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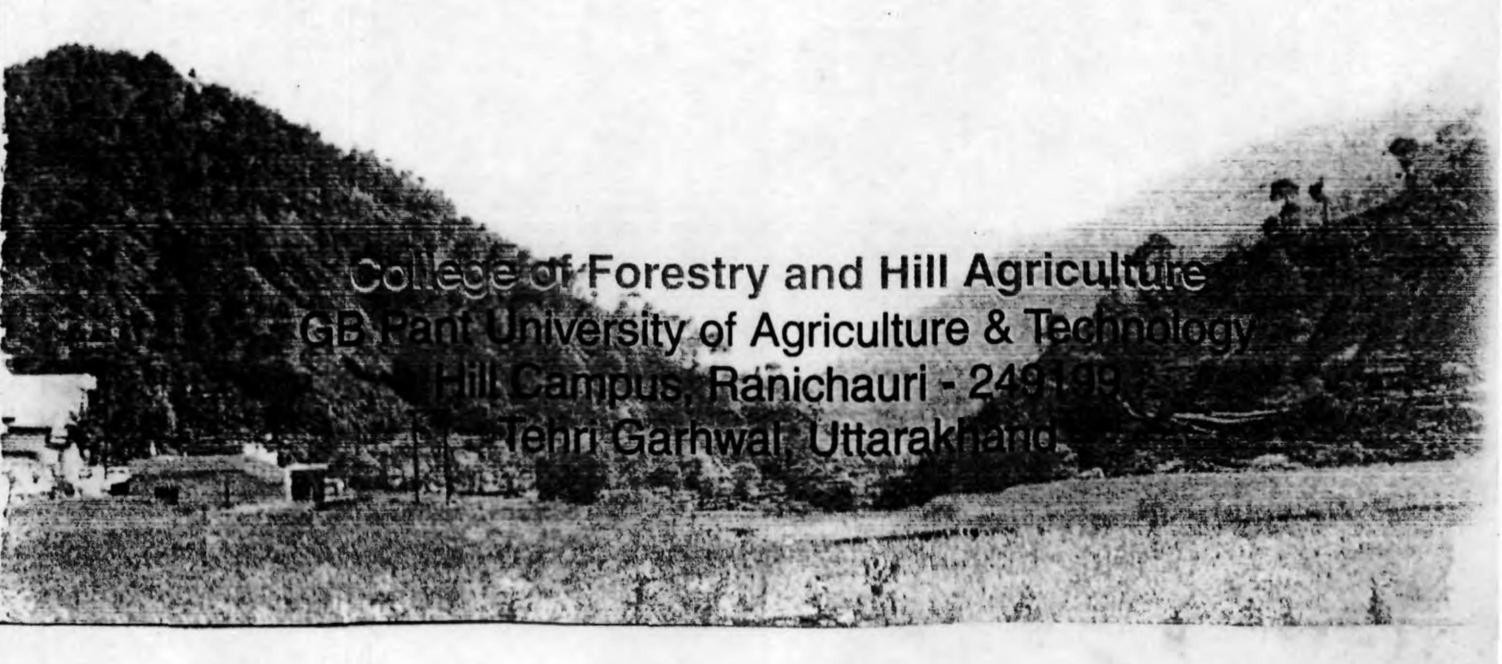

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Phytophthora diseases of rubber tree (*Hevea brasiliensis*)

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Hevea brasiliensis the para rubber tree is one of the major commercially cultivated tree species in India. It requires a warm equable humid climate and a fairly distributed rainfall of 200 mm for satisfactory growth and optimum yield. The annual rainfall in rubber growing regions is fairly high varying from 3000-6000 mm, two thirds of which is received during the South West monsoon period from June to September. Because of the high humidity during the rainy season, the rubber trees become highly prone to diseases caused by *Phytophthora* sp. This pathogen infects different parts of the rubber tree causing various diseases viz., abnormal leaf gall, shoot rot, patch canker and bark rot (black stripe).

