# CHAPTER 15

# DISEASES OF ECONOMIC IMPORTANCE IN RUBBER

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The para rubber tree, Hevea brasiliensis Muell. Arg., is cultivated in many countries in the world, as a monocrop, in over six million hectares of land. Rubber makes a significant contribution to the export earnings and agricultural employment especially in countries of south and south-east Asia, where it has traditionally occupied a predominant position. The world's production of natural rubber exceeds five million tonnes and is still increasing and most of it is produced by the smallholders who are often subsistence farmers. The losses caused by diseases are a key factor affecting the productivity of their holdings and eventually the quality of their life.

The rubber tree is susceptible to several diseases but their economic importance and severity vary with the climatic conditions and the cultural practices in each country. This chapter discusses the major diseases of economic importance, which can be divided, for convenience, into four categories: leaf, stem and branch, panel and root diseases.

## LEAF DISEASES

Leaf diseases had assumed greater importance during the post-war years, owing to the extensive cultivation of clones primarily selected for high yield at the expense of resistance to diseases. There are five major leaf diseases that can cause damage of economic importance to Hevea in different countries. These are caused by Oidium heveae Steinm., Colletotrichum gloeosporioides (Penz.) Sacc., Phytophthora spp., Corynespora cassiicola (Berk. and Curt.) Wei., and Microcyclus ulei (P. Henn.) V. Arx. The diseases caused are secondary or abnormal leaf fall of immature and mature leaflets.

### *Oidium leaf fall*

General: Oidium leaf disease (OLD) caused by the fungus Oidium heveae Steinm., attacks the immature leaflets when trees refoliate after

the annual wintering, causing secondary leaf fall. It is widespread in many countries (Stoughton Harris, 1925; Beeley, 1930; Cramer, 1956; Ramakrishnan and Radhakrishna Pillai, 1962a; Kaiming, 1987), but in a few it is of minor importance (Peries, 1966a). The severity of the disease varies with the pattern of wintering (Liyanage, 1977a), leaf age (Lim and Sripathi Rao, 1976), elevation (Murray, 1929; Liyanage et al., 1971), clonal susceptibility (Peries, 1966b; Van Emden, 1954; Lim, 1973b) and weather conditions prevailing at the time of refoliation (Beeley, 1932; Fernando, 1971; Lim, 1972).

Symptoms: The copper-brown and apple green leaflets are most susceptible to the infection. Symptoms appear as white powdery patches on both leaf surfaces, especially on the lower leaf surface near the veins as the fungal hyphae grow radially to form extensive circular colonies, sometimes covering the entire leaf surface with the fungus. When the tender leaflets are affected, they shrivel and fall off, leaving the petioles on the stem for sometime. When semi-mature leaves are attacked leaflets become distorted and characteristic translucent brownish spots develop which later become necrotic and persist throughout the life of the leaflets.

A severe attack of Oidium leads to extensive defoliation, resulting in poor canopies being retained on the trees and often with loss of yield. It can also result in a serious retardation of the rate of growth and bark renewal. Repeated defoliation in areas where the disease is not controlled, particularly at high elevations leads to the depletion of food reserves in the trees resulting in dieback of twigs and branches, assisted by secondary parasites, mainly Botryodiploidia theobromae Pat.

O. heveae also affects the inflorescences causing them to wither and shed prematurely, with consequent loss in seed production.

Biology: Studies in vitro indicated that the temperature and humidity are the most important environmental factors that affect the viability, germination, sporulation and infectivity of the fungus (Lim, 1972; Peries, 1974; Liyanage et al., 1985; Chua, 1970). The optimum temperature for germination, infection and sporulation ranged from 23-25°C, while the humidity requirement exceeded 90% (Lim, 1972; Peries, 1974; Liyanage et al. 1985). Spore viability was adversely affected by temperatures exceeding 32-35°C, exposure to ultra-violet light and direct sun light for a short period and prolonged immersion in water (Chua, 1970). Spore germination and conidophone formation were significantly better in artificial light than in the dark (Chua, 1970). It was possible to evolve short-term methods of forecasting oidium leaf disease incidence using weather parameters, especially temperature and humidity (Lim, 1972; Liyanage et al. 1985).

Epidemiology: Although wintering is a physiological process (Chua, 1970), its commencement, duration and completion are largely influenced by weather conditions. It has been observed that PB 86 which is a clone susceptible to Oidium escapes the infection due to its early wintering habit. Dry weather conditions encourage early and rapid wintering and this often helps the refoliating leaves to mature rapidly and escape an attack of Oidium. Similarly, wet weather at the time of wintering delays it, causing the refoliating leaves to be exposed to weather factors conducive for disease development, resulting in a high incidence of the disease (Liyanage, 1977a).

The fungus survives from one season to the next on young leaves which emerge periodically within the canopy or on tender foliage in rubber nurseries. Although it has been suggested that Euphorbia pilulifera is an alternative host of O. heveae (Young, 1952), it is not readily transferable from one species to the other (Ramakrishnan and Radhakrishna Pillai, 1962a; Peries, 1966b).

The fungus is disseminated by means of air borne conidia. O. heveae has a typical afternoon pattern of spore release reaching a peak around 1300 h. The spore production and spread are influenced by weather conditions, especially low humidity, high temperature and high air turbulence prevalent during the period of spore liberation (Fernando, 1971; Chua, 1970; Peries, 1965a).

General field observations between weather and disease outbreaks have revealed that overcast humid and relatively cool weather with misty mornings and intermittent light rain provide ideal conditions for spread of the fungus (Peries, 1965a; Wastie and Mainstone, 1969; Liyanage, 1976). Bright sunny periods militate against the development of the fungus and have a lethal effect on detached spores (Liyanage et al. 1985; Peries, 1965a). Heavy rains, as well as leaf wetness for long periods, were inimical to the development of the fungus, as the conidia get washed off by heavy rains (Fernando, 1971) and the presence of free water kills the fungus (Liyanage et al. 1985), thus preventing the build up of inoculum.

Control: Young (1951) considered that manipulation of the time of refoliation to coincide with a period less favourable to disease development appeared to be an efficient means of indirect control of Oidium and used calcium cyanide in the initial defoliation trials. Aerial spraying has been tried out with good effect to artificially defoliate trees with 2,4,5-T (Hutchison, 1958). Subsequently, organo-arsenical dessicants were areially sprayed to advance and accelerate wintering of susceptible clones to coincide refoliation with the dry period thus favouring disease avoidance. However, several practical difficulties have made it difficult for the industry to adopt wider use of this technique of indirect control (Lim, 1982).

The application of a supplementary dose of nitrogenous fertilizer towards the end of the wintering season helped to minimise the adverse effects of repeated defoliation (Beeley, 1935; Murray, 1936), by enhancing the leaf maturity before the onset of conditions favourable for Oidium leaf disease. Thus, a judicious application of nitrogen, up to twice the currently recommended rate at the onset of refoliation, was considered as another means of disease avoidance (Lim, 1974). This method yielded additional benefits from improved bark renewal and growth as well as reduced weeding costs.

An alternative to growing resistant clones is to crown-bud a high yielding clone with a mildew resistant crown. This method was adopted especially to control oidium leaf disease of susceptible clones with the Oidium tolerant clone LCB 870 (Van Emden, 1954). However, the delay in reaching maturity of crown budded trees, their generally lower yields and changes in the properties of latex have prevented its wider use. Nonetheless, it still remains a useful technique.

