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Chapter 17

Root diseases and non-microbial maladies

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1. INTRODUCTION

Rubber trees are affected by several root diseases causing severe damage in most rubber growing countries. However, in India, their occurrence is sporadic. The most damaging root disease, white root disease, has not been reported from India.

Maladies of non-parasitic nature also affect rubber plantations, sometimes causing extensive damage. Vagaries of nature such as sunscorch, drought, wind, lightning, hail-storm, *etc.*, affect the trees. Certain phanerogamic parasites also parasitize the rubber trees.

2. ROOT DISEASES

Roots of rubber trees are susceptible to several diseases which, if neglected, will result in appreciable reduction in stand. Among the root diseases, white root, red root and brown root diseases are the major ones. The minor root diseases include dry root rot, *Poria* root rot, black root rot, stinking root rot, *Rhizoctonia* root rot (John, 1964), *Armillaria* root rot and purple root disease.

The intensity of root disease incidence varies with countries. In Malaysia, Sri Lanka, Indonesia and Ivory Coast, root disease is a very serious problem and plant protection operations are mainly directed towards root disease control. The intensity of root disease is very mild in Thailand, Burma and Vietnam. In India, root diseases are not a serious problem and only sporadic occurrence is noticed.

Rubber trees are affected by root diseases irrespective of age and can ultimately lead to their death. In general, the diseases spread by root contact, the source of inoculum being infected stumps of felled rubber or jungle trees. The survival structures of the pathogen are mostly rhizomorphs. Disease affected trees are generally identified by canopy symptoms.

2.1 Brown root disease

Brown root disease is the only major root disease reported from India (Ramakrishnan and Pillay, 1962). Low incidence of brown root rot has been noticed in Assam and Tripura (Mondal *et al.*, 1994). The disease occurs in patches or may be widely scattered. The occurrence is sporadic and often noticed in replanted areas and in sandy or light soils. Brown root disease is reported from Malaysia, Sri Lanka, Africa, Congo and Thailand but is of less significance as compared to white root and red root disease.

2.1.1 Disease development and symptoms

The symptoms visible above ground are leaves losing their shiny appearance, drooping and partial or extensive yellowing and buckling of the foliage (Plate 50. a) accompanied by growth retardation. The leaves turn purplish or reddish yellow and in course of time dry up and may shed or remain attached to the tree (Plate 50. b,c). Occasionally, flowering and fruiting also occur indicating disease-induced stress. The twigs dieback and eventually the tree also dies.

The typical symptoms of brown root disease are seen on the roots. The infection occurs on one or more of the lateral roots or on the tap root or on both. The surrounding soil and small stones form a thick coating around the infected root (Plate 50. d). This soil encrustation is very hard and yellowish brown patches of fungal rhizomorphs can be seen when the soil is removed. The cortex appears brown, mottled with white patches internally. The wood shows brown discolouration and brown lines are often noticed in the wood.

2.1.2 Causal organism

The disease is caused by the fungus *Phellinus noxius* (Corner) G.H.Cunn. This fungus is widespread in the tropics and attacks several other perennials like breadfruit tree, coffee, tea, Ceara rubber, jack and cocoa.

The bracket-shaped fruiting bodies of the fungus are very rarely seen. Large hard brackets may be seen attached to the base of the old infected trees or stumps. These are dark grey on the underside and brownish purple or black on the upper surface with prominent growth rings and a yellowish margin. Innumerable pores are seen on the underside and basidiospores are produced in profusion from these (RRIM, 1974a). The spores blown by wind may cause stump infection which help in further spread of the disease. However, the chief method of spread is by root contact.

2.1.3 Control measures

The stumps of cut rubber or other host trees serve as a reservoir of inoculum and infection is likely when planting is done close to the stumps. While replanting, care should be taken not to plant very close to earlier planted rows.