Abnormal leaf fall

Abnormal leaf fall caused by *Phytophthora* spp. is the most serious disease of *Hevea* in South India. The disease was reported during 1910 in an estate in Palappilly area near Pudukkad, Trichur district, Kerala State (Mc Rae, 1919). Later the disease has spread to other parts and at present it occurs in most of the rubber growing areas in the country. The disease is present in other rubber growing countries as well.

Crop loss

The damage caused by abnormal leaf fall disease is reflected in several ways on rubber plants. In young immature plants up to 3 years, leaf fall and shoot rot occur causing extensive die back. The growth is retarded and immaturity period extended. In mature plantations extensive defoliation causes reduction in yield. A total crop loss of up to 60% has been reported by several researchers in different clones of *Hevea* (Ramakrishnan, 1960; Pillai *et al.*, 1974). Disease also affects growth, bark renewal and dry rubber content of the latex besides increasing plugging index. This disease also favours weed growth due to the sparse canopy ultimately increasing input costs (Jacob *et al.*, 1989). A long term evaluation of the crop loss due to the disease over a period of 14 years in the popular rubber clones RRIM 600, GT1 and RRII 118 revealed loss of 31.66, 8.21 and 7.15 per cent respectively while no overall loss was recorded for the clone RRII 105, mainly due to post wintering resurgence in crop production (Jacob *et al.*, 2006).

Casual agent

Four species of *Phytophthora* viz., *P. palmovora, P. meadii, P. nicotianae* var. *parasitica* and *P. botryose* are observed to cause abnormal leaf fall in India. Among these *P. meadii* is the predominant species in South India. *P. botryosa* was found to occur in the Andamans and *P. nicotianae* var *parasitica* was isolated from high elevation areas.

Biology and Ecology

Mature green rubber pods are attacked first by the pathogen causing pod rot. Initially a water soaked pale green to brown lesion appears on the pods. Few drops of latex also ooze out and coagulate forming dark spots on the infected pods. Under congenial conditions a thick white cheesy coating can be seen on the surface of such lesions containing large crops of sporangia. On the leaves, petioles are the main seat of infection. A typical light brown to brownish black lesion is formed on the petiole. Often a drop of latex is found coagulated on the lesion. Brownish lesions are also noticed on the leaflet stalks, midribs and on the veins. Water soaked lesions are noticed on the lamina. The infected leaves fall down while green or after turning coppery red. Usually defoliation is sudden and is completed within a fortnight under favourable atmospheric conditions for disease development. After defoliation, the pathogen attacks young shoots causing extensive die back. Refoliation is sparse and the trees remain denuded.

Phytophthora enters the host through the stomatal openings (Thankamma *et al.*, 1975). Hyphae of the pathogen are inter and intracellular and ramify within the infected tissues. During favourable climatic conditions, sporangia are produced in abundance on rubber pods, which aid in the quick dispersal and spread of the disease. By sexual reproduction thick walled oospores are formed and over summers in the soil as oospores (George and Thomson, 1975). In *P. meadii* two mating groups are reported (Rajalakshmy *et al.*, 1980).

Epidemiology

Abnormal leaf fall is an annually recurring disease during the South West monsoon period. The climatic factors, which trigger the leaf fall, were identified as rainfall, temperature, relative humidity and sunshine. A total rainfall of 112 mm or more with at least 1 mm per day for a period of 5 days and a minimum temperature of 22-23°C and a maximum of 29-31°C with a mean R.H. of 80 percent and a minimum of 0.1 hour sunshine per day during the South West monsoon period are reported to cause disease in a period of 9-15 days (Jayarathnam *et al.*, 1987).

The primary source of inoculum is the soil which harbours injected dried pods, leaves and twigs (George and Edathil, 1975). Rain splashes were found to throw the inoculum to a height of 1.2 metres (Rajalashmy *et al.* personal communication). However, due to the undulating nature of rubber estates, the plants at different levels provide ample chances for infection. Alternative hosts also form additional sources of inoculum (Edathil *et al.*, 2000). Spread of the disease through sporangia carried in small water droplets blown by wind and through insects like cockroaches, ants, vinegar flies and beetles has been demonstrated (Edathil and Pillai, 1976).

Disease Management

Disease management can be achieved either by growing clones tolerant to the disease, by crown budding or by prophylactic spraying of the plants with fungicides.

