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Chapter 8

Agroclimate

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1. INTRODUCTION

The natural habitat of rubber (*Hevea brasiliensis*) is the rain forests of the Amazon basin, situated within 5° latitudes at altitudes below 200 m. The climate of this region is equatorial monsoon type characterized by mean monthly temperature of 25 to 28°C, well-distributed rainfall with no marked dry period (Strahler, 1969; Bradshaw, 1977). The trees evolved in this environment have developed a preference for warm, humid weather (Polhamus, 1962; Opeke, 1982). Under commercial cultivation, rubber trees perform best in climates closely resembling that of its original habitat.

Rubber is predominantly grown in the tropics where an equatorial monsoon climate prevails. This comprises a large region between 10°S and 8°N latitude and includes most of the Indonesian archipelago, Malaysia, southern part of Sri Lanka and some other islands. The main characteristics of this region are the existence of a mixture of land and sea surfaces, receipt of an annual rainfall of over 2000 mm and absence of drought, all of which provide a warm, humid and equable climate optimum for the growth of rubber.

Climatic conditions necessary for optimum growth of rubber trees are : (1) rainfall of 2000 mm or more, evenly distributed without any marked dry season and with 125 to 150 rainy days per annum; (2) maximum temperature of about 29 to 34°C and minimum of about 20°C or more with a monthly mean of 25 to 28°C; (3) high atmospheric humidity of the order of 80 per cent with moderate wind; and (4) bright sunshine amounting to about 2000 h per annum at the rate of 6 h per day throughout all the months (Webster and Baulkwill, 1989; Rao and Vijayakumar, 1992).

Only a very few regions in India meet all these requirements. Fortunately, rubber can be grown successfully under moderately deviating conditions also.

2. CLIMATIC FACTORS

The fundamental elements that influence rubber cultivation are rainfall, temperature, sunshine, relative humidity and wind, of which the former two play a very decisive role in selection of areas for rubber cultivation (Table 1).

Table 1. Implications of weather conditions for rubber growth and production

Rainfall (mm)	Rainfall period*	
	8 - 10 months	4-7 months
< 1500	May be suitable	Results not available
1500 - 2000	Sufficient to raise good plantation Immaturity period below 7 years Rainguarding may not be necessary	Rubber can be tried Immaturity period may exceed 9 years Rainguarding may be necessary
2000 - 3500	Optimum conditions Immaturity period below 7 years Rainguarding may be necessary	Rubber can be cultivated Immaturity period may exceed 9 years Rainguarding may be obligatory
> 3500	Sufficient to raise good plantation Immaturity period below 7 years Rainguarding may be obligatory	Rubber cultivation possible Immaturity period may exceed 9 years Rainguarding may be obligatory

* T min. 10-28°C with low temperatures for one or two months in winter

* T max. 28-35°C with high temperatures for one or two months in summer

* Areas with prolonged low temperatures of <10°C/prolonged high temperatures of >35°C/rainfall period of less than 3 months may not be suitable for rubber cultivation

2.1 Rainfall

Rubber plants are traditionally grown under rainfed conditions except in nurseries where essential irrigation is given. Ideally, monthly rainfall should be sufficient to meet the water requirement of the plantation. In the tropical monsoon climate, the potential evapotranspiration rate is around 4 mm per day (Montieth, 1977). Therefore, an equally distributed rainfall of 125 mm per month is considered essential to maintain optimum growth. In the traditional rubber growing areas, the total rainfall ranges between 2000 to 4000 mm, spread over 140 to 220 days. It is evenly distributed throughout the year, with not more than one to four dry months. The quantity and distribution of rainfall in the different rubber growing regions show considerable variation.

There is a positive correlation between rainfall deficit and cumulative crop loss during a season (Ninane, 1970; Cretin, 1978). At low soil moisture levels, the rate and duration of latex flow as well as yield are reduced (Buttery and Boatman, 1976; Sethuraj *et al.*, 1984; Devakumar *et al.*, 1988; Vijayakumar *et al.*, 1988; Rao *et al.*, 1990). Clones also vary in their tolerance to moisture stress (Saraswathyamma and Sethuraj, 1975; Vijayakumar *et al.*, 1988). In heavy soils, excess rainfall may lead to problems associated with waterlogging. Heavy rainfall also causes nutrient loss by run off and leaching. Soil erosion is yet another problem.

Some of the rubber growing regions of the world are free from water deficits. Annual water deficits of the order of 200 to 350 mm are found in marginal areas brought under plantations, indicating the adaptability of the species to dry conditions (Moraes, 1977). In such regions, however, there could be water surplus during the rainy season.

Cultivation of rubber is extended even to regions with well-defined and prolonged dry season (of five to seven months) in many countries. Around 15 per cent growth inhibition was recorded in Thailand which has a marked dry season of six months (Saengruksowong *et al.*, 1983). In Ivory Coast, growth of clone GT 1 under dry conditions was found to be reduced significantly (Omont, 1982). At Dapchari, in the subhumid tropics of India, compared to irrigated plants of clone RRII 105, inhibition of growth was observed in rainfed plants (Vijayakumar *et al.*, 1998). The irrigated plants took about six years to mature whereas the rainfed plants took more than 10 years to attain maturity.

Regional yield fluctuations in South India, were related to the moisture availability in soil (Rao *et al.*, 1990). By increasing the availability of moisture to the plant by way of irrigation, or by adopting moisture conservation techniques like maintaining silt pits and mulching, problems of initial establishment, retarded growth and low yield can be avoided to some extent (Haridas *et al.*, 1987; Vijayakumar *et al.*, 1988).

Rainfall exceeding 9 to 11 mm per day is not congenial to high yield owing to difficulties in harvesting and other operations (Liyanage *et al.*, 1984; Haridas and Subramaniam, 1985). A higher than optimum number of rainy days in a year decreases the total yield expected for that year. It is difficult to operate a plantation economically with more than 150 rainy days due to loss of tapping days, unless tapping is done with the help of rainguard and panel protectants. Rainfall higher than 34 mm in 24 h may obstruct tapping. Such conditions may also enhance soil erosion.