Protective dusting with sulphur with portable or tractor-mounted machinery has been the standard method of economically controlling O. heveae for many years (Murray, 1921; Wastie and Mainstone, 1969). At the inception, 10-12 rounds of sulphur dusting were used at 5-7 days intervals as a blanket cover throughout the refoliation period (Murray, 1921). Later, the number of rounds was reduced to 3-4, at weekly intervals, if accurately timed, based on the pattern of refoliation and weather parameters (Lim, 1972; Liyanage et al. 1985; Peries, 1965a). Currently, with better knowledge of these factors, the routine control of the disease has been dispensed with and dusting is restricted to areas where the disease is severe (Liyanage et al. 1985). Sulphur dust has the disadvantage of being easily washed off by rain, resulting in poor control of the disease, necessitating repeated application thereby increasing the cost. To overcome these difficulties oil-based systemic fungicides, such as tridemorph, which have anti-sporulant action have been used. Further, low-volume spraying of new rain-fast fungicidal formulations with shoulder mounted mini micron sprayers provide cost effective and better control of the disease (Lim, 1982). More recently, an efficient ground based mechanised fogging has been used to dispense oil-based fungicides at an ultra low rate. Fogging leaves adequate quick-drying and rain-fast residues on leaflets giving a fairly lasting protecting against fungal infestations (Lim, 1982).

Phytophthora leaf fall

General: Abnormal leaf fall caused by Phytophthora species occurs

during periods of prolonged rain and generally originate from sporangia and zoo-spores produced on infected green rubber pods. Several species of Phytophthora have been reported as the causal organism of various diseases affecting the rubber tree. These are Phytophthora meadii Mc Rae (Mc Rae, 1918), P. palmivora (Butl.) Butl. (Tucker, 1931), P. heveae Thompson (Thompson, 1929), P. botryosa Chee (Chee, 1969), P. citrophthora (R.E. Sm., & E.H. Sm.) Leonian (Ho et al. 1984), P. nicotianae Van Breda de Haan Var. parasitica (Dast.) Waterhouse (Thomson and George, 1976), P. phaseoli Thaxter (Ho et al. 1984), P. citricola Swada (Liyanage, 1989) and P. cactorum (Leb & Cohn) Schroet (Ho et al. 1984). A species currently designated P. palmivora Morphological Form 4($MF_4$) (=P. capsici), has been identified and the presence of P. megakarya Brasier & Griffus is suspected to be present in Brazil. The causal organism is separated into different species on the basis of several diagnostic features which include colony characteristics as well as sporangial, oospore and chlamydospore production and morphology.

Symptoms: The most conspicuous symptom is seen on the leaf petiole. A greyish to black lesion develops along the petiole with white globules of coagulated latex, at the point of entry of the pathogen (Fig. 1). Petiolar infection results in leaf fall due to the formation of a premature abscission layer. At this stage the leaflets are still attached to the petiole but they

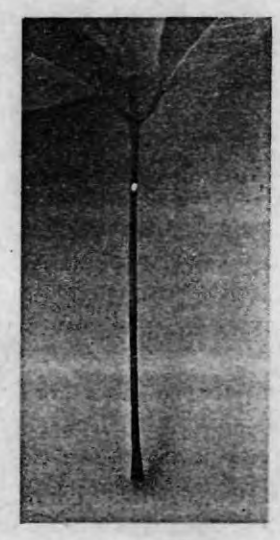

Fig. 1. Coagulation of latex on the petiole at the point of entry of Phytophthora.

often become reddish brown while some remain green. On leaflets, circular brownish water soaked lesions appear on the lamina. These lesions eventually coalesce to form large irregular areas and the leaflets are easily shed on vigorous shaking. Under favourable conditions trees of susceptible clones defoliate rapidly and they remain bare until the subsequent refoliation season. The vigour and yield of such trees are considerably reduced.

Biology: Cardinal temperatures for growth of P. meadii (Peries and Fernando, 1966; Dantanarayana et al. 1984), P. palmivora (Chee, 1969), P. botryosa (Chee, 1969), P. citrophthora (Ho et al. 1984) and P. cactorum (Ho et al. 1984) ranged between 5-35°C with an optimum between 25-28°C. The fungus sporulated freely at room temperature but germination of sporangia was favoured at temperatures slightly below room temperature. Free water is essential for the propagation of the fungus, which is rapidly killed on exposure to conditions of low humidity, direct sun light or ultra-violet radiations (Peries and Fernando, 1966).

The occurrence of both compatibility types of P. meadii, with compatibility type $A_2$ predominating, was initially reported (Satchuthananthavale, 1963). Subsequently, the existence of homothallic P. meadii was shown (Peries and Dantanarayana, 1965). Recent studies provided evidence for a shift in the P. meadii population towards a predominance of $A_1$ compatibility type (Liyanage and Wheeler, 1989; Dantanarayana et al. 1984). In P. cactorum abundant sex organs were produced readily in single cultures but none were produced in P. citrophthora and P. palmivora single cultures or by pairing among isolates of the same species or any other species. However, Chee and Turner claim to have seen homothallic isolates of P. palmivora in India and Sarwak, respectively. Rubber, cacao and atypical (non-complementary) strains of P. palmivora, and (+), (-) and non-complementary strains were recognised for P. botryosa (Chee, 1969).

Oospores and chlamydospores are important propagules for long term survival. Incubation of paired cultures of P. meadii in the dark at temperatures between 18°-22°C proved most favourable for the formation of oospores. At higher temperatures (25-35°C) the number of oogonia were considerably reduced but moderate numbers were formed at 30°C (Liyanage, 1986). P. citrocola, on the other hand was well adapted and produced oospores in abundance at 20°, 25° and 30°C both in the light and in the dark but their germination was poor (Liyanage, 1986). Production of a few oospores of P. botryosa was stimulated by light but none were induced in P. palmivora (Chee, 1969).

Higher temperatures favoured chlamydospore production of P. palmivora in deionized water and there was a fourfold increase between 17 and 32°C.

The optimum pH was about 5.8 and the optimum temperature for germination was 27°C although it germinated over a wide range of temperatures (Chee, 1973). On the otherhand, chlamydospores of P. meadii are formed abundantly in the dark and at temperatures below 20°C, even as low as 10°C (Liyanage, 1986). In P. botryosa, Chlamyolospore production was infrequent (Chee, 1969) and none were formed in P. cactorum and P. citrophthora (Ho et al. 1984).

Epidemiology: The fungus survived in mummified rubber pods and pod stalks as chlamydospores under Sri Lankan conditions (Peries, 1965b) and as oospores in infected plant parts in India (George and Edathil, 1975), respectively. With the advent of favourable weather conditions, the dormant propagules germinated to act as primary inoculum. A selective antibiotic medium was successfully used to isolate both P. palmivora and P. botryosa, from old lesions in different plant parts in Thailand but the dormant structures from which the infection occured was not identified (Tsao, 1976).

In Sri Lanka and India, inoculum of P. meadii for leaf fall was derived mainly from sporangia produced on mature green rubber pods where sporulation was most prolific (Peries, 1969; Liyanage et al. 1983). Infected pods provided inoculum for periods ranging from three to five weeks depending on the interim weather conditions after infection (Liyanage et al. 1983). The inoculum disseminate in water droplets and repeatedly inoculate other plant parts to cause infection. However, P. botryosa is more freely sporulating and has a lower requirement for free moisture for infection and is capable of causing direct petiolar infection rather than via pods (Wastie, 1973). Water is essential for both dispersal of sporangia and germination of zoospores (Peries and Fernando, 1966; Peries, 1969). Little germ tube growth occurs in the absence of free water even in a saturated atmosphere. The minimum period of surface wetness for in vitro field respectively (Peries, 1969), but for P. botryosa it was 30 min (Wastie, field respectively (Peries, 1969), but for P. botryosa was 30 min (Wastie, 1973). An attempt was made to forecast outbreaks of Phytophthora disease using the formula: if the temperature was not above 29°C, relative humidity above 80%, atleast 25 mm of rain per day, less than 3 h sunshine per day prevailing for four consecutive days when mature green pods are present, leaf fall was likely to occur within fourteen days (Peries, 1969). The work in Malaysia showed that the severity of defoliation is closely correlated with the duration of surface wetness and 100% relative humidity seven days previously. Rainfall, temperature and solar radiation do not influence defoliation directly once it has begun, but are important in determining its onset (Wastie, 1973). Later, it was shown that rainfall is the main

climatic factor governing the onset and severity of the disease.