Development of tolerant clones

In general all high yielding clones and clonal seedlings are found susceptible to abnormal leaf fall disease under Indian conditions. Clones like PB 86, RRIM 600, Tjir 1, Tjir 16 and PR 107 are highly susceptible to the disease and show leaf fall even when sprayed with chemicals whereas clones RRII 105, Gl 1, GT 1 and BD 10 show some tolerance to the disease with chemical protection. It was noticed that RRII 105, a high yielder, shows good tolerance and even lower yielder, shows good tolerance (Jayarathnam *et al.*, 1994) and even lower dosages of copper oxychloride was effective for protection in low rainfall areas (Edathil *et al.*, 1994; Jacob *et al.*, 1996). This tolerance trait is inherited from GI 1, one of the parents of RRII 105 as evidenced by RAPD studies (Jacob, 1996). Evidences are available for involvement of eleven PR proteins in the tolerance reaction of *Hevea* to *Phytophthora* (Narasimham *et al.*, 2000). Attempts were also made to identify resistance gene analogues from the resistant rubber clones (Licy *et al.*, 2000).

Crown budding

Top budding of high yielding clones with tolerant clones is another method to contain the disease. When high yielding susceptible clones like GT 1, RRIM 600 and RRIM 628 were crown budded with tolerant crowns of F 4542, FX 516 and RRII 33 their leaf retention was observed to be higher than that in protected trunk clones. The yield of crown budded plants with RRIM 600 and RRIM 628 as trunk clones was found to be higher than that of control plants (Pillai *et al.*, 1980, 1986). But due to low budding success the method has not gained popularity.

Chemical control

A single round of prophylactic spraying with copper fungicides is recommended for protection of rubber trees from this disease. However, prophylactic spraying should be done as close to the onset of the disease as possible, but needs to be completed before the rain breaks in as spraying becomes practically impossible during the rains. This allows only a very short period of about a month within which large areas have to be protected.

High volume spraying using 3000-5000 litres/ha of 1% Bordeaux mixture before the onset of monsoon has been recommended to give protection in 1 hectare of mature rubber (Idicula *et al.*, 1989). Addition of 0.5 per cent zinc sulphate to 0.5 per cent Bordeaux mixture was found to reduce the cost of spraying by about 35 per cent without affecting efficacy (Idicula *et al.*, 1994). Since high volume spraying is labour intensive, costly and slow method, low volume spraying using oil dispersible copper oxychloride in agricultural spray oil has been widely adopted. Experiments to evaluate other oil dispersible fungicides have shown that oil dispersible mancozeb (Jacob *et al.*, 1994) and a combination of metalaxyl with copper oxychloride (Jacob *et al.*, 2001) are also effective. The spraying can be carried out either from the ground using micron sprayers or aerially using helicopters. Copper oxychloride is mixed with spray oil in 1:5 proportion and for micron and aerial spraying 30-42 litres of fungicide mixture is required per hectare (Pillai and George, 1973). Lighter sprayers developed and introduced by RRII in collaboration with Indian manufacturers *viz*, Microspray power 400 and Aspee turblow have been found very effective (Jacob and Jayarathnam, 1993). Tractor mounted spraying has also been tried with advantage in some estates. Fogging machines like Tart/Tiga and Pulsfog were also experimented with reasonably good control of the disease (Edathil *et al.*, 1984).

Other diseases caused by Phytophthora

Shoot rot

Shoot rot is a disease that occurs on young plants in the field as well as in nurseries during the South West monsoon period. The pathogen attacks tender green portions of the plants. Water soaked dark lesions appear on the leaves. The infection advances and spreads on the green shoot and progresses from the tip downwards. The affected portions of the shoot turn dark brown and are shrunken. The disease can be controlled by prophylactic spraying of 1 percent Bordeaux mixture before the onset of monsoon and by protecting all the new shoots developed during the rainy season by repeated spraying (Ramakrishnan, 1957). Spraying with 0.5 per cent zinc sulphate incorporated in 0.5 per cent Bordeaux mixture is more economical (Idicula *et al.*, 1992).