The diurnal pattern of rain also has a marked influence on crop harvesting. Rainfall in the early hours of the day or just before the normal time of tapping, makes the bark wet and untappable. Such a condition may necessitate late tapping and will be reflected in a pronounced decrease in the total volume of latex, but may result in increased dry rubber content (DRC) due to increased rate of evaporation caused by high radiation and vapour pressure deficit (VPD). Rain during tapping causes spillage and wash out. Heavy rainfall before latex collection leads to wash out even with the skirt-type of rain guard. When rain occurs after latex collection, an increase is generally noticed in the volume of latex obtained on the next day. However, DRC will be below normal due to dilution of latex as a result of increased moisture availability and higher plant moisture status.

The response of trees to chemical yield stimulation is also influenced by weather and soil moisture. A highly significant positive correlation has been demonstrated between response to stimulation and cumulative rainfall during the months preceding stimulation. Use of chemical stimulants during water stress period is not only ineffective but also harmful to the tree.

2.2 Temperature

Temperature is one of the key environmental factors which influences plant growth. *Hevea brasiliensis*, being a species adapted to moderate temperatures, gets affected by extremes in temperatures. Mean monthly temperatures of 20 to 25°C have been found to be optimum. In South India, temperature ranges between 23 to 34°C, whereas in the Konkan region (North West India) the maximum is 34°C and above for three months and the minimum 20°C or below for five months. Occasionally, temperature rises above 40°C in this region.

High temperature conditions result in higher rates of evapotranspiration, leading to severe soil moisture stress in the absence of rainfall. High temperatures above 37°C, coupled with soil moisture stress, result in injury to leaf and drying of leaf margins (Chandrashekar *et al.*, 1990; Vijayakumar *et al.*, 1998). Thermal injury coupled with water deficit results in increased tree loss. Clonal variation in susceptibility to thermal injury has been reported (Rajagopal *et al.*, 1988). However, drying of leaf margins due to the combined effect of drought and high temperature could be completely prevented by providing adequate irrigation in the North Konkan region (Vijayakumar *et al.*, 1998). Contact shading of leaves by spraying a suspension of china clay was also found to be effective in mitigating thermal injury (RRII, 1991).

In North East India, the mean minimum temperature is less than 20°C for five months and the lowest can be as low as 2°C and the maximum temperature throughout the year is less than 34°C. During periods of low temperature, growth retardation has been observed in North East India and also in China. At Agartala (in North East India) during winter months, the clones RRII 118, RRII 300 and RRIM 600 performed better (Sethuraj *et al.*, 1989). In China, growth of rubber is retarded drastically during winter and the growing period is limited to June to October (Zongdao and Xueqin, 1983). In areas experiencing low temperature the growth rate increases with increase in temperature. The threshold temperature for growth is around 20°C (Jiang, 1988). Clonal variation in susceptibility to occasional low temperature has been reported (Polhamus, 1962).

In China, it has been demonstrated that a 10 day mean temperature of over 22°C at 0600 IST during July to September was conducive to latex regeneration but unfavourable for latex flow. A temperature of 18 to 21°C at 0600 IST on the other hand, favoured latex flow (TCRI, 1986). According to Shangpu (1986), optimum temperature for latex production is 27 to 28°C while an ambient temperature of 18 to 22°C is more ideal for latex flow. High temperature was found to retard latex flow and reduce yield (Lee and Tan, 1979). A significant positive correlation between the temperature at 0800 IST and plugging index was reported (TCRI, 1986).

At altitudes higher than 200 m, for every 100 m rise in altitude, a six-month delay in attaining tappable trunk size has been observed (Dijkman, 1951; Moraes, 1977). This corresponds to approximately 0.6°C decrease in temperature for every 100 m increase in altitude. About 26 per cent growth inhibition has been recorded for different clones under tropical high elevation conditions. At high elevations RRIM 600 and GT 1 were found to perform better than RRII 105. In China, GT 1, Haiken 1, PR 107 and RRIM 600 were found to be better performers in the cold-ridden high altitude subtropical monsoon regions.

2.3 Relative humidity

Transpiration rate is influenced by temperature and relative humidity (RH) of the surrounding atmosphere. Moisture exchange capacity of the atmosphere is indicated by RH. Conditions of high and low RH occur during rainy and dry seasons respectively. In the rainy season, radiation is low and duration of leaf wetness is high.

It has been demonstrated that diurnal variation in latex yield is inversely related to saturation deficit of the air (Paardekooper and Sookmark, 1969; Ninane, 1970). By conducting tapping at different hours of the day, it was found that latex yield was maximum and almost constant between 2000 IST and 0700 IST and decreased gradually to a minimum of 70 per cent of the maximum at around 1300 IST. The decrease in yield during the course of the day is related to increased loss of water due to transpiration and the resultant drop in pressure potential in the latex vessels (Buttery and Boatman, 1976; Devakumar *et al.*, 1988). The recovery of yield in the late afternoon is correlated to reduction in VPD. A sharp decline in yield was also found whenever VPD reached 8 mm and restoration of yield in the afternoon lagged behind the decrease in VPD (Ninane, 1970).

2.4 Sunshine

Though photosynthetic light conversion efficiencies of agricultural crops with closed canopy are in the range of only 7.4 to 10.2 per cent, a positive correlation exists between radiation and biomass production. Effect of sunshine hours on crop growth and productivity is often mediated through its effects on photosynthesis and crop water requirements. Under limited soil moisture availability, longer sunshine duration will have a negative effect on photosynthesis and growth. Any condition contributing to good supply of water to tissues or limiting loss of water by evapotranspiration (ET) is favourable for prolonged flow of latex. Seasonal variations in the availability of water and sunlight result in change in DRC levels.

The duration and intensity of sunshine should have a significant influence on latex sucrose levels (Tupy, 1989). An increase in sunshine duration towards the end of the rainy season is often associated with an increase in latex production. Also, low rubber yield during rainy season can be attributed to reduced sunshine hours.

High radiation and its long duration from December to April cause scorching of bark (spear-head damage) in young rubber plants. To protect the bark, painting of stem with reflectants like lime is adopted in South India. Contact shading of leaves (spraying of leaves with china clay) of young rubber plants is beneficial in reducing radiation effects. Seasonal variation in yield may be influenced by differences in hours of sunshine also, but the exact requirement for optimum yield is yet to be quantified.

