseases can be carried out easily, the establishment of a second germplasm collection should be considered, situated in an area of Brazil suitable for rubber tree growth but unfavorable to infective agents and pests to this culture.

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