Control: Phytophthora leaf fall is an annually recurring disease of rubber in India, causing severe yield losses ranging from 38-56% (Satchuthananthavale and Dantanarayana, 1973; Ramakrishnan, 1960; Radhakrishna Pillai, 1977). Recent experiments indicate an yield loss of 9 to 16% in susceptible clones (RRIM 600 and PB 86) of 10 to 25 years age when prophylactic spraying against the disease is skipped for one season (Jacob et al. 1989). However, in Malaysia and Sri Lanka the maximum yield reduction reported was about 8% (Tan and John, 1985; Tan et al. 1977) and 2% (Lloyd, 1963), respectively.

In India, where the disease occurs in an epiphytotic scale almost every year, spraying with 1% Bordeaux mixture as a premonsoon application has been for many years, the most effective method of control of Phytophthora leaf fall, since it was first recommended. Although it is a laborious process and uneconomical for large scale use, high volume spraying of Bordeaux mixture with rocker sprayers is still widely practised (Radhakrishna Pillai and George, 1973). Dusting copper fungicides as a prophylactic measure did not provide adequate protection, as dusts were easily washed-off by heavy rains. Further, dusting was as expensive as spraying, owing to the high cost of fungicides, offsetting the savings in labour (Ramakrishnan, 1960; Lloyd, 1963). Pre-monsoon low volume application of copper-in-oil, using mini micron sprayers from the ground or aerial application with helicopters (Fig. 2), confers complete protection

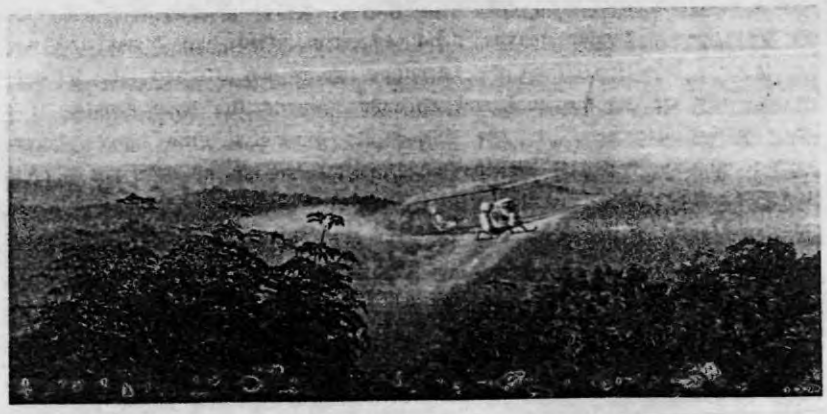

Fig. 2. Aerial spraying for protection against abnormal leaf fall disease.

against the disease (Radhakrishna Pillai and George, 1973). More recently, fogging copper-in-oil or captafol-in-oil, significantly reduced leaf fall caused by Phytophthora (Lim et al. 1981; Tand and John, 1985). Fortunately, the severity of the disease in all rubber growing countries, except India is not of enough economic importance to warrant expenditure on its routine control.

Good control of Phytophthora leaf fall has been achieved in Sri Lanka by the planned restriction of sulphur dusting to control oidium leaf fall, where the causal fungus affects the flowers too. This reduces pod set and consequently the inoculum for causing severe leaf fall (Peries et al. 1985).

Although crown budding has not become widely accepted as a method of disease control, due to some adverse effects of the crown on the growth, yield and properties of latex, this technique is being used in India for more than three decades to control Phytophthora leaf fall successfully (Sarma and Ramakrishnan, 1985).

Colletotrichum leaf fall

General: Colletotrichum leaf disease caused by the fungus Colletotrichum gloeosporioides (Penz.) Sacc., occurs in many rubber growing countries with different degrees of severity. This disease attacks tender leaves of immature plants and also leaves developing towards the latter part of the refoliation season of mature rubber trees. However, this disease occurs throughout the year but becomes more dominant with the onset of wet weather conditions to cause extensive defoliation, in most susceptible clones. The severity of secondary leaf fall depends on both the susceptibility of the clone to the pathogen and to the weather conditions at the time of refoliation.

Symptoms: Tender leaves produced soon after bud burst are most susceptible to infection. When the immature leaves are affected, the infection begins at the tip of the leaf and spreads towards the base causing it to produce a necrotic area. If the damage is extensive, the leaves become distorted, shrivel and fall off leaving the petioles on the stem for a short period. Sometimes, the portions affected by the disease drop away leaving behind unaffected area of the lamina on the shoot. When semi-mature or mature leaves are infected, the natural resistance of the host usually prevents extensive damage. Such leaves are covered with numerous spots having a brown margin surrounded by a yellow halo. The spots become raised and prominent as the leaf gets older.

Repeated defoliation due to Colletotrichum could result in dieback of succulent shoots of young buddings. Sometimes the fungus grows down

Affecting the bud patch and killing the entire plant. It can also cause gradual death of the twigs and branches and may even kill the entire tree, when it is highly susceptible to the disease, especially at higher elevations or in areas where wet weather is experienced continuously.

Biology: The germination of the fungus was poor when the spore concentrations were above $7x10^6$ per ml (Wimalajeewa, 1967). The optimum temperature for growth and sporulation was between 26-32°C (Wastie, 1972a), with a maximum around 28°C (Wimalajeewa, 1967). Germination decreased on exposure of spores to sunlight (Wimalajeewa, 1967; Wastie, 1972a) and exposure to ultra-violet radiation for short periods (Wimalajeewa, 1967). Continuous light favoured spore production in vitro, but spores produced in the dark had a higher percentage germination (Wastie, 1972a). Spore viability and germination were sensitive to atmospheric conditions. At 99% relative humidity spore viability and germination were reduced by 50% when compared to 100% relative humidity (Wimalajeewa, 1967). Germination decreased by up to 30% after 3 h storage at 80% relative humidity (Wastie, 1972a). Loss of spore viability was also observed when they were stored at temperatures of 50°C and above for more than 6 h. In contrast, spores were found to remain viable for relatively long periods at very low humidity (Wimalajeewa, 1967). Complete inhibition of germination was observed in the absence of oxygen in the ambient atmosphere (Wimalajeewa, 1967). No differences were detected between the numbers of spores germinating on leaves of different ages (Wastie, 1972a), but on slightly older leaflets spores tended to form longer germ tubes (Senechal et al. 1987). Similar germination occured on both resistant and susceptible clones (Liyanage and de Alwis, 1978; Samarajeewa and Liyanage, 1986; Zainuddin and Omar, 1988), but more appressoria were formed on resistant clones. Leaf diffusates obtained from susceptible and resistant cultivars stimulated and inhibited spore germination, respectively, indicating the possibility of using this as a technique for screening clones for disease resistance in the laboratory (Liyanage and de Alwis, 1978). However, there was no correlation between thickness of the cuticle and clonal susceptibility (Wastie and Sankar, 1970). In susceptible clones, extensive ramification of the pathogen was observed within the leaf tissues and acervuli were formed 72 h after inoculation, but in resistant cultivars disorganisation and necrosis of epidermal and mesophyll cells were observed (Senechal et al. 1987; Liyanage and de Alwis, 1978; Samarajeewa and Liyanage, 1986).

C. gloeosporioides obtained from Hevea vary considerably in their growth, morphology, intensity of sporulation and relative infectivity (Wastie and Janardhanan, 1970). Studies carried out in Sri Lanka showed that there

were differences in the pathogenicity of isolates obtained from different agro-climatic regions and also that an inverse relationship exists between the leaf infection and leaf area damaged (Liyanage, 1976; Liyanage, 1977b).