2.5 Wind

Wind is another important weather factor having a tremendous influence on the performance of rubber plantations. Frequent gales can cause considerable damage to plantations by way of branch snap, trunk snap, uprooting, *etc.* Morphological and anatomical deformations are usually associated with high wind velocities. In addition to the mechanical effects, advective cold and dry winds affect physiological processes. One of the notable features of trees in windy locations is the deformation of their canopies to produce asymmetric structure in which the branches appear to be swept to the leeward side (Grace, 1977). In valleys where the wind direction is often upslope in the day and downslope in the night due to cold air drainage, flagging can be seen in the direction of night winds.

Windiness, indicated by mean wind velocity or frequency of gales, has a tendency to increase near the coast and at higher elevations. In general, the mean wind speeds in the rubber growing areas are in the range of 1 to 4 m per s (Oldeman and Frere, 1982). Wind causes mechanical and physiological damages and often leads to low productivity (Yee *et al.*, 1969).

In general, young plants with heavy canopy may show stem bending and require corrective pruning and propping. Susceptibility to wind damage is the greatest at the time of maximum girthing and canopy development. Trees with narrow crotches are more prone to wind damage (Dijkman, 1951). Rubber cultivation is not advisable in tracts experiencing strong wind. It is reported from China that an annual mean wind velocity below 1 m per s, has a favourable effect on the growth of rubber trees. At a velocity of 1.0 to 1.9 m per s, no retardation in growth was observed but at 2.0 to 2.9 m per s both growth and latex flow were affected. At a velocity of above 3 m per s, growth and latex flow were severely inhibited. Strong winds of 8 to 14 m per s caused crinkling and laceration of young leaves. A cold wave with strong wind will aggravate the damage. When wind velocity is beyond 17 m per s, trunks and branches of wind susceptible clones snap. At wind speeds of over 24 m per s, most of the rubber trees are uprooted. Clonal variations in susceptibility to wind have also been reported (Zongdao and Xueqin, 1983).

Windbreaks are widely used in China to protect rubber trees in highly wind prone areas. Shelter belts of 20 to 25 m width consisting of main, secondary and tertiary level trees are made forming dense mixed forest belts. Main trees shall be fast growing and wind resistant species such as *Eucalyptus* with *Acacia confusa*, *Homalium hainanensis* and *Michelia macclurei* as secondary trees and *Camellia oleifera* as tertiary trees (Zongdao and Xueqin, 1983). High density planting with wind resistant clones will provide mutual shelter and will tend to limit crown size leading to reduced chances of wind damage.

3. RUBBER GROWING REGIONS IN INDIA

The rubber growing regions in India can be classified under two major zones namely the traditional and the non-traditional on the basis of the agroclimatic conditions. The traditional zone includes Kanyakumari district of Tamil Nadu, whole of Kerala and Dakshin Kannada and Coorg districts of Karnataka state. Rubber is now being grown in the north-eastern states, West Bengal, Konkan region of Goa and Maharashtra, parts of Andhra Pradesh,

Table 2. Climatic characteristics of a few important places in the rubber growing regions in India

Place	District	State/Union territory	Latitude (°N)	Longitude (°E)	Altitude (m)	Mean air temperature		Mean annual rainfall (mm)
						Maximum	Minimum	
Traditional zone								
Paraliar▲	Kanyakumari	Tamil Nadu	08°26'	77°36'	33	32.3	23.0	2000
Trivandrum*	Trivandrum	Kerala	08°29'	76°57'	64	30.7	23.5	1800
Chethackal+	Pathanamthitta	Kerala	09°22'	76°50'	80	30.8	22.4	4000
Kottayam•	Kottayam	Kerala	09°32'	76°36'	73	31.6	23.0	3500
Calicut*	Calicut	Kerala	11°15'	75°47'	5	30.9	23.7	3300
Mangalore*	Dakshin Kannada	Karnataka	12°52'	74°51'	22	30.5	23.7	3500
Nettana▲	Dakshin Kannada	Karnataka	12°45'	75°32'	110	31.8	20.3	4500
Port Blair*	South Andamans	Andaman & Nicobar	11°40'	92°43'	79	29.6	23.5	3200
Non-traditional zone								
Guwahati▲	Kamrup	Assam	56°11'	91°45'	105	30.0	19.4	1800
Agarthala▲	West Tripura	Tripura	23°53'	91°15'	20	30.7	20.5	2000
Tura▲	West Garo Hills	Meghalaya	25°31'	90°14'	600	28.1	17.7	2300
Kolasib▲	Aizwal	Mizoram	24°13'	92°41'	150	32.2	18.3	2500
Nagrakatta▲	New Jalpaiguri	West Bengal	28°54'	88°25'	229	28.5	16.0	3000
Marmagao*	North Goa	Goa	15°25'	73°47'	62	29.5	23.7	2600
Dapchari▲	Thane	Maharashtra	20°04'	72°04'	48	32.7	20.4	2400
Jagdalpur*	Bastar	Madhya Pradesh	19°05'	82°02'	553	31.2	18.9	1600
Kadlipal▲	Dhenkanal	Orissa	20°49'	85°30'	100	32.5	21.5	1800

• RRII Head quarters; + Central Experiment Station; ▲ Regional Stations; * Source : IMD, 1966.

Madhya Pradesh and Orissa states. These come under the non-traditional zone. Dry and wet monsoon climate prevails in these regions and the annual and diurnal ranges of temperature and the period of drought vary depending on the location, altitude and latitude (Table 2).

3.1 Traditional zone

Major portion of the rubber area in India is confined to the west coast of the country extending from Kanyakumari district of Tamil Nadu in the south to Coorg district of Karnataka in the north (8° to 12°N). In the traditional zone the rubber plantations are confined to the narrow belt, approximately 700 km in length, on the western side of the Western Ghats which enjoys the benefit of both the southwest and northeast monsoons (Fig. 1. a-f). There are also limited areas in Andaman and Nicobar Islands. Pre-monsoon showers start by April and merge into the southwest monsoon from the beginning of June to middle of August. Northeast monsoon is received from early October and extends up to the middle of November. Kanyakumari district in Tamil Nadu and part of Trivandrum district in Kerala, particularly the former, receive more or less an equal quantum of rain from both the monsoons and experience a climate much akin to that of equatorial monsoon. Towards the north, the southwest monsoon becomes more intense but the northeast monsoon turns out to be more and more scanty and undependable.