Bark rot (Black stripe)

Bark rot also known as black stripe caused by Phytophthora spp. is noticed on the tapping panel region of the rubber tree during the South West monsoon period. When tapping is done on wet days, the pathogen enters through the wounds and infects the healthy bark. The bark gets decayed, dries up and becomes ad pressed causing depressions. Rotting and discoluration are found to extend even deep into the wood.

Mancozeb is effective at 0.0375% ai and phosphorous acid at 0.08% (Jacob *et al.*, 1995) and these dosages has been recommended for wide use on weekly intervals.

Patch Canker

Patch Canker is a minor disease observed during the south West monsoon period. The disease can occur on any part of the three either on the main stem, branches, tapping panel collar region or roots. The symptoms are evident during the advanced stages of infection. Certain swellings are noticed on the infected area. The bark cracks in this area and a foul smelling liquid oozes out. Beneath the bark, a coagulated rubber pad can be observed. Bark and wood show brown discolouration.

For controlling the disease, the rotten bark and wood tissues are removed using a sharp knife. The rubber pad is also removed. Application of Bordeaux paste in portions away from tapping panel has been recommended (Ramakrishnan, 1964). But if infection is near the tapping panel, the wound is washed with mancozeb (Dithane M 45 0.75% a.i.) solution and when dry, a petroleum wound dressing compound is applied (Rubber Board, 1994).

Gap analysis

Control measures developed in India have been very effective against *Phytophthora* diseases of rubber. Copper fungicides have been found to be effective in controlling abnormal leaf fall disease. Prophylactic spraying of copper fungicides has to be carried out as close to the monsoon as possible. It is difficult to complete the spraying operations in such a short time when large areas of rubber are to be protected. Though water miscible formulations of Dithane M 45 were found ineffective, oil based formulations appear promising. The systemic fungicides phosetyl-Al (Aliette) and metalaxyl (Ridomil) were found ineffective. Motorized ground sprayers now used can through the fungicide droplets only up to a height of 25 meters and taller trees in certain estates do not get sufficient protection. Absence of tractor lanes in rubber plantations is a set back for using tractor mount sprayers. Non-availability of sufficient number of helicopters for aerial spraying and the difficulty in importing their spare parts, is another constraint. In the case of crown budding the difficulty in budding at a height of 2.5m and poor budding success prevented its wide applicability.

Future priorities

Clonal variations have been noticed in the susceptibility of rubber to abnormal leaf fall and more research is needed on the host parasite interrelationships to understand basis of resistance. Exploration for resistant germplasm from the centres of origin of different species of *Hevea* can be undertaken. We have a collection of nearly 4500 germplasm materials from Brazil, the centre of origin of rubber. Large scale screening of the germplasm material to locate sources of resistance to *Phytophthora* is now under way. The molecular tools can be effectively used to locate markers linked to resistance in the *Hevea*. These genes can be introduced into clones, which are otherwise agronomically desirable to generate transgenic plants. Agrobacterium mediated transformation at callus stage and subsequent regeneration of transformed plants now being carried out at the RRII offers a new pathway for development of resistance clones.

Automatic weather stations are to be installed both in high and low rainfall region so that epidemiological models can be prepared, correlating the various weather parameters with actual leaf fall to forecast disease more effectively. Ground spraying using micron sprayers is the cheapest method of protecting rubber against abnormal leaf fall. Attempts are being made to introduce more effective less labour intensive sprayers. Another area in which research is to be concentrated is developing effective, cheaper substitutes to copper fungicides. To prevent pollution by spraying fungicides, alternative methods of protection are to be identified.

Reducing inoculum density is another method of controlling the disease. Biological control using more effective antagonists of *Phytophthora*, which can provide prolonged protection, can be attempted. It may not be possible to maintain a large population of antagonists continuously on the tree as it is deciduous. However, reduction of inoculum in soil using antagonists can be tried. Defruiting using growth regulators is nother technique to reduce the inoculum build up. As the intensity of abnormal leaf fall vary with location and clone, clone wise and location specific recommendation for plant protection has to be evolved to optimise the use of chemicals and reduce their impact on the environment.

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