Control of the disease is effective if tackled in the initial stages of infection. The trees which show yellowing of leaves should be treated. The soil around the tree base should carefully be removed and the root system exposed. The roots are to be traced to see if there is any infection. Dried portions of roots should be cut and destroyed by burning, along with any stump and wood pieces lying in the soil in the neighbourhood. In the case of partially affected roots, the affected portions may be scraped. All the exposed portions should be washed with fungicide solution and when dry, a petroleum compound applied (Ramakrishnan and Pillay, 1962). *In vitro* screening of fungicides has shown that thiram (TMTD), propiconazole, triadimefon and tridemorph are effective (Rajalakshmy and Arthassery, 1994). The fungicide recommended for brown root disease in India at present is one per cent tridemorph (Calixin) or one per cent propiconazole (Tilt) solution (Rubber Board, 1999). The petroleum compounds generally used are atlasol, rubberkote, sopkot, *etc.* After treatment, the tree base is packed firmly with soil and drenched around with the fungicide solution. As a prophylactic measure, the neighbouring trees may be protected by drenching their root surroundings with the fungicide solution. The fungicide solution can be poured into a funnel-shaped furrow made around the tree base. Sometimes, by the time the canopy symptoms are noticed, the infection might have progressed to such an extent that the treatment would not be effective. In such cases, the tree has to be uprooted and the whole root system destroyed. In Malaysia, painting the collar with 10 per cent tridemorph incorporated in a bitumen or grease base is recommended for preventing the disease (RRIM, 1974b).

The possible role of potential antagonists in brown root disease control has been studied. The total actinomycete population was 1.8 to 3.5 fold in the rhizosphere of *Hevea* than in the soil away from the root zone. Higher degree of antibiosis was observed for actinomycetes isolated from the rhizosphere of the clones Fx 516 and PR 107 (Kothandaraman *et al.*, 1991). *Trichoderma* spp. are found effective against *Phellinus noxius* infecting rubber. Stimulation of growth of rubber seedlings was observed when *T. hamatum* and *T. harzianum* were introduced in the rhizosphere (Jacob *et al.*, 1991).

2.2 White root disease

White root disease poses the most serious problem in Malaysia, Sri Lanka, Congo and Ivory Coast. The losses are more in replanted areas, previously infested with the disease.

The disease appears in the stand a year after planting, reaching the peak period of infection in the fourth year. This disease alone is responsible for more losses than red root disease and brown root disease together. White root disease is not prevalent in India.

2.2.1 Disease development and symptoms

Yellowing of the foliage is the external symptom of the disease. The infection can readily be identified by the external rhizomorphs on the root. The rhizomorphs are firmly attached to the roots, forming a network as they advance. They are initially pure white in colour, but later assume a yellow or faint reddish brown colour depending on the colour of the soil. The rhizomorphs vary in size and the thickest are seldom more than 4.5 mm thick. Sometimes they unite to form a continuous sheet. When the fungus appears above ground level, the strands become subdivided into finer threads. Apart from these external rhizomorphs, the infected roots show no other distinguishing features. The infected wood remains hard and brown with a greyish tinge (RRIM, 1974a).

2.2.2 Causal organism

White root disease is caused by *Rigidoporus lignosus* (Klotzsch) Imazeki. Strands of *R.lignosus* can traverse small distances through soil but die, if separated from their base. The disease generally spreads by root contact. New infection can arise at the time of felling trees through wind or insect-borne spores of the pathogen colonizing the stumps.

Fructifications are bracket-shaped, unstalked and formed in many tiers. They are orange yellow with parallel zonations and white margin on the upper surface and orange red or brown with numerous minute pores on the lower. The bracket generally appears at the collar region of diseased trees and on rotting stumps, particularly during wet weather.

2.2.3 Control measures

Close watch of the foliage at quarterly intervals from the first year of planting is necessary for disease detection. The collar of diseased as well as neighbouring plants are inspected for the presence of rhizomorphs. The plants in the initial stages of infection and the neighbouring healthy ones are given protective fungicide dressings (Fox, 1966). A collar protectant dressing containing 20 per cent pentachloronitrobenzene (PCNB) in a grease base was developed in Malaysia (RRIM, 1974b). Tillex was found effective against white root disease (Tan and Lim, 1971). In the past, PCNB was widely used in Malaysia and Sri Lanka (Fox, 1966; Liyanage, 1984). However, PCNB being carcinogenic, was banned and it was found that two per cent pentachlorophenol (PCP) could be used for white root disease management in Sri Lanka (Jayasinghe *et al.*, 1994). Though effective, the method of control by collar dressing is very laborious. A simpler soil drenching method has been developed for white root disease control in West and Central Africa and promising results are obtained in Ivory Coast with 10 g tridemorph per tree (Tran, 1985a; 1985b). Recently, triazole fungicides have been reported to be effective and triadimefon (Bayleton) and propiconazole (Tilt) are recommended in Malaysia (Tan and Hashim, 1991, Chan *et al.*, 1991). The dosage is 5 g a.i. per tree (20 g triademefon or 20 ml propiconazole) in 2 L of water for two to five-year-old trees. For younger trees below the age of two years, the rate is halved (10 g triadimefon or 10 ml propiconazole in 1 L of water). Two drenchings at six-monthly interval give satisfactory control. Further experiments have shown that a still lower dose of propiconazole, *i.e.* 7.5 ml per tree is effective (Chan *et al.*, 1991). Fungicide drenching with triadimefon, triadimenol and propiconazole appeared promising for the control of white root disease in China (Tan, 1990). Generally, disease control in plants showing foliage symptoms is not effective since the disease would have reached an advanced stage by that time.