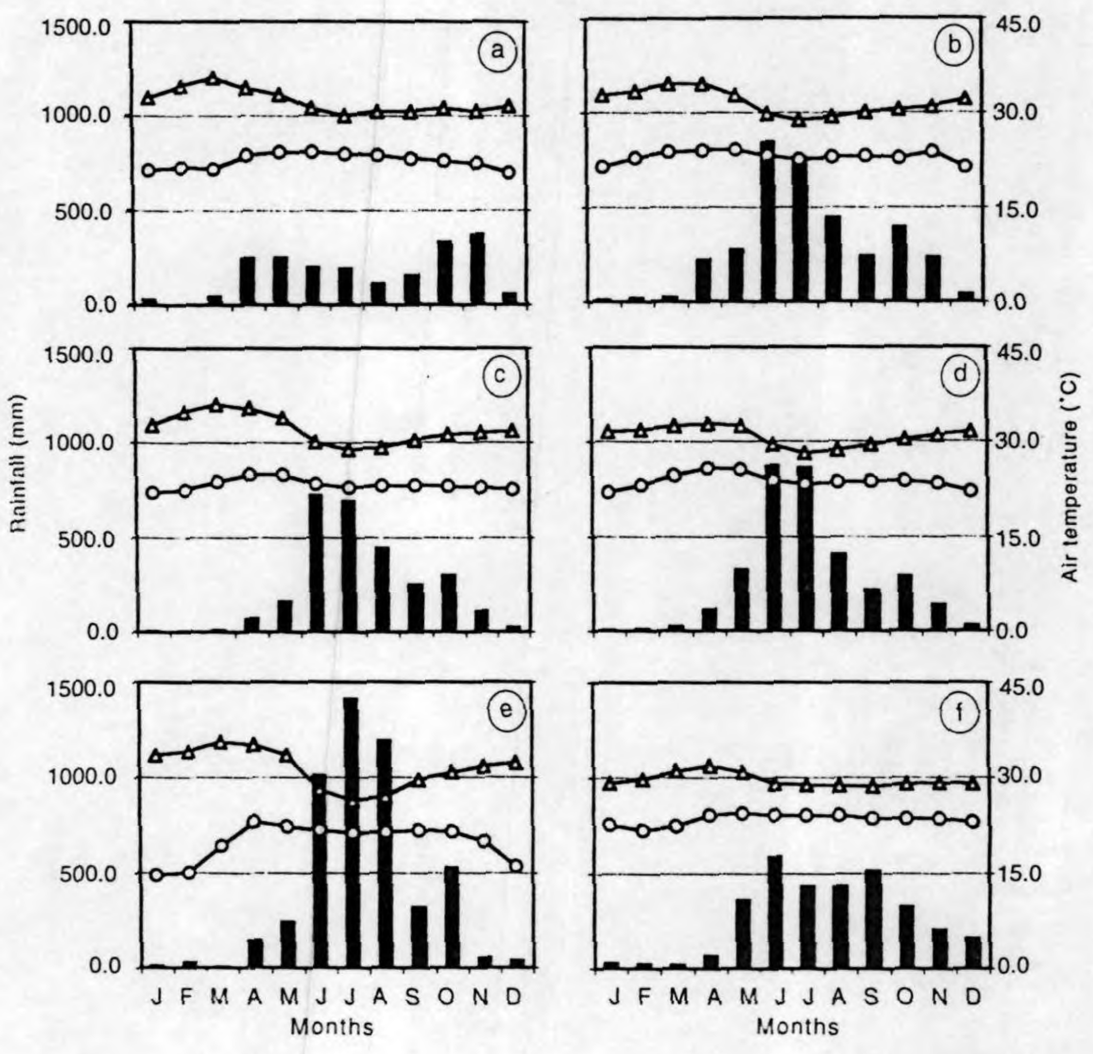

Fig. 1. Rainfall and temperature pattern in different regions of the traditional zone

■ Rainfall △ Maximum temperatrure ○ Minimum temperature

a : Paraliar, Kanyakumari b : Kottayam, South Kerala c : Trichur, Central Kerala
d : Calicut, North Kerala e : Nettana, South West Karnataka f : Port Blair, Island Region

In general, heavy rainfall experienced in the traditional zone results in loss of substantial number of tapping days. On an average 70 to 80 tapping days are lost annually. The morning rains common in southwest monsoon not only results in wet bark but also causes wash out. During the northeast monsoon the rains are usually in the afternoon and bark remains wet even up to next morning.

The traditional zone experiences moderate soil moisture stress in summer, the intensity of which increases towards the north. The onset of wintering is closely related to the rainfall pattern during November to January. Earlier the cessation of post-monsoon rain, the earlier is the wintering. Accordingly the peak production period is also shortened.

Though annual soil moisture deficit is moderate (350 mm), in certain years severe drought conditions are also experienced (Vijayakumar *et al.*, 1988). In such situations tapping rest becomes necessary. On the other hand, tapping has not shown any harmful effects under moderate stress conditions. Early receipt of good pre-monsoon showers is important for high productivity. Timely planting is desirable in view of the annual soil water deficit. Late planting can result in poor growth and tree loss. Mulching of plant basin and white washing of stem are essential in the summer season. In view of the annual growth inhibition experienced due to soil moisture stress, it is very important that the tappable girth of 50 cm is attained before opening. Early opening results in severe inhibition of growth. The traditional zone can be conveniently divided into seven agroclimatic regions:

3.1.1 Kanyakumari region

Rainfall in this region is moderate and more or less evenly distributed (Fig. 1. a). The annual rainfall is about 1900 mm which does not exceed 350 mm in any month. Both southwest and northeast monsoons are equal in this region. Hindrance to tapping by rainfall is least. Hence rainguarding is not recommended. Temperature variations are not marked. This region has only occasional, moderate incidence of abnormal leaf fall which is comparatively the most damaging disease prevalent in most of the rubber growing areas of the country. However, the incidence of powdery mildew disease is severe.