Epidemiology: It has been shown that free water is necessary for optimum germination of the fungus and it accounted for the close relationship between secondary leaf fall and rainfall. However, disease establishment can occur in a few hours at 100% relative humidity (Wastie, 1967), or longer at humidities down to 96% (Wimalajeewa, 1965), even in the absence of free water. The severity of leaf fall was correlated to the higher total amount and frequency of rainfall (Wastie, 1972b). The spore discharge followed a regular diurnal pattern and peak spore catch usually occurred late at night but declined to low concentrations as the humidity dropped during the day time and also during rainy periods (Wastie, 1972a). The overall incidence and severity varied in different environments, but the relative degree of resistance of the clones was not markedly affected by the environmental differences. The relationship between the incidence and severity was linear when the plants were less affected by the disease while a curvilinear trend was evident in susceptible clones when they were heavily infected (Samarajeewa et al. 1985).

Control: This disease was controlled by the application of Bordeaux mixture (RRIM, 1968) and colloidal copper (Wimalajeewa and Shanmuganathan, 1963), with the former being more effective than the latter as it provided better initial coverage and good rainfastness. The use of carbamate fungicides such as Zineb (zinc ethylenebisdithiocarbamate) and Ferbam (ferric dimethyldithiocarbamate) and organic formulations, Daconil (chlorothalonil) and Difolatan [Cis-N(1,1,2,2-tetrachloroethylthio) cyclohex-4-ene-1,2-dicarboxymide] gave good control of the disease (RRIM, 1968). However application of organo-mercurials was more effective and advantageous due to their systemic nature (Peries and Wimalajeewa, 1970) but later it was found that Daconil and Benlate (Benomyl) were more effective and could replace antimucin (phenyl mercuric acetate) (RRIM, 1977). The application of water miscible fungicides was done with knapsack sprayers or power driven mist blowers, but the fungicides were easily washed off during rains and did not give the desired results in controlling the disease. To overcome this problem low volume application of Daconil as an oil-water emulsion with a mist blower was undertaken to reduce the severity of the disease (RRIM, 1977). Subsequently, mechanised fogging of captafol-in-oil thrice, at weekly intervals, during the refoliation period gave good control of the disease in Malaysia (Tan and John, 1985). Mechanised spraying or fogging with chlorthalonil in water and in oil, respectively, gave better

results than with captafol (Lim, 1987). In Cameroon, artificial defoliation using ethrel was also used as a means of induced defoliation and refoliation to effect avoidance of secondary leaf fall (Senechal and Gohel, 1988).

Corynespora leaf fall

General: Corynespora leaf fall disease caused by Corynespora cassiicola (Berk & Curt.) Wei., was first observed in seedling nurseries in India (Ramakrishnan and Pillai, 1961) and later in Malaysia on iron deficient nursery plants (Newsam, 1961). Subsequently, the disease was reported from other countries in Asia (Situmorang and Budiman, 1985; Liyanage et al. 1986; Kajornchaikul, 1987), Africa (Awoderu, 1969) and South America (Liyanage, 1986). In many rubber growing countries the disease has caused severe damage only in a few introduced and indigenous clones but in Sri Lanka it has become the most devastating disease, affecting more than 3000 ha of susceptible clones, mainly the clone RRIC 103, both in immature and mature plantations (Liyanage, 1987a). Several alternate hosts are known to harbour the fungus (Situmorang and Budiman, 1985; Liyanage et al. 1986; Liyanage, 1987b).

Symptoms: The fungus affects the immature and mature leaves, the former being more susceptible. The symptoms first appear as greyish brown spots which enlarge into conspicuous circular or irregular lesions of varying sizes and shapes. Several spots may coalesce to produce extensive crisp brown areas on the leaf, some of which may become irregular papery lesions giving a scorched, shrivelled appearance. On mature leaves the characteristic feature of the disease is the browning or blackening of the veins adjacent to the lesions giving a 'fish bone' appearance. The area around the lesions gradually become chlorotic due to the destruction of chloroplasts. Even a single lesion on a leaflet could result in defoliation. Greyish black lesions may also be seen on some petioles causing defoliation even without lesions on the leaf blade (Liyanage et al. 1986; Liyanage, 1987b). Repeated defoliation results in the severe retardation of growth, extending the period of immaturity and eventually causing die back of shoots and branches (Liyanage et al. 1986), bark splitting along the trunk (Kajornchaikul, 1987) and even death of trees (Liyanage et al. 1986; Kajornchaikul, 1987).

Biology: The fungus is very variable in cultural morphology, growth rate and sporulation (Liyanage, 1987b; Chee, 1987; Soekirman and Purwantara, 1987). Abundant sporulation was observed with two hours daily exposure to ultra-violet (UV) light and progressively less with continuous light, alternate light and dark, two hours daily fluorescent light and continuous dark (Chee, 1987). Exposure to near UV light for varying periods did not

encourage heavy sporulation (Liyanage, 1988). Sporulation was enhanced by washing the culture with running water for 24 h and drying it at 25±2°C for a period of two weeks (Liyanage, 1988), but daily scraping of the aerial mycelium of the culture did not increase sporulation (Chee, 1987). When cultures were incubated in the dark for three days followed by incubation in the light for a further three, six or nine days, there was significantly more sporulation after six days than after three or nine days (Chee, 1987). Most conidia germinated within 3-4 h at 25-30°C producing one or more germ tubes which arose from both ends of the spore (Liyanage et al. 1986; Liyanage, 1987b; Chee, 1987; Soekirman and Purwantara, 1987). At lower temperatures of 15°C and 20°C a period of 12 h was required for spore germination to occur. At 40°C conidia germinated but germ tube growth was limited (Liyanage, 1987b; Soekirman and Purwantara, 1987). Free water stimulated spore germination (Liyanage, 1987a; Soekirman and Purwantara, 1987) but it was not essential as the spores germinated when the relative humidity was close to dew point. At lower humidities it required longer periods of incubation for spore germination (Soekirman and Purwantara, 1987; Liyanage, 1988). Spore germination was best at 100% relative humidity with a progressive reduction at lower humidities and none germinated after 24 h exposure to 50% relative humidity (Soekirman and Purwantara, 1987; Liyanage, 1988). The lower leaf surface supports better germination of spores than the upper surface. The spores germinated in 3-4 h and entered pallisade cells in between epidermal cells and ramified inter-cellularly in the mesophyll cells, producing conidia at the opposite leaf surface 96 h after inoculation (Liyanage, 1987b). In many instances a single lesion around the vein was sufficient to cause defoliation, though mechanical removal of such lesions prevented defoliation of leaves (Liyanage, 1987b; Chee, 1987). The fungus produced a toxin in a synthetic medium and the maximum amount of toxin was produced after 10 days of incubation at 28±2°C (Liyanage and Liyanage, 1986). A technique was developed for rapid screening of clones in the laboratory using the culture filtrate containing the toxin (Liyanage and Liyanage, 1986).

Epidemiology: The conidia are wind dispersed. The pattern of spore release followed a diurnal rhythm. Spore release began around 0500 h and tailed off by 1800 h. The maximum spore release occured between 0730 and 1130 h with a peak production at 0930 h and very few spores or none were released during the night (Liyanage, 1987b). However, in Malaysia the spore release started at 0800 h and reached a peak around noon and declined to a low level until sunrise the next day (Chee, 1987). Fewer spores were caught during wet weather but a high spore count was recorded

on five days succeeding a day of wet weather (Chee, 1987). Conidia on leaves remained viable for a period of 30 days after their exposure to natural conditions.

Over 80 alternate hosts of the fungus have been reported (Situmorang and Budiman, 1985; Liyanage et al. 1986; Chee, 1987). Under Malaysian conditions Hevea isolates did not cross infect other hosts nor did the Carica papaya (pawpaw) isolate infect Hevea (Chee, 1987) but in Sri Lanka they infected both C. papaya and Mikania scandens, but the leaves were only mildly infected (Liyanage, 1987a).