The use of antagonistic microorganisms like *Trichoderma* spp. has been tried in white root disease control (Jollands, 1983). The disease control was improved when fungicide drenching was integrated with *Trichoderma* (Hashim, 1990). The fungi *Trametes* sp. and *Schizophillum commune* are reported to have antagonistic properties against *R. lignosus* in *in vitro* (Jayasuriya and Deacon, 1995). The potential of furfuraldehyde as a mild fumigant in weakening the pathogen was also explored. (Jayasuriya and Deacon, 1996; Jayasuriya *et al.*, 1996). Amendment of surface soil with sulphur, while refilling the planting holes activates antagonists and thus reduces the disease incidence (Sachuthananthavale and Halangoda, 1971; Hashim and Taat, 1985). In Ivory Coast, *Tithonia diversifolia* used as a cover crop is found to reduce the incidence of white root disease (Rao, 1972).

2.3 Red root disease

The disease causes considerable damage to young rubber from the third to the eighth year of planting in Malaysia and China. Red root disease has not been reported from Sri Lanka and India.

2.3.1 Disease development and symptoms

External symptom of the disease is yellowing of foliage, but such symptoms appear only after a lapse of many years after infection. Those plants that look healthy externally may sometimes be completely infected. The rate of progress of the disease is slow. The affected plants produce numerous adventitious roots from the unaffected root portions.

In mature trees, the woody tissue of attacked roots degenerate into a soft spongy mass from which water can be squeezed by light pressing. This condition is not very obvious in young plants. The mycelium forming a red mat around the infected root is a typical characteristic of the disease. This can be seen only when the soil is washed away. When the mycelial strands are young, they are light red and when dry the colour fades to dirty white, but reappear on moistening. The older strands appear deep claret and remain unchanged on drying. When the roots are rotten, the colour of the rhizomorphs approaches blackish violet. A single separated rhizomorph is seen only occasionally. The red fungal mat is not formed on portions exposed to light. The wood shows discolouration with brown or black lines. Honeycombing of the wood is also seen. In the advanced stage, annual layers of the diseased wood become so disintegrated, that they resemble mummified roots with an external red mat surrounding an aggregated mass of fungal tissue.

2.3.2 Causal organism

The pathogen responsible for red root disease is *Ganoderma philippii* (Bres. & P. Henn.) Bres. Spread of red root disease is mainly by root contact. Infection from spores may also occur. Fruiting bodies are hard, woody brackets with dark reddish brown, wrinkled upper and ashy white lower surfaces with creamy white margin bearing spores in abundance (Plate 51. a). Fructifications are generally rare and occur at the collar region of the affected plants (RRIM, 1974a).

2.3.3 Control measures

Formulations containing 10 per cent drazoxolon or tridemorph are recommended as protective dressings against red root disease in Malaysia (Tan and Lim, 1971; Rao, 1972; RRIM, 1974b). As in the case of other root diseases, pre-planting eradication of sources of inoculum is carried out, followed by measures to prevent spread in the stand. In case of infection, early detection and treatment of infected areas are recommended. Chemically-assisted stimulation of antagonistic microflora by fumigation with methyl bromide or Vapam in combination with mulching, application of NPK fertilizers and drenching with drazoxolon are reported to control red root disease (Varghese *et al.*, 1975). An integrated control system involving pre-planting removal of sources of infection, post-planting inspection and treatment by drenching 0.75 per cent tridemorph (Calixin) at six-monthly intervals for two years was found useful in China (Tan and Fan, 1990).

2.4 Dry root rot

Dry root rot is generally noticed in old rubber areas and is reported from Malaysia, Sri Lanka, Indonesia and India.

2.4.1 Disease development and symptoms

Infection occurs during wet weather. Copious exudation of latex from the affected area at the collar is the first symptom noticed. Further, grey, crust-like fruiting bodies are seen on the bark surface at the collar region. By this time, the disease would have reached an advanced stage. The infected root shows symptoms of dry rot. Double black lines can be seen in the bark as well as on the wood. They run irregularly in the tissues forming circles surrounding dark-coloured patches of diseased wood. There are no external mycelia on the infected root. Sometimes when the bark is removed, white patches of felt-like mycelia may be observed on the surface of wood (Sharples, 1936). The progress of the disease is slow. The fungus is largely confined to the medullary rays. The infected tissues become soft and dry, and the affected trees are blown over by wind. Profuse adventitious root formation is also noticed.