3.1.2 South Kerala region

This region comprises the districts of Trivandrum, Quilon, Pathanamthitta, Alleppey and Kottayam. Majority of rubber plantations are concentrated in this region. The region has a tropical humid climate, with an aggressive summer and plentiful seasonal rainfall. January and February are normally dry months. The hot season from March to May is followed by the southwest monsoon from June to September. The northeast monsoon is from October to November. The annual rainfall ranges from 2000 to 4500 mm (Fig. 1. b). June and July are the wettest months. The mean maximum and minimum temperatures are 36 and 21.15°C respectively (NARP, 1989). The climatic conditions are highly conducive to *Phytophthora* and pink diseases. Adoption of extensive control measures is necessary.

In Kottayam, which is a tropical low elevation region, the monthly mean temperature varies from 26 to 28°C. Adequate soil moisture and sunshine are the major contributing factors for higher productivity. During the peak production period of November, daily temperature varies from 22 to 31°C. During this period adequate soil moisture is available from 200 to 250 mm rainfall. The average duration of sunshine during this period is 6.5 h per day. In July, on the other hand, heavy rainfall of the order of 600 mm or more is received. In this month, the mean minimum and maximum temperatures are 22 and 29°C respectively. Average daily sunshine duration is only 2.3 h. These conditions are not congenial for good productivity and the latex yield is lower during this period. Temperatures of 23 to 34°C during March with 9.4 h of sunshine and low rainfall of around 60 mm also result in low yield. This may be due to the combined effect of high temperature and soil moisture stress in addition to the effect of annual defoliation.

3.1.3 Central Kerala region

Three central districts (Ernakulam, Trichur and Palghat) of Kerala are included in this region. This region is characterized by a comparatively heavier rainfall during the southwest monsoon with maximum rainfall in July and August. Northeast monsoon is comparatively weak and ends by November leaving in between a dry spell of 6 months from December to May (NARP, 1989). Annual rainfall ranges from 3000 to 4000 mm. Wet and dry seasons are well pronounced. Pre-monsoon showers are usually received during April and the diurnal variations in temperature are not much (Fig. 1. c). Incidence of abnormal leaf fall disease is moderate in most parts, but severe in certain pockets. The presence of Palghat gap influences the climate of this region. Summer temperature is comparatively high. Most of the areas experience strong dry wind which is a limiting factor for successful rubber cultivation.

3.1.4 North Kerala region

Four northern districts (Calicut, Malappuram, Cannanore and Kasaragod) of Kerala constitute this region. The region receives rains during both the monsoons. The annual average rainfall is about 3400 mm (Fig. 1. d). The mean maximum and minimum temperatures are 33 and 23°C respectively. Incidence of abnormal leaf fall disease is high. Westerly and northwesterly winds prevail during December to March. The maximum wind speed is between 10 to 15 km per h. Although the rainfall is plentiful, a prolonged dry spell of four to five months duration does occur every year from December to May (NARP, 1989). Moisture stress during this period affects the growth and production of rubber.

3.1.5 South West Karnataka region

This region is located in the northern most part of the traditional rubber belt in India and is characterized by the longest summer season. At present most of the rubber cultivation is concentrated in Dakshin Kannada and Coorg districts. Annual rainfall varies from 2100 to 4500 mm. Southwest monsoon contributes the major part of the rainfall with July as the wettest month. The mean minimum and maximum temperatures range from 20 to 35°C. Northeast monsoon is very weak (Fig. 1. e). The conditions prevalent in this region are conducive to *Phytophthora* and powdery mildew diseases. Severe incidence of *Corynespora* leaf disease has been reported recently.

Though Dakshin Kannada district enjoys climatic regimes more or less comparable to those in other traditional rubber growing regions, the other districts of the state which have potential for rubber cultivation shows wide variation in climatic features and soil characteristics. Karnataka region, in general, is therefore regarded as non-traditional.

3.1.6 Tropical high altitude region

This region comprises the districts of Wynad and Idukki, Nelliampathy and Attappadi hill ranges of Palghat district, Tannithode and Seethathode areas of Pathanamthitta district, Aryankavu, Kulathupuzha and Thenmala areas of Quilon district and Peringamala, Aryanad, Vithura, Kallikad and Amboori areas of Trivandrum district. Some parts of Coorg district of Karnataka and Nilgiri Hills of Tamil Nadu are also included in this region.

The average rainfall is about 4000 mm. The areas receive heavy rainfall during the southwest monsoon from June to September. Northeast monsoon and pre-monsoon showers account for the major portion of the remaining precipitation. Dry spells occur during December to March. The mean maximum temperature is about 29°C. November to January is the cold period with temperature varying between 1 to 15°C. During this period, overhanging mist is often present.

Rubber cultivation in high altitudes above 450 m is normally not advisable mainly because of the problems associated with low temperature. However, many enterprising farmers have taken up rubber cultivation beyond this limit with varying degree of success. Because of low temperature and overhanging mist, powdery mildew is severe in high elevation plantings. Incidence of abnormal leaf fall disease and prolonged exposure to wind are other constraints. Growth of plants is poor compared to those in lower elevations. Bark regeneration is also poor. Late dripping, low DRC and incidence of TPD are high.

3.1.7 Island region

In the islands of Indian territory, rubber is cultivated only in the Andaman and Nicobar areas. Climatic conditions prevailing in this region, especially in Nicobar Islands, are favourable for rubber cultivation. Rainfall is moderate and evenly distributed. No pronounced wet and dry seasons exist (Fig. 1. f). Both the monsoons are experienced equally. Temperature fluctuations are minimum. Mean annual rainfall is about 3200 mm. Annual mean maximum and minimum temperatures are 29.6 and 23.5°C respectively. The overall climatic conditions are ideal for rubber. Mild attack of *Phytophthora* and powdery mildew diseases is noticed in this region.