Control: In India two rounds of prophylactic spraying with 1% Bordeaux mixture or 0.2% Dithane Z-78 (zineb) was recommended for budwood and seedling nurseries and immature clearings, as a prophylactic measure (Ramakrishnan and Pillay, 1961). In Sri Lanka, application of 0.3% Benomy, mancozeb and Orthocide and 0.4% Propineb at 4-5 day intervals during wet weather and seven day intervals during dry period was recommended. In Thailand 1% Bordeaux mixture was recommended as a prophylactic treatment on untapped trees, and application of 0.75% a.i. was suggested as an alternative spray (Kajornchaikul, 1987). In Malaysia, benomyl was found to be the most effective fungicide under laboratory conditions, but under field conditions, only partial control was achieved with the application of six rounds of 0.15% benomyl and thiram, at weekly intervals, during the refoliation period (RRIM, 1975). More recently, several chemicals such as chlorothalanil, benomyl, triademtan and tridemorph have been used as protective sprays (Liyanage, 1986). In Sri Lanka spraying mature trees with vehicle mounted thermal foggers using fungicides such as benomyl and mancozeb did not give adequate control. Field trials using portable thermal foggers and mist blowers indicated that neither is suitable for use in mature trees but were adequate for immature clearings and nurseries (Liyanage, 1987b). It was also observed that if spraying was done at five day intervals, commencing at refoliation, it prevented the establishment of the disease. When spraying was stopped after six months, the leaves succumbed to the disease and within a further period of six months dieback was observed (Liyanage, 1987b). Thus, chemical control of corynespora leaf fall is likely to be much more difficult than that of secondary leaf fall caused by other foliar diseases as the disease occurs throughout the year and on leaves of all ages. Further, the fungus produces a toxin which induces leaf abscission, so that one lesion on the petiole or main vein is sufficient to cause leaf fall.

In view of the seriousness of the disease and the extended period

of fungicide application, many susceptible clones, especially the immature trees were successfully crown budded and base budded (Liyanage, 1987a). Alternatively, planting of resistant clones appears to be the only practical method of combating the disease.

South American leaf blight

General: South American leaf blight (SALB) caused by Microcyclus ulei (P. Henn.) Arx is indigenous to South America. It occurs in the region of the Amazon river system, the Guianas, the upper Orinoco and the Matto Grosso. SALB is presently confined to South America and is absent from Africa and Asia where most of the world's rubber is planted. This disease has caused many plantations of rubber in South America to be abandoned and is a serious impediment for any future expansion of the industry.

M. ulei is known only from Hevea species. Of the nine species of the host which are not uniformly distributed throughout the geographical range of the genus, five are known to be susceptible, ie. H. brasiliensis, H. benthamiana, H. guianensis and H. spruceana (Chee, 1976a) and H. camporum (Junqueria, 1988). The rest were not infected naturally. The disease spread throughout the South American countries from infections arising from wild trees (Alandia and Bell, 1957), but spread to Trinidad and Central America and to Bahia and Sao Paulo areas in Brazil, presumably through planting material when attempts were made to grow rubber in these regions.

Symptoms: The symptoms of the disease are most conspicuous on the leaves. When immature leaves are infected conidia appear in grey black lesions, usually on the lower surface, accompanied by leaf distortion. If the infection is severe, the leaves blacken, shrivel and fall off. When older leaves are infected distortions may be absent or slight, but a few lesions which may develop assure a ragged shothole appearance. The leaves that survive the primary infection show characteristic black pycnidia mostly on the upper surface around the edges of shotholes. At full maturity of the leaves, the stroma increase in size and become rough to touch, having well developed ascospores. These symptoms can also occur on petioles, green stems, inflorescences and young fruit leading to distortions, suberisation and splitting.

Biology: The obligate nature of the causal fungus M. ulei makes it difficult to manipulate in vitro. Growth of the fungus in culture is correlated with conidial viability, which depends on seasonal changes (Chee, 1978a). The medium most suitable for growth and sporulation was potato sucrose agar (Chee, 1978a; Holliday, 1970), but enriching this medium with

purified vitamins and growth substances often resulted in inhibition of growth (Chee, 1978a). Fresh rubber leaf extract stimulated growth and sporulation (Langford, 1943a) but subsequent studies showed that air dried rubber leaves gave better results (Chee, 1978a). Two morphological strains and three distinct colony types were formed amongst field isolates and laboratory produced conidia, respectively (Chee, 1978a). The optimum temperature for germination and germ tube growth on various media was around 24-28°C (Holliday, 1970; Langford, 1943a; Blasquez and Owen, 1957) but later investigations showed that the fungus grew best at 23°C (Chee, 1978a). The optimum temperature for lesion development on inoculated leaf discs was between 24-26°C under a 16/8 h light/dark period of six days (Chee, 1976b). The growth of germ tubes was slower in distilled water than on susceptible leaves (Holliday, 1970). Exposure of the fungal culture to near ultra violet light daily, for a period of 45 min increased sporulation (Chee, 1978a; Holliday, 1970). Good conidial germination was observed after three days when the cultures were exposed to 70% relative humidity at 27°C (Chee, 1976b). Conidia stored under normal laboratory conditions survived for two weeks (Brookson, 1963; de Jonge, 1962). Similar observations were made when conidia in leaf lesions germinated (50%) after leaves were stored in dessicators for 15 weeks or frozen (-20°C) for two weeks or kept at 40°C for several days (Chee, 1976c). Leaf infection occured more readily with dry conidia at 100% relative humidity than at 65% relative humidity. However, sporulation occured at both 65% and 100% relative humidity after lesion formation, but was mot abundant at 100% relative humidity (Chee, 1976c), especially at temperatures between 23-25°C (Kajornchaiyakul et al. 1984). Dry conidia require 6 h of high humidity immediately after deposition and the disease intensity was higher when plants were incubated at 19-25°C than at 26-32°C with the optimum around 23-25°C (Kajornchaiyakul, et al. 1984). Exposure to ultra violet light (2537 °A) for 4 min, killed 90% of the conidia (Brookson, 1963; de Jonge, 1962), and light reduces viability with time, compared with dark and natural indoor light (Holliday, 1970).

The temperature for ascospore germination was 24°C, but none germinated at 12°C or 32°C (Chee, 1976c). Ascospores completed germination in 2.5 h in darkness and took 6 h in the light (Chee, 1976c). Germ tubes were three times longer in the dark than in the light after 6 h (Chee, 1976b). No germination occurred after nine days at relative humidities above 80% or after 15 days under desiccation (Chee, 1976c). The germination rate of ascospores was consistently high irrespective of the conditions under which they were produced (Chee, 1976b). The germination of ascospores was higher in floating than in submerged spores (Chee, 1976c). Ascospores were killed by a 4 min exposure to ultra violet light (Chee, 1976c).

Variation in cultural characteristics such as colony appearance, growth rate and sporulation have been observed (Chee, 1978a; Holliday, 1970; Junqueira et al. 1984). Experimentally, races 1 and 2 (Langdon, 1965) and races 3 and 4 (Miller, 1968) were differentiated. The existence of nine races with eight of them present in the state of Bahia, Brazil was demonstrated (Chee et al. 1986) by using field inocula introduced on leaf discs of various Hevea clones from which the differentiating clones were selected. Three main groups of isolates were identified in Brazil from cultural characteristics but no attempt was made to classify them into races (Junqueria et al. 1985). However, they were designated 4a, 4b and 4c (Sudhevea, 1970). These were later renamed as races 4, 5, 6, respectively (Chee et al. 1986). However race 4c was similar to race 7 of Chee et al. (1986). Later, physiologic races of isolates were identified by inoculating leaf discs and differential plants grown as polybags. More recent work in the state of Bahia indicated that isolates studied could be classified into more predominant races 2, 4, 5 and 6 and morphologically into two groups based on differences in their growth and sporulation in medium (Hashim and de Almeida, 1987). It was also observed that a clone could be infected by more than one race in the field simultaneously. It has also been shown that a race may consist of strains of different virulence which can account for the differences in pathogenicity from locality to locality (Langdon, 1966; Liyanage and Chee, 1981).