2.4.2 Causal organism

Dry root rot is caused by the fungus *Ustulina deusta* (Hoffm. ex Fr.) Lind which is a wound parasite. Spores are produced in abundance in the fruiting bodies and are disseminated by wind or insects.

2.4.3 Control measures

Sanitation greatly helps in the prevention of the disease. The accumulation of earth scrap at the base of the tree for a long time results in suffocation of the cortical layers beneath and predisposes roots to the attack of *Ustulina*. So, care should be taken to avoid accumulation of latex at the base of the tree. Unnecessary wounding of trees at the collar region may be avoided. Adequate manuring may be carried out to improve tree vigour (Ramakrishnan and Pillay, 1961).

Fruiting bodies on the affected trees are scraped off after washing with thiram 0.75 per cent and are destroyed along with rotten tissues. Subsequently thiram paste in petroleum compound (10 g of Thiride in 1 kg of petroleum compound) is applied on the wound (Idicula *et al.*, 1990).

2.5 Stinking root rot

Stinking root rot was first recorded in Sri Lanka in 1907. It is reported from Malaysia, China and India. Generally it occurs in low-lying areas, especially after floods. The disease is so called since the infected rubber roots and the surrounding soil have a foul smell.

2.5.1 Disease development and symptoms

The leaves of the affected tree become flaccid and turn yellow and are shed in severe cases. The branches also die back. The progress of the disease is slow and it takes a long time to kill the tree. The affected roots can be distinguished by the presence of black flattened radiating rhizomorphs which are seen between the bark and the wood. No external rhizomorphs are seen. When fresh and growing vigorously, the rhizomorphs are greyish white with scattered reddish tinge. Later, they become deep red in colour and turn black with the death of the root. Even when the rhizomorphs have decayed, their former position is indicated by the presence of corresponding dark lines on the wood. Orange red pins with pinkish white heads (Plate 51. b) containing a mass of spores is another characteristic symptom of the disease (Sharples, 1936).

2.5.2 Causal organism

The disease is caused by the pathogen *Sphaerostilbe repens* Berk. & Br. The fungus produces both sexual and asexual spores. Sexual spores are borne on small, dark red, globular perithecia. The asexual stage known as 'stilbum', consists of red or pinkish heads with red stalks. This stage arises from the submerged rhizomorphs in the cortical tissues of the diseased root. Perithecial stage follows conidial stage. The spores are readily disseminated by wind and cause new infection. The disease is spread locally by root contact.

2.5.3 Control measures

Maintenance of good drainage is important since the pathogen generally does not infect healthy plants in well-drained soil. Diseased plant material may be removed and destroyed.

2.6 *Poria* root rot

Poria root disease of rubber tree was first reported in 1905 in Sri Lanka on roots of two-year-old plants. Later, the disease was reported from Tropical America (Weir, 1926), Malaysia (RRIM, 1974a) and India (Rajalakshmy and Pillay, 1978) on a mild-scale.

2.6.1 Disease development and symptoms

Yellow discolouration of leaves is the only external symptom of the disease. The affected root shows soil encrustation as in the case of brown root disease, but to a lesser extent (Plate 51. c). Around the root, the fungus forms a complete mat, pale white in colour intermingled with brick-red and black tinges. The wood also shows discolouration.

2.6.2 Causal organism

The pathogen causing the disease is *Poria vincta* (Berk.) Cooke. Flat and plate-like basidiocarps are formed at the collar region of the affected tree closely adpressed to it. They are brown when young becoming greyish brown later on. Spores, produced in profusion, cause fresh infection when disseminated by wind.

2.6.3 Control measures

Control measures adopted are similar to that for brown root disease.

2.7 Black root disease

Black root disease is another minor root disease of *H. brasiliensis*. The disease was first reported from Sri Lanka (Petch, 1923) and is widespread there (Munasinghe, 1971).

2.7.1 Disease development and symptoms

The first recognizable symptom is the appearance of clusters of fructifications which arise from the dead lateral roots especially at the collar region of the tree. A continuous, thin smooth and black fungal mat is seen around the affected root. Rarely, a slight soil encrustation is also found. Bark and wood become discoloured and the wood remains hard. Wetness in this region is a major characteristic feature. On infected tap roots, exudation of latex is noticed. The absence of any marked foliar symptoms even at the advanced stage of infection is another feature of the disease. Reduction in refoliation vigour resulting in thin canopy is the only noticeable symptom. With the rotting of roots, the tree is often uprooted by wind.