3.2 Non-traditional zone

Attempts have been made to explore the possibility of cultivating rubber outside the traditional belt. Experimental planting was initially done in the north-eastern region, followed by Konkan region of Goa and Maharashtra, Orissa, Andhra Pradesh, Madhya Pradesh and West Bengal. Based on the experience from the pioneer plantings, commercial plantations have been raised in some of these areas. The non-traditional area is classified into four regions namely, north-eastern region, Konkan region, eastern region and sub-tropical high altitude region.

3.2.1 North-eastern region

The north-eastern region comprises the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. Northern parts of West Bengal lying between 22° and 29.5° N latitude also fall in this region. The Rubber Board has established a Research Complex of the Rubber Research Institute of India, with headquarters at Guwahati to concentrate on need-based research investigations relevant to the region. The complex has regional research stations in Assam, Meghalaya, Mizoram and Tripura and a regional experiment station in the Jalpaiguri district of West Bengal.

Hevea, though genetically adapted to tropical environment, has proved to thrive and be commercially viable in subtropical environments of North East India and China.

Rubber planting was introduced into this region in the early sixties with the pioneer plantations started by the Forest Department. Planting of rubber has been undertaken in a big way since then. This region presents a climatic feature considerably different from the traditional rubber growing region. Growth performance of *Hevea* in the initial years was found to be inhibited. (Sethuraj *et al.*, 1989). Various stress factors, particularly, prolonged low temperature, affect growth and yield. The north-eastern region has been climatically indexed for rubber cultivation as either moderate or marginal (Rao *et al.*, 1993). Certain agronomic practices to offset the deleterious effects of various stress factors are essential for raising a successful crop in the region.

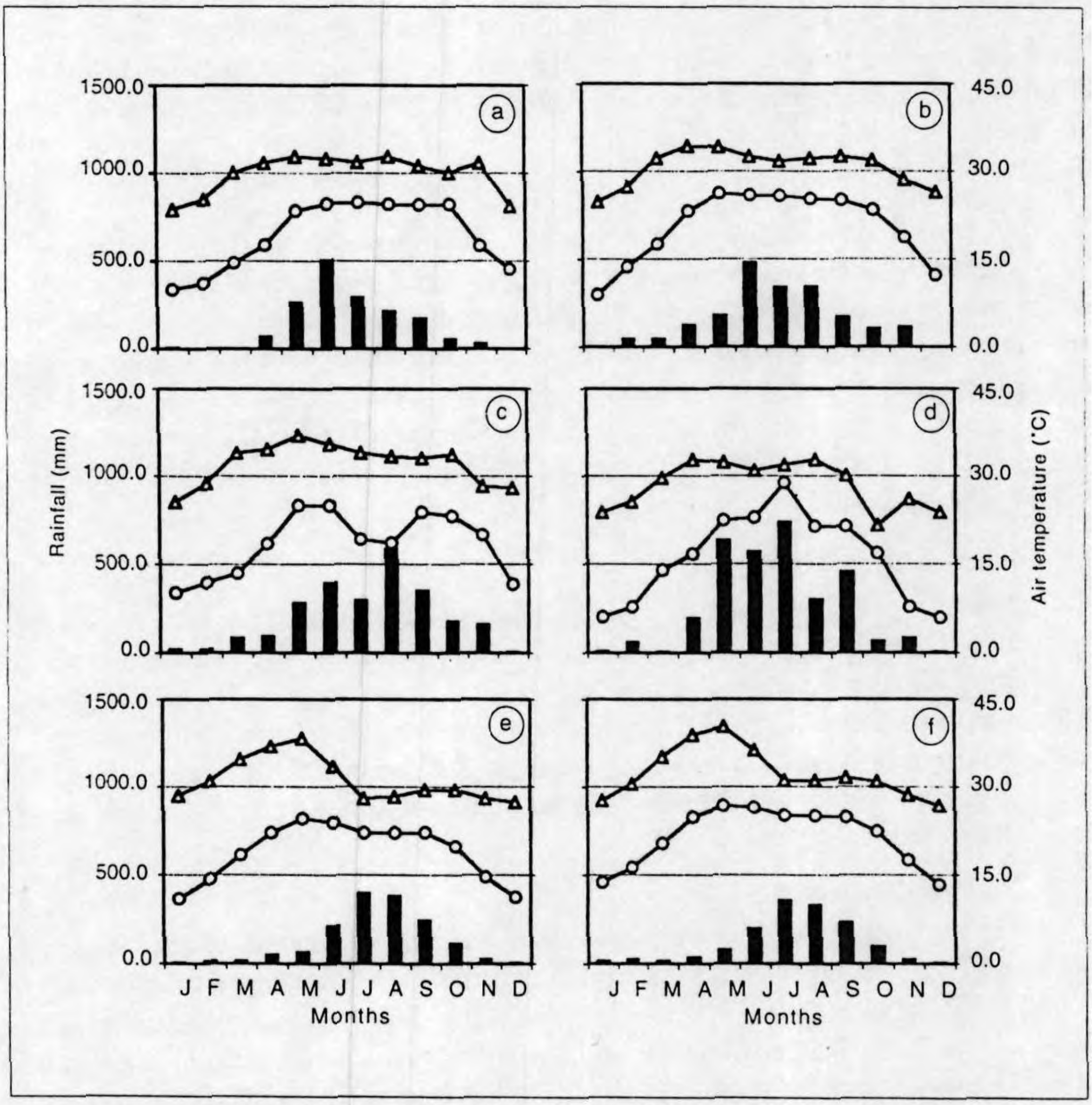

Fig. 2. Rainfall and temperature pattern in north-eastern region

■ Rainfall △ Maximum temperatrure ○ Minimum temperature

a : Guwahati, Assam b : Agarthala, Tripura c : Kolasib, Mizoram

d : Nagrakatta, West Bengal e : Jagdalpur, Madhya Pradesh f : Kamakhyanagar, Orissa

3.2.1.1 Air temperature

A major environmental constraint in this region for optimum growth and yield of *Hevea* is the low temperature encountered during winter season (Fig. 2. a-c). From December to February the mean minimum temperature is around 10°C. This is in contrast to nearly 20°C observed in Kottayam during the same period. Tura in Meghalaya and Agartala in Tripura experience lower mean minimum temperatures compared to rubber growing areas in other states. Growth is retarded when the temperature falls below 20°C (Jiang, 1988) and photosynthetic activity ceases when below 10°C (Zongdao and Xueqin, 1983). The success of bud grafting is affected when performed during winter season. In Tripura it was observed that green budding was more successful than brown budding when performed from February to June. The period from November to March was found to be unsuitable for brown budding (Sethuraj *et al.*, 1989).