Epidemiology: Both conidia and ascospores play an important role in the spread of the disease. The diurnal periodicity of conidial production with a maximum around 1000 h and decreasing towards the evening, with a minor peak between 2000 h and 2100 h, reaching a minimum in the early morning was reported (Holliday, 1969). Subsequent investigations showed that peak production of conidia occurred a little later than 1000 h. However, similar number of conidia were trapped between 1000-1200 h on both cloudless and cloudy days (Chee, 1976d). No conidia were trapped during the dry season although a few were found on old lesions. The maximum conidial production coincided with the time of widespread field infection (Holliday, 1969; Chee, 1976d). On the otherhand, ascospores were present throughout the year. Ascospore production on dry days followed a marked diurnal pattern, with low catches during the day but increasing to reach a peak at 0600 h (Chee, 1976d). However, in wet weather the heavy ascospore production also occured during dry weather with a day time maximum coinciding with a rainfall peak which is usually higher than the peak production on dry days. Wetting of perithecia is a prerequisite for ascospore discharge (Holliday, 1969) and the presence of ascospores in the air

coincided with rise in relative humidity, temperature and dew than with rain (Chee, 1976d).

Epidemics of the disease occur when the daily temperature is under 22°C for longer than 13 h, relative humidity over 92% for a period over 10 h and rainfall exceeding 1 mm per day the preceeding seven days (Holliday, 1969; Chee, 1976d). Continuous heavy rain is inimical to the spread of the disease as it can wash off the spores, but light intermittent showers distributed throughout the year is favourable for disease development (Holliday, 1969; Chee, 1976d; Stahel, 1917). There is evidence to suggest that the spread of the disease to Haiti is from the spores brought over by wind and rain from Guiana and Trinidad (Compagnon, 1976). Similarly, there is strong circumstantial evidence that the spread of the disease from the Amazon basin to the surrounding areas was caused by long distance dissemination and deposition of spores (Liyanage, 1981a).

Control: The beneficial effect of Bordeaux mixture to control the disease was first demonstrated in 1913 (Bancroft, 1913) and later the use of insoluble copper and wettable sulphur gave good results (Langford, 1943b). Subsequently, ferbam (ferric dimethyldithiocarbamate) (Hilton, 1955) and zineb (zinc ethylenebisdithiocarbamate) were found to be more effective (Langford and Echeverri, 1953; Langford and Townsend, 1954). More recent experiments in Brazil have shown that both mancozeb (Dithane M 45) and benomyl (Benlate) were effective (Rogers and Peterson, 1976). In field trials thiophanate methyl (0.07% a.i.) and benomyl (0.025% a.i.) were most effective in controlling leaf infection, followed by chlorothalonil (0.15% a.i.) and mancozeb (0.32% a.i.). Benomyl suppressed conidial sporulation, whereas one application of thiophanate methyl (0.14% a.i.) to perithecia, inhibited ascospore release; half of this concentration applied to conidial lesions or pycnidia caused the perithecia formed subsequently to abort (Chee, 1978b). These fungicides have been used widely in plantations in Brazil (Chee and Wastie, 1980). More recently, triadimefon (0.015% a.i.), triforine (0.038% a.i.) and bitertanol (0.03% a.i.) have also given promising results in nursery trials. It was also shown that mixtures of systemic and protective fungicides were more effective than the application of individual fungicides alone (Santos et al. 1984).

The difficulty of spraying fungicides to reach the canopy of mature rubber trees was recognised early. The use of portable mist-blower to spray several fungicides was unsuccessful (Rocha, 1972). Aerial spraying was soon therefore considered the only feasible means of spraying mature trees. The first attempt to control the disease by aerial spraying was made in 1971. Since then, numerous fungicides have been used involving different

dilutions, intervals and diluents (Rogers and Peterson, 1976; Mainstone et al. 1977), and also various types of aircrafts were tried for spraying in Brazil (Mathews, 1976). An alternative to aerial spraying was fogging with portable thermal foggers (Tifa vehicle mounted 'TART' and wheel drawn 'TIGA', vehicle mounted 'LECO' and Dynafog). These machines can cover 200-600 ha in a day and use either 200 g thiophanate methyl or 1 kg mancozeb per hectare (Chee and Wastie, 1980). These two fungicides are used on a large scale in Brazil starting before refoliation and continuing at four day intervals initially and later at seven day intervals to complete 12 rounds. Thiophanate methyl was applied at a rate of 175 g $ha^{-1}$ suspended in 6 l of an 80:20 mixture of shell spray oil and diesel fuel (Chee and Wastie, 1980).

The technique of artificial defoliation to hasten refoliation while the weather is still dry so as to enable the trees to escape infection as practised in Malaysia (Rao, 1972) was also tried in Brazil. Two defoliants Folex (merphos 2.2 kg $ha^{-1}$) and Dropp (thidiazuron 0.6 kg $ha^{-1}$) were tested by aerial application and fogging but results were variable (Romano et al. 1982) and this method was not widely adopted in Brazil.

Crown budding of high yielding clones of eastern origin with crowns of resistant clones was first attempted at Ford's Beltera in the Amazon basin. This method was used on a large scale for many years (Tollenaar, 1959). Several clones of Fx and IAN origin as well as H. pauciflora clone PA 31 were recommended for crown budding (Rands, 1946; Ostendorf, 1948). This technique was not popular because of the adverse effects on depressing growth and yield due to the interaction of the crown on high yielding scion clone. To minimise the unfavourable interactions, crown budding at a height of 2.5 m has been recommended (Rands, 1946). Later, when H. brasiliensis was crown budded with H. guianensis, H. spruceana, H. collina and H. confusa it yielded better than the latter clones when used alone (Ostendorf, 1948).

Breeding programmes to incorporate SALB resistance with high yield were done mostly in Brazil at Belterra and Belem (IPEAN) and also on a small scale in Costa Rica and Guatemala (Langford, 1943). Although a large number of resistant clones were bred in Brazil, only six appear to be acceptable for commercial planting. They are Fx 3810, Fx 3899, Fx 3925, IAN 717, IAN 710 and Fx 25. Of these, the first four have H. benthamiana, clone F4542 as the resistant parent while the last two derived their resistance from F409 and F351 (also H. benthamiana clones) respectively. However, variation in susceptibility between localities (Chee and Wastie, 1980) and also breakdown of resistance due to occurrence of physiologic races (Langdon,

1965) are two problems which affect the progress of the breeding programme. Breeding for SALB resistance was started in Malaysia and Sri Lanka with 25 clones and 42 clones, respectively (Brookson, 1956; Baptiste, 1958), obtained on an exchange basis. These clones were used as in a hybridization programme and also tested for their vigour and yield under Malaysian and Sri Lankan conditions. Out of these clones, an illegitimate progeny of Fx 25 and IAN 873 gave yields comparable to PB 86 in Malaysia (Subramaniam, 1969). Several clones with resistance to SALB together with all desirable secondary attributes have been obtained from a breeding programme initiated in 1961, some of which having a combination of different sources of resistance, have been recommended for large scale planting in Sri Lanka (Fernando, 1962; Fernando and Liyanage, 1980).

More recently biological control methods have been successfully carried out using the hyperparasite Hansfordia pulvinata (Berk & Curt Huges), which grows well on conidial lesions as well as on stromatic layers of M. ulei. Under high humidity conditions, the parasite colonized 93% of the conidial lesions, and 86% of the stromatic areas were destroyed (Lieberel et al. 1989).