2.7.2 Causal organism

The pathogen causing the disease is *Xylaria thwaitesii* Berk. & Cooke. The fungus advances in a fan-like pattern. The growing portion is white but it rapidly turns grey to black in colour. The fruiting bodies arise as white knob-like structures developing into erect clubs 2 to 6 cm in height and 0.5 to 2.0 cm in diameter. Each cluster may have 2 to 30 fructifications. Perithecia are produced from the lower parts of the fructification. Spores can cause new infection. Generally, the disease spreads by root contact.

2.7.3 Control measures

Treatment with 10 to 15 per cent PCNB in grease base (Fomac) along with destruction of inoculum gives effective disease control (Munasinghe, 1971).

2.8 Purple root disease

Purple root disease has been reported from Uganda (Snowden, 1921) Dutch East Indies (Boedijn and Steinmann, 1930), Indonesia and El Palmar (Martin, 1947). In China, purple root disease is more widely distributed than white and red root disease causing destruction of rubber seedlings and immature and mature rubber trees (Zhang and Chee, 1989a,b). The disease is not reported from Malaysia, Sri Lanka and Thailand (Chee, 1990). In India, the disease is reported on a mild-scale (Rajalakshmy and Joseph, 1994).

2.8.1 Disease development and symptoms

The infected plants have sparse crowns and shrivelled appearance and a badly damaged root system. By profuse formation of adventitious roots, the plants generally withstand the attack. The presence of distinct fruiting bodies girdling the collar region of infected seedlings is another important feature of the disease (Plate 51. d). The bark of the affected root rots away completely and sloughs off easily exposing the wood. Purplish brown rhizomorphs traverse the root surface as a net or cover the whole bark surface of the root.

2.8.2 Causal organism

The fungus *Helicobasidium compactum* Boedijn is responsible for causing purple root disease which spreads by root contact.

2.8.3 Control measures

Elimination of all diseased planting material, providing good drainage system and improving the vigour of the trees help in the prevention of the disease. Drenching the soil with tridemorph or carbendazim was found to be effective in China.

2.9 *Armillaria* root rot

Armillaria root rot is a major root disease in West and Central Africa. It has not so far been reported from Asia. The pathogen is *Armillaria mellea* (Vahl. ex Fr.) P. Karst.

3. NON-MICROBIAL MALADIES

Non-microbial maladies include physical damage due to sunscorch, drought, wind, cold, lightning, fire, hailstorm, waterlogging, chemical toxicity and also deformities like fasciation and woody nodules. Self-pruning, stem bleeding, *etc.*, also come under non-microbial maladies of the rubber tree.

3.1 Sunscorch

Rubber plants are highly susceptible to sunscorch. The damage due to sunscorch is more for young plants in the nursery and in the field. In the field, when the canopy closes, the plants are protected from exposure. In the case of young nursery seedlings, bark at the collar region gets scorched resulting in girdling effect and the affected seedlings dry up subsequently. This is mainly due to heating up of the soil around the collar.

In young clearings, bark at the collar region or above on the side facing south or south-west often gets damaged owing to sunscorch. In the affected cases, bark dries up and sometimes exudation of latex is noticed. In budded plants the dead snags of stocks often fall off, leaving a depression above the bud union. When this faces south or south-west, sunscorch becomes more prominent and the dried bark becomes adpressed to wood forming a depression in the shape of a spearhead (Plate 52. a). The affected bark is often colonized by secondary colonizers like *Diplodia* spp. In due course, cracks are developed in the affected bark. The bark falls off exposing the wood which becomes greyish or blackish in colour. Such plants, if left untreated, dry up ultimately or break at the affected point and are likely to be blown over by wind. Care should be taken to avoid the bud patch facing south or south-west while planting.

Application of black panel protection/wound dressing compound may also cause scorching of the bark, if the treated parts are directly exposed to sun. To overcome this, as a general practice, treated portions may always be whitewashed using lime.

Sunscorch incidence can be prevented by providing dry organic mulch for nursery plants and young rubber planted in the field. Providing suitable shade with bamboo basket (tree guard) or plaited coconut leaf during the first year of planting is desirable as an added protection. In sunscorch-prone areas protective covering with locally available thatch grass or hay is found to be very effective. From second year, young plants may be white-washed using lime from the collar up to the brown portions of the bark. Whitewashing may be carried out before the beginning of the dry weather, preferably in November itself or latest by December. For whitewashing, fresh quick lime is superior, though china clay can also be used. In the case of affected plants, if the damage is not deep and extensive, the lesion may be scraped to remove all dried up bark and washed well with 0.75 per cent mancozeb (Dithane/Indofil M45) solution. When the fungicide dries up, a wound dressing compound may be applied as a thin coating, to facilitate quick healing of the wounds. Treated plants may also be whitewashed.