Growth of rubber in the immature phase was observed to be low during the winter period which is characterized by low temperature. Only 20 per cent of the annual growth takes place in the winter half of the year (Vinod *et al.*, 1996). Planting operations in the field have to be completed at least by the second week of August to help the young plants to get established before the onset of winter. Irrigation during the winter period enhances the growth (Philip, 1997).

In the yielding phase, latex flow characteristics are drastically altered in winter. Plugging mechanism is delayed considerably under low temperature and hence there is prolonged flow. There is also a drop in the dry rubber content. It is possible that rubber biosynthesis is adversely affected by low temperatures. This period generally coincides with low soil moisture availability which usually causes early cessation of latex flow in the traditional tropical regions. When the minimum temperature falls below 10°C, it is advisable to give tapping rest. Though irrigation is not practised in areas with abundant water supply, irrigation during December to March at fortnightly intervals will be a good management practice to mitigate the adverse effect of low temperature.

More than air temperature, soil temperature is probably the major factor controlling tree growth in winter season. In the hills of the north-eastern region, the soil temperature in the south facing slopes was found to be higher than the north facing ones. This is so due to the differential capture of solar radiation by land terrains of different aspects, modifying heat flux and soil temperature. Consequently the tree growth was favoured in south facing slopes (Saseendran *et al.*, 1993b).

3.2.1.2 Rainfall

Annual rainfall in this region varies between 1500 to 2500 mm (Fig. 2. a-c). The southwest monsoon is active but the northeast monsoon is absent. However, there are good post-monsoon showers during October and November. Pre-monsoon summer showers are also very active from March to May and constitute about 24 per cent of the total rainfall. Though higher quantum of rain is received in Mizoram and Meghalaya, in Tripura, the distribution of rain is more even. The total rainfall in the wettest month is highest in Tura (Meghalaya) followed by Kolasib (Mizoram). Among the states in this region, dry spell is shortest in Tripura and longest in Assam. Using water balance studies Saseendran *et al.* (1993a) concluded that moderate water stress on rubber trees in Tripura is confined only to the summer months from March to May. However, prolonged soil moisture deficit conditions, which stretches up to summer, exists in most areas during winter. Irrigation to provide a soil moisture tension in the range of –0.033 to –0.10 MPa in inter-row area during winter period enhanced the volume yield of latex by 20 per cent (Philip, 1997).

Soil and water conservation in this region has received only scanty attention. Collection of run off water is important for optimum utilization of the precipitation received. Establishment of complete contour terraces, in hilly terrains, as practised in the traditional rubber growing region is not advisable in states like Mizoram, where landslides are triggered when soil is disturbed. In such areas it is better to make silt pits to retain run off water and to recharge the soil.

3.2.1.3 Relative humidity and sunshine

The fall in RH during winter is more pronounced in this region than in the traditional region. Commencement of tapping during early hours is, therefore, essential for obtaining optimum yield. Sunshine is not a limiting factor in this region.

3.2.1.4 Storms and hailstorms

Storms are regular in North East India and can be problematic in exposed areas. Windbreaks have to be established around the boundary, prior to raising new plantations in wind prone areas. Hail accompanied by high velocity winds is a far more serious problem for rubber cultivation in this region. The crown and bark get damaged during hailstorm. Detailed studies on the frequency of hailstorms are not available. Analysis of damage wrought by a hailstorm in Tripura, four years after it struck, revealed that while bark regenerated even when the injury is deep up to the cambium, the development of latex vessels was not complete. Thirty six per cent yield decrease was also noticed in the affected side compared to the unaffected side (Meenattoor *et al.*, 1995).

3.2.2 Konkan region

The Konkan region stretches between 15° and 20°N latitude, comprising a narrow strip of land on the western side of the Western Ghats of Goa and Maharashtra. The region includes the state of Goa and four coastal districts of Maharashtra namely Sindhudurg, Ratnagiri, Raigad and Thane.

Rubber has been grown in the region on a small-scale and non-commercial basis in the 1930s itself. One such plantation was by the Portugese at Baty near Sanguem in Goa. Another was by the then Maharaja of Sawanthawadi at Danoli in South Konkan of Maharashtra. The vegetative growth of trees in both the cases was fair and was indicative of good potential. It is reported that later plantations raised with high yielding clones are yielding more than 1000 kg per ha per year (Chandrashekar, 1983,1991; Rubber Board, 1985). Observations from these early plantations have prompted the Rubber Board to establish a Regional Research Station at Dapchari in Thane district of Maharashtra.

3.2.2.1 Rainfall

The annual rainfall varies from 3000 to 5000 mm. Total rainfall is good but its distribution is far from satisfactory (Fig. 3. a,b). Most of the rainfall is received from June to September with the maximum being received in July and August and thus it is monomodal. This results in long dry periods extending from October to May. There is only a mild winter from December to February. Summer is from March to May during which the drought conditions are very severe.