STEM AND BRANCH DISEASES

Stem and branch diseases are present in many rubber growing countries but they usually do not cause serious damage except in certain localities where conditions favourable for disease development are present. Pink disease, Ustulina stem rot, Phellinus stem rot and Botryodiploida die back caused by Corticium salmonicolor Berk. & Br., Ustulina deusta (Hoffm. ex Fr.) Lind., Phellinus noxius (Corner) G.H. Cunn. and Botryodiploida theobromae Pat., respectively are the more common diseases. However, pink disease can cause extensive damage and the remaining diseases are essentially caused by weak parasites, which gain entry in to trees through wounds, mainly caused by natural or accidental injuries.

Pink disease

General: Pink disease caused by Corticium salmonicolor Berk. & Br., is the only important stem disease of rubber. The fungus is widely distributed in all the countries and has a wide host range. The fungus attacks the bark of the main stem and branches of 3-7 year old immature trees, particularly at the fork region during periods of wet weather. Pink disease also occurs on mature trees and on such trees, stems and branches are somewhat slower to develop disease symptoms.

Symptoms: The first indications of an attack are exuding drops of latex from the region of the fork. This is followed by the appearance of white silky threads on the bark surface, which later give a cob-web appearance (Fig. 3). Under favourable conditions the disease spreads and a pink mass

Fig. 3. Pink disease affected tree showing exudation of latex and cob web like mycelium.

of sterile mycelium begins to appear, when the outer bark dies. At this stage pink pustules erupt in lines through cracks in the bark, which disappear as the dead bark sloughs off. The 'corticium' stage that produces basidiospores consists of a smooth, pinkish-white surface covering the pink crust, while the nector stage consists of organge-red pustules composed of a tight mass of spores which are scattered over the upper surface of side branches. When the disease spreads it causes ring-barking causing the dormant buds below the injured portion to produce numerous side shoots. In a more advanced stage of infection, death of branches occurs, exposing bare shoots.

Biology: Both basidiospores and necator spores can be grown readily in culture on a variety of media (Hilton, 1958) and on distilled water at room temperature giving rise to sterile mycelia. At times mycelial aggregates formed in culture have to be regarded as analogous with the necator stage (Brooks and Sharples, 1951) but later investigations showed that such aggregations are structureless and are comparable with the pustular stage (Hilton, 1958).

Epidemiology: The disease occurs in wet weather and also in humid locations but it does not occur in the coastal areas of Malaysia (Hilton, 1958) and in soils where boron toxicity occurs. The former indicates the effect of drying winds in reducing humidity and thereby the disease incidence, and the latter is caused by a nutritional effect. The severity of the attack varies from one locality to another according to the rainfall pattern (Yeoh and Tan, 1974).

Unlike leaf and panel diseases which have well defined patterns of severity varying from clone to clone, pink disease shows more uniformity. A few clones are known to be of above average susceptibility but most cultivars are prone to the disease.

Control: Since the beginning of this century Bordeaux mixture was used widely to control this disease (Anstead, 1914). Eventhough copper was only mildly toxic to the fungus, it was preferred for its high tenacity under heavy rainfall conditions. With the refinements in the application methods it was used either as a brush-on 10% paste or as 1% liquid sprayed as a jet from the ground using a knapsack sprayer with a long lance with its swirl plate removed (Ramakrishnan and Radhakrishna Pillay,1 962b). In wet weather the chemical gets washed off an becomes less effective necessitating repeated applications. Further, trees in tapping cannot be treated with copper fungicides because of the risk of contaminating latex with copper (Wastie and Yeoh, 1972). Later, application of 0.5% solution of Fylomac 90 (tetradecyl pyridinium bromide) as a spray or brush-on application gave satisfactory control and was used to control the disease in mature trees (Alston, 1953; Yeoh and Tan, 1974). A number of non-copper fungicides are highly effective against the fungus in laboratory tests but under field conditions, most are ineffective since they rapidly get leached by rain (Wastie and Yeoh, 1972). This difficulty was overcome by incorporating 5% Calixin (75% N-tridecyl 2,6 dimethyl morpholene) with natural rubber latex as a binder. One brush-on application of it gave good control for periods upto three months (Wastie and Yeoh, 1972). Subsequently, a formulation based on prevulcanised natural rubber (50%) as a carrier in 1.5% tridemorph as a fungicide was more effective than Bordeaux mixture (Yeoh and Tan, 1974). A polyvinyl acetate based formulation using either propiconazole or tridemorph was also reported to be effective (Jacob and Edathil, 1986). A formulation of 1.5% MK 23 [n-(P-fluorophenyl)-2,3 dichloromaleimide] in diluted field latex, applied as two sprays at six weekly intervals have given good control upto three months, and the costs are comparable to the brush-on calixin application (Tan and Yeon, 1976).

DRY ROT

General: Dry rot disease caused by Ustulina deusta (Hoffm. ex Fr.) Lind. causes complete loss of attacked trees as the trees break at the point of infection (Radhakrishna Pillai and George, 1980). This disease is rare in young rubber plantations. The pathogen is known to cause collar rot and root rot besides stem rot.

Symptoms: The initial symptom is copious exudation of latex from the point of attack. The attacked wood turns pale brown and is readily fragmented. Irregular flat grey fructifications of the fungus appear on the bark surface which later turn black and brittle. Infected wood shows a network of black double lines (Sripathi Rao, 1975).

Biology: The fungus grows well in vitro at 23°C, the mycelium being white to grey initially but becoming greyish brown with formation of conidia and black after 2 to 3 weeks (Hawksworth, 1972).

Epdidemiology: Ustulina deusta is essentially a wound parasite (Petch, 1921). But the pathogen also gains entry through lenticels and moribund root initials. The pathogen is known to show selectivity to live hosts rather than dead trees (Varghese, 1971). The incidence of the disease is observed to be more after heavy winds during the rainy season.

Control: Field sanitation and cutting and removal of infected branches followed by painting the cut surfaces with tar or asphalt mixutre has been recommended by early workers (Petch, 1921; Sharples, 1936). Application of a organomercurial fungicide solution followed by wound dressing was found to contain the disease (Radhakrishna Pillai and George, 1980). Direct application of any of the fungicides viz. methoxyethyl mercurychloride, thiram, oxycarboxin, carbendazim or thiophanate methyl, incorporated in a petroleum wound dressing compound after removal of affected tissues, was as effective as fungicide wash followed by painting with wound dressing compounds. Bordeaux paste was ineffective (Idicula et al. 1990).

PATCH CANKER

General: The occurrence of patch canker was reported first from Sri Lanka in 1903 and subsequently from other rubber growing countries. The disease is caused by infection of untapped bark by Phytophthora palmivora or Pythium vexans (Radhakrishna Pillai and George, 1980).

Symptoms: Exudation of latex is observed from the point of infection. Accumulation and coagulation of latex under the bark at these points forms a pad which give a foul odour and leads to cracking of bark. Internal tissues show discolouration and rotting. The purplish discolouration (Sharples, 1936) is absent in some cases (Chee, 1968).

Biology and Epidemiology: The biology of the pathogen has already been discussed under Phytophthora leaf fall. Pythium vexans is associated only when the canker is on the collar or on roots. Infection is through wounds. Wet weather favours the spread of the disease.

Control: Excision of the disease affected tissues followed by painting of the wound with organomercurial fungicides is effective (Sharples, 1936; Radhakrishna Pillay and George, 1980). This should be followed by application of a wound dressing compound. Application of Bordeaux paste also is effective (Ramakrishnan, 1964).

PANEL DISEASES

Besides the stem diseases described, panel diseases like black stripe, mouldy rot and panel necrosis also are reported.

Black stripe

General: Among the panel diseases, black stripe disease caused by Phytophthora palmivora (Butl) Butl., P. meadii Mc Rae or P botryosa Chee, is more important (Chee, 1990).