3.2 Drought

Performance of the *Hevea* tree is highly influenced by water relations and the cultivation of the crop is ideal if confined to humid areas where hardly any stress conditions prevail. Rubber trees have to confront conditions of soil moisture stress in the non-traditional areas like Orissa and Maharashtra. Even in South India, where rubber plantations are raised in rainfed areas, the wet season may be followed by six months of dry period extending from October/November to March/April. Seasonal droughts are common in humid climates where wet and dry seasons are clearly defined. (Thornthwaite, 1947). The unusual drought in India during 1986-87 caused an yield drop of 36 to 37 per cent as compared to favourable wet season yield of 1987 (Rao, 1991). Besides yield depression, drought leads to drying up of field-planted young budded plants. The leaves become white, papery in texture and dry up. Even rubber trees more than 10 years in age die back and dry due to severe drought and the effect persists (Plate 52. b). Another effect of drought is early inducion of wintering which further results in yield depression. Stand establishment and growth of rubber trees are also affected by drought. Life-saving irrigation or soil injection with water may be done to overcome the effects of acute drought (Mohankrishna *et al.*, 1991; Chandrasekhar *et al.*, 1994; Vijayakumar *et al.*, 1998).

3.3 Wind damage

Wind damage is a very serious problem in rubber plantations. Some clones like Tjir 1, RRIM 501, RRIM 605, RRIM 623 and PB 311 are inherently susceptible to wind damage. Clones like PB 86, PR 107, PB 5/51 and GT 1 are reported to be wind-fast (Rubber Board, 1999). Wind damage is observed in rubber plants of all age groups. The growth of young plants in exposed and wind-lashed areas becomes very much stunted. The leaves of plants in such locations are observed to be lacerated and crinkled and the crown becomes sparse and open. In older plantations, wind damage may be in the form of uprooting, trunk snap or branch break. Uprooting (Plate 52. c) usually occurs in soils with shallow profile, high water table or a laterite hard pan. Branch snap is common in clones like PB 5/63, RRIM 605, RRIM 607 and Tjir 1. In this case, the branches are torn off in the region of crotch. Trunk snap (Plate 52. d) is the most serious form of wind damage. Breakage can be at any point of the trunk. If the breakage occurs in tapping panel region, the tree is beyond repair. Clones susceptible to trunk snap are RRIM 501, RRIM 603, RRIM 605, RRIM 614, RRIM 623 and PB 311.

Usually, tall trees with heavy crowns are affected by wind. The intensity is more near vacant patches within a stand and is severe during wet months. The trees which are opened for tapping have a reduced rate of girthing which sometimes is not compensated by proportionate reduction in crown growth. This condition, which is more pronounced in some clones like RRIM 501, makes the trees more susceptible to wind. Trees with heavy main branches and those with branches arising at narrow angles from the main stem are more susceptible to wind damage. Wind damage is high in elevated areas. Thus, height of trees, unbalanced branches, heavy canopy and extra weight due to water carried on the leaves after rain, coupled with the poor girth increment on tapping, all add to the tree being top-heavy and having high turning movement around the trunk. The presence of gaps in ravines or vacant patches in the stand may bring about lateral imbalance.

Planting of fast-growing trees on the borders to form a windbreak is one of the measures to mitigate the adverse effect of wind on young plants. Growing an intercrop like banana also reduces the damage to young plants due to strong wind. In the case of susceptible clones, application of balanced fertilizer on the basis of soil and leaf analyses is helpful in avoiding wind damage. Early selective pruning of heavy lateral branches to reduce crown weight and to develop a balanced canopy also helps in prevention of wind damage.

3.4 Cold damage

Though *H. brasiliensis* is a tree species which originated in a tropical rain forest, it exhibits inherent adaptability to withstand low temperatures, but at temperatures below 5°C, symptoms of cold injury are noticed. The response to low temperature varies with clone, age, parts and vigour of the tree. The type and intensity of damage differ from location to location and year to year. Due to low temperature stress, brown spots appear on leaf blades at tips and margins, extending to the whole leaf in due course which become discoloured and dry, finally falling off. In severe cases, die-back of injured twigs or drying of young plants occurs. On trees under tapping, necrosis of tapping panel is also noticed. Two types of damage *viz.* chilling injury and freezing injury, are noticed due to low temperature stress. No ice formation within the tissues is observed in chilling injury, while in freezing injury ice forms within tissues. Both lead to breakdown of plasma membrane and to increased cell permeability which in turn cause solute leakage, sharp increase in plasma concentration and metabolic disorder.

Cold resistance is a genetic character and varies with clones. GT 1 and IAN 873 have better cold resistance whereas clone RRIM 600 has poor. SCATC 93-114 and Hekou 3-11 are reported to be cold-tolerant clones (Senyuan, 1990; Xu Wenxian and Pan Yanqing, 1990) in China. Chilling injury at temperatures below 0°C is the dominant limiting factor for rubber cultivation in North China (Xu Wenxian and Pan Yanqing, 1992). Effect of cold is prolonged and predominant in North India especially in the north-eastern region. The cold season begins in December and ends in February. The minimum temperature at Agartala and Guwahati goes down to 10°C and at Tura to 8°C in January. The effect of cold climate is more pronounced at a higher altitude of 600 m above msl at Tura where only 8.5 per cent of the annual girth increment is contributed from December to February. Yield obtained is low to normal. Latex dripping continues even 8 to 9 h after tapping and the DRC sometimes goes down below 18 per cent. Plugging index, photosynthetic rate and transpiration are low. Clones like RRII 5, RRII 203, RRIM 605 and GT 1 show some tolerance to cold (RRII, 1994).

3.5 Lightning damage

Rubber trees of all age groups are susceptible to lightning injury. Lightning may affect a group of trees in lines or in a scattered pattern. Even a single tree may sometimes be affected (Plate 52. e). The extent of damage on trees varies. The manifestation of visible symptom of distress is sudden. Seriously affected trees are completely killed and dry up within a week. Partial damage to main stem or to some branches may also occur. In the affected portion, exudation of latex is often observed from several points and the bark gets separated from the wood. The damaged bark is colonized by borer beetles. A characteristic feature is that the cambium tissue is damaged first and as a result, the cambium and the inner bark are coloured scarlet or dark violet. Tissue damage starts from the cambium, extending through the bark in an outward direction. Soon after lightning damage, incidence of patch canker also increases.

After the incidence of lightning, the extent of damage may be assessed by careful examination. Completely affected and killed plants may be removed. In the case of partially affected plants, the damaged bark may be scraped off and washed with 0.75 per cent mancozeb (Dithane/Indofil M45) solution. When the fungicide dries up, a wound dressing compound may be applied on the treated surface. If the affected plants are exposed to sun, they may be whitewashed after the treatment.

3.6 Fire damage

Young rubber plantations with accumulated mulch due to the luxuriant growth of cover crop and mature plantations with accumulation of dried leaves following wintering are highly prone to fire damage during the dry summer months. Fire may be from a neighbouring jungle, due to carelessness or by accident. The extent of damage varies from superficial burning of dead bark to deep injury and burning of the healthy bark. The lower leaves become scorched and dead. Exudation of latex from scorched bark portion is often noticed (Plate 52. f). Colonization of damaged bark by borer beetles and high incidence of patch canker are also observed following fire damage.

To prevent fire damage, all precautionary measures may be adopted. During the summer, firebreaks may be made and maintained. Warning boards may be put up in different locations to prevent fire. Smoking and lighting of fire within the plantation should be strictly prohibited. In affected areas, the treatments to be adopted are similar to those for lightning damage.

3.7 Hailstorm

Hailstorms are common in North East India and generally occur along with pre-monsoon showers. Hailstorms with normal wind velocity and normal-sized ice pieces do not cause serious problems. But thunderstorms accompanied by high wind velocity and large hailstones caused serious damage to rubber trees. Chiselling of bark causing serious injuries damaging even the cambium is noticed. Bark regeneration in such areas is uneven with many protuberances and takes many years to become near normal. Latex vessels are damaged, causing yield depression. Branch and trunk snap and splitting of trunk are also noticed. Nursery and immature plants are also seriously damaged (Meenattoor *et al.*, 1995). Affected bark may be treated as in the case of lightning damage.

3.8 Waterlogging

Young rubber plants are highly vulnerable to damage due to stagnant water in the soil. Because of stagnant water, the roots rot and the plants die off. The collar region of affected plants show enlargement of lenticels. The leaves turn papery white and wither away. Care should be taken to provide good drainage for plants in polybags in the nurseries and in the field.