Symptoms: The disease appeares as a vertical linear depression in the tapping panel which when scraped shows black lines on the wood beneath. The pathogen destroys the bark tissue leaving large wounds which make subsequent tapping on the same panel difficult (Radhakrishna Pillay and George, 1980).

Biology and Epidemiology: The biology of the pathogen has already been discussed. The disease is severe when tapping is continued during rainy season unless regular panel protection measures are undertaken (Ramakrishnan and Radhakrishna Pillay, 1963). Humidity over 90% and frequent wetting of tapping panel favour the spread of the disease.

Control: Black stripe can be controlled by application of organomercurial fungicides at frequent intervals on the tapping panel during rainy season (Ramakrishnan and Radhakrishna Pillay, 1963a). Other fungicides like captafol (Yeoh and Tan, 1980), oxadixyl (Tran, 1986) and mancozeb (Thomson et al. 1988) are also reported to be effective. Application of a panel dressing compound on renewed bark before the onset of monsoons helps in the prevention of disease incidence.

ROOT DISEASES

Among the root diseases of rubber, three are considered to be of significance - white root disease, brown root disease and red root disease (Chee, 1976). As the infection of roots and collars of trees leads to death

of trees, these diseases cause reduction in the mature stand and yield per hectare.

White root disease

General: White root disease caused by Rigidoporus lignosus (Kl.) Imazeki is the most serious root disease of rubber due to its fast spreading nature (Sharples, 1936) and its early appearance in the field. This disease was first reported from Singapore (Ridley, 1904) and from Sri Lanka in 1905 (Petch, 1921).

Symptoms: In affected trees general discolouration of the foliage turning off-treen in colour and giving a ripened appearance are the earliest above ground symptoms. Leaves later turn yellow and drop. Premature flowering and die back of the branches are also common. On the affected roots white rhizomorphs, which turn pale orange red when old, are seen. The fruiting bodies are firm, flesh and usually tiered (Hilton, 1959). Wood newly affected by the fungus is brown and hard but in later stages it is white or cream and firm (Chee, 1976a).

Biology: Rigidoporus lignosus is a basidiomycete which produces bracket like sporophores on the collar of naturally infected trees. The fungus spreads through rhizomorphs. The isolates of the fungus could be identified by its characteristic penetration pattern on Jenson's agar medium. Fruitification of the fungus was induced in inoculum containing pathogen on malt extract agar (600 ml) when field conditions were simulated in the laboratory (Fox, 1960).

Twenty isolates collected from a range of geographical origins could be grouped according to their origin on the basis of soluble protein banding patterns obtained by isoelectric focussing of isozyme profiles (Louanchi et al. 1992).

Epidemiology: Freshly felled rubber stumps get infected by airborne spores (Sharples, 1936) but the chief method of spread is by root contact (Hilton, 1959). The mycelium can travel in soil for some distance but the need for a food base for the rhizomorph to remain viable has been demonstrated (John, 1961). The fructifications appear near the collar of affected trees during wet weather. The influence of planting distance on the incidence of the disease also has been established (Liyanage, 1981b).

Control: Field sanitation and removal of all affected root materials have been suggested as the most important preventive measures (Petch, 1921; Sharples, 1936: Hilton, 1959). Complete mechanical removal of roots of trees while clearing before planting was preferred to stump poisoning method (Newsam, 1967). Leguminous cover crops grown in rubber plantations

act as decoy hosts and help in reduction of inoculum potential (Fox, 1965). Application of sulphur to the plant bases has been of advantage in reducing soil pH and stimulating soil antagonists which cause lysis of the pathogen (Peries and Liyanage, 1983). In vitro antagonism of several soil fungi like Trichoderma viride, T. harzianum, Gliocladium roseum has been demonstrated (Jollands, 1983). Several fungicides have been reported to be useful as collar drench. These include tridemorph (Tran, 1986), triademefon, triademenol, propiconazole (Tan, 1990). An integrated approach using both fungicides (Triademofon and Tridemorph) and the antagonistic fungus Trichoderma has been observed to improve the disease control. Introduction of the antagonist two months after drenching with fungicides ensured that a high population of the antagonist was maintained in the soil (Hashim, 1990).

BROWN ROOT DISEASE

General: Brown root disease caused by Phellinus noxius (Corner.) was first reported from Sri Lanka (Petch, 1921). It is of greater significance in Sri Lanka and India (Rajalekshmy, 1980). Higher disease incidence is observed in light soil.

Symptoms: The incidence of the disease can be detected by the discolouration of the foliage along with cessation of growth (Ramakrishnan and Radhakrishna Pillay, 1963b). The trees showing such external symptoms can not often be saved as the infection might have progressed considerably killing the root tissue. However, prophylactic measures can be undertaken if roots are only partially infected. The rhizomorphs form a continuous fungal mat over infected roots, brown in colour turning black with age (Chee, 1976d). A layer of soil mixed with fungal mycelium forms a hard brittle mass which is difficult to be washed off (Petch, 1921). Wood also shows brownish discolouration and in advanced stages honey combing is seen (Ramakrishnan and Radhakrishna Pillay, 1962c).

Biology and Epidemiology: Phellinus noxius is a basidiomycete forming bracket shaped sporophores. The fruiting bodies are brownish purple or black on the upper surface with concentric growth rings and grey on the under surface. Abortive sporophores are often seen at the collar region. These are tawny brown and water soaked. The fungus colonises the stumps of trees left in the plantations which form a source of infection. Underground root contact between healthy and diseased roots is the chief method of spread. The progress of disease from tree to tree is slow when compared to that of white root disease (Petch, 1921). Several cultivated tree crops and forest trees are alternate hosts of the pathogen (Sripathi Rao, 1975).

Control: Curative treatments are effective only if the disease is detected early. The root systems of affected trees are excavated and portions of dead roots removed. The partially affected roots are scraped, washed with an organomercurial fungicide and then painted with a petroleum wound dressing compound. The tree bases are then refilled and packed firmly. Prophylactic dressing with a bitumin or grease compound in which 10% tridemorph is incorporated is reported to be effective (RRIM, 1974b).

RED ROOT DISEASE

General: Red root disease caused by Ganoderma philippii (Bres. & P. Henn.) Bres is a less common disease which develops slowly and is more frequently encountered in mature plantations (Hilton, 1956). However recent reports from China indicate that even young plantations are affected and that the spread is relatively fast (Tan and Fan, 1990).

Symptoms: The symptoms of brown root disease and red root disease are similar except that in the case of red root disease, the mycelium which covers the root surface is red or reddish brown with creamy white growing margins. The affected wood is pale brown and hard at first becoming pale buff, wet and spongy and breaks easily in layers when dry.

Biology and Epidemiology: Ganoderma philippii is a basidomycete which forms bracket like fruiting bodies which are hard and woody with dark reddish brown wrinkled upper surfaces and ashy white lower surfaces. Mature fructification bear abundant spores (RRIM, 1974a). Although infection from spores is likely, the spread is largely by root contact. Larvae of certain flies which breed within the fructifications are capable of spreading the disease as the spores are viable even after passing through their gut (Lim, 1971b).

Control: The control measures include preplanting eradication of the sources of infection and prevention of the spread in the stand. Protective dressing of roots with fungicides (10% Drazoxolon or 10% Iridemorph) is recommended (Tan and Lim, 1971). Soil fumigation along with mulching and application of fertilizers and drenching with Drazoxolon is also reported to be effective as it helps in stimulation of native anatagonists (Varghese et al. 1975). An integrated control system involving preplanting inspection and removal of source of infection, post planting inspection and treatment prior to and after opening for tapping both by eliminating infected material and by drenching 0.75% Tridemorph at the rate of 200 ml per tree at 6 months interval for two years was found useful in China (Tan and Fan, 1990).

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