3.9 Chemical toxicity

Rubber plants are susceptible to chemical injury caused by use of excess spray oil, old stock of copper fungicide, certain types of coaltar, kerosene oil and some rainguard adhesives. Certain clones like Gl 1 and LCB 1320 are found to be more susceptible to this. In the case of injury on leaves, they often turn yellowish and fall off. In some cases, tissues of the leaf lamina dry up in patches (Plate 52. g). These symptoms are noticed when phytotoxic oils or excess of diluent oil-fungicide mixtures are sprayed on trees. Phytotoxicity due to spray oil is seen on plants within four to six days after spraying. Oil-based copper fungicides stocked for long periods sometimes cause phytotoxcity on rubber plants. Oil-based copper fungicide applied on the bark as a paste also causes such phytotoxicity. Certain types of coal tars and mineral oils like kerosene are also phytotoxic. In the nursery, physical contact of fertilizers with shoot portion of the plant causes injury to the tissue. Application of excess quantity of chemical fertilizers and high dose of copper fungicide to very young plants may cause scorching and defoliation. Drift of herbicides on to young plants can also cause such damage. Kerosene added to panel protection compounds for dilution, can cause severe phytotoxic symptoms on the bark. In such cases, profuse exudation of latex is noticed from the affected bark which later becomes deep grey to chocolate brown in colour and dries up in due course. Some rainguard adhesives also cause injury to the bark. Chemical toxicity also occurs when growing regions of young/nursery plants come into contact with weedicides like 2,4-D. In such cases, growth malformations may be seen. Care should be taken in handling weedicides near nurseries and young clearings. To avoid chemical toxicity, planters should use only materials recommended by the Rubber Board at proper dosages.

3.10 Fasciation

Certain deformities of growth resulting in flattened, curved and branched or unbranched shoot growth with many scale leaves and buds are occasionally noticed on rubber plants. This phenomenon could be due to clustered cell division or fusion of cell walls. The exact cause of such abnormal growth is not fully established. Very often, removal of the fasciated shoot results in normal growth.

3.11 Woody nodules

Woody nodules are sometimes noticed in the cortex of rubber plants. Nodules are found fully or partially embedded in the bark. Nodules may be round, oval or irregular in shape and vary in size (Plate 52. h), at times forming woody projections termed burs. The woody nodules are formed as a result of abnormal meristematic activity outside the normal cambial layer. Trees growing under unfavourable conditions, especially in areas with prolonged drought or heavy wind are observed to produce woody nodules in the bark. By a gentle tap on the projected portion of the nodule above the bark surface with a tapping knife, the woody nodule comes out of the bark. They could also be extracted easily from the bark with a sharp knife. A thin layer of bark is generally found underneath the nodule, separating it from the wood. Exact reasons for the developments of such nodules are not known. Woody nodules, when observed, may be removed and the wound treated with a petroleum compound to facilitate quick healing.

3.12 Self-pruning

In young rubber plantations (5 - 10 years), self-pruning of lower branches is noticed. This is more in areas with vigorously growing plants and where the stand per ha is higher than normal. Because of vigorous growth, the canopy closes early and complete shade prevails. Under the shaded conditions, the leaves on the lower branches turn yellow and fall off. The defoliated branches start drying up and fall off in due course. After initiation of the process of drying, borer beetle attack is sometimes noticed on such branches. Since the lower branches dry off owing to shade effect only, no treatment is required.

3.13 Stem bleeding

Certain clones like PB 86 show small swellings on the stem and exudation of latex from many points especially on the south-western side. The only remedy is to protect them from sunscorch by whitewashing. When the tree grows older, it will be rectified. Stem bleeding is a clonal character of PB 235 and PB 5/51 also and the damage is enhanced by infection of pathogens like *Phytophthora.*

3.14 Phanerogamic parasites

Dendrophthoe falcata (mistletoe) and *Cuscuta campestris* are two phanerogamic parasites noticed to cause some damage to rubber plants. *Dendrophthoe* is a semi-parasite. Though the leaves possess chlorophyll and synthesize carbohydrates, mineral nutrients and water are drawn from the rubber plants through haustoria. *Cuscuta* (dodder) is a yellow thread-like leafless twiner possessing no chlorophyll and appearing as an intertwining tangled mass on branches. It is totally dependent upon the host for water and nutrients. When these angiospermous plants parasitize rubber plants, the branches become unhealthy and in severe cases die off. The best remedy is to physically destroy such parasites at the initial stage itself along with the host part by cutting and burning of attacked parts. So far, no selective chemical is available for the control of these parasitic plants.

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