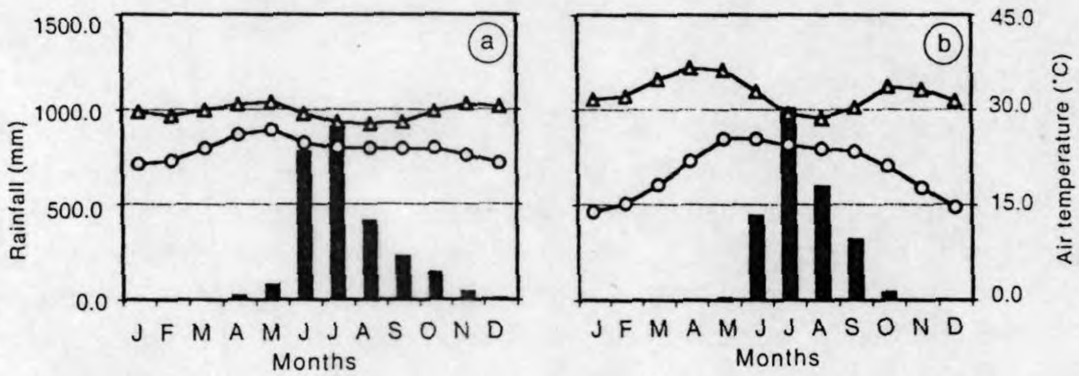

Fig. 3. Rainfall and temperature pattern in Konkan region

■ Rainfall △ Maximum temperatrure ○ Minimum temperature

a : Marmagao, Goa (South Konkan) b : Dapchari, Maharashtra (North Konkan)

3.2.2.2 Sunshine hours

The region receives adequate sunshine hours in all the months except during southwest monsoon period. It ranges from less than 2 h per day in July and August to more than 10 h per day from January to April. The months of May, October, November and December receive a daily average sunshine of less than 10 h. June and September receive more than 4 h of sunshine per day. Variation is the highest in July and August and lowest in January.

3.2.2.3 Air temperature

Mean maximum temperatures are high from March to May (40°C). The months of July, August and September record the mean maximum temperature of around 30°C and in the months of December and January it is below 25°C. Diurnal variation in air temperatures is usually similar in November and January with January having lower temperatures in the morning hours. In April the maximum air temperature can cross 40°C and most of the middle part of the day has temperature above 35°C. Temperature variations of the region are presented in Figure 3 a and b.

The region has a typical winter from December to February during which the minimum temperatures are very low. Lowest minimum temperatures are usually observed during the months of December and January (6 – 12°C).

3.2.2.4 Relative humidity, soil moisture and wind

Normally the RH in all the months is above 75 per cent in the morning hours. In the afternoon hours, RH is high during June to September, moderate in October and

November and low in the remaining months. Soil moisture is very low during January to May and stress is evident. Diurnal variations in soil temperatures in the exposed areas are similar in November and January with slightly higher temperatures in November. The highest temperature attained is about 38°C. In April, the temperature can rise up to 50°C. From 1100 to 1800 IST, the mean soil temperature is above 40°C in April. Wind velocity in the region is moderate in all the months. High velocity storms are generally absent. In general, the agroclimatic conditions in the southern part of Konkan are more favourable for rubber.

3.2.2.5 Crop performance

The major constraints in the region are the very low soil moisture conditions coupled with higher temperatures, especially during summer months. The effects of prevailing drought conditions on plant performance are multifarious but in terms of significance to man, their effect on growth and yield assume more importance. Growth of plants occurs only during the rainy season (Chandrashekar *et al.*, 1996; 1998; Vijayakumar *et al.*, 1998). During the dry period stem growth stops completely and repeated defoliation and refoliation take place. Leaf injury, very low conductance and transpiration rates and defoliation are also observed (Chandrashekar *et al.*, 1990; Mohankrishna *et al.*, 1991; Chandrashekar, 1997; Vijayakumar *et al.*, 1998). All these lead to prolonging of immaturity period to more than 10 years and high tree loss under rainfed conditions. Irrigation at the rate of 50 per cent of crop evapotranspiration (ETc) can reduce the immaturity period to 6 years with significant reduction in tree loss and increased uniformity in girth (Vijayakumar et al., 1998). Higher rates of irrigation did not result in significant increase in growth performance. The estimated water requirement, *i.e.* ETc, after canopy closure is around 33500 L per tree per dry season. In the rainfed plants the first year yield of clones GT1 and RRIM 600 was comparable with that of the traditional region. Yield obtained during the summer months of March to May was very low and uneconomical (Chandrashekar *et al.*, 1990). Inspite of the limitations of the prevailing environment overall performance of the crop appears to be satisfactory (Chandrashekar *et al.*, 1990; 1994; 1998). Under rainfed conditions the yield is around 1 t, which can be improved upto 1.7 t with irrigation in clone RRIM 600 (Devakumar *et al.*, 1998).

3.2.2.6 Implications

Implications of the prevailing conditions in Konkan for *Hevea* cultivation are many. In order to minimize the deleterious effects of the existing conditions, care should be given to appropriate site selection, choice of planting materials, cultural practices and plant protection. In selecting lands for rubber cultivation, adequacy of soil depth, retention of soil moisture at subsoil levels during dry periods and availability of water for light irrigation should get thorough consideration. Field planting operations have to be planned well in advance. Direct field planting with stumps, like in the traditional region is likely to cause heavy casualties. Use of advanced planting material raised in polybags is the only prudent method for field planting which should coincide with the onset of monsoon. The polybag plants should at least be of three whorl stage. This will enable plants to get established well by the end of monsoon and to overcome the ensuing dry period better. In order to protect the plants in the dry period drought alleviation measures should be implemented well in advance of the onset of dry period. The measures to be adopted are heavy mulching of as much area as possible around plant bases, white washing of the stems to prevent sunscorch and contact shading of the leaves. If water is available life saving irrigation can be provided in the initial years.

In the absence of proper irrigation, tapping in summer months may not be economical and it is prudent to rest the trees in these months. During the monsoon months tapping with rainguarding is advantageous (Chandrashekar *et al.*, 1990).

3.2.3 Eastern region

Surveys and trial plantations in selected localities in Orissa, Madhya Pradesh and Andhra Pradesh have proved that there is considerable potential for rubber cultivation in these states. Regional stations of RRII have been established at Kamakhyanagar (Dhenkanal district, Orissa), and Sukma (Bastar district, Madhya Pradesh). This region also present conditions more or less similar to that of Goa and Maharashtra (Fig. 2. d-f).

3.2.4 Subtropical high altitude region

Cultivation of rubber in the high altitude areas in this region has been attempted with a fair degree of success. In 1985, the RRII had set up a Regional Research Station at Tura, in the West Garo hills of Meghalaya, with experimental farms at altitudes of 600 to 1100 m above msl. The winter temperature is very low with overhanging mist (Fig. 4. a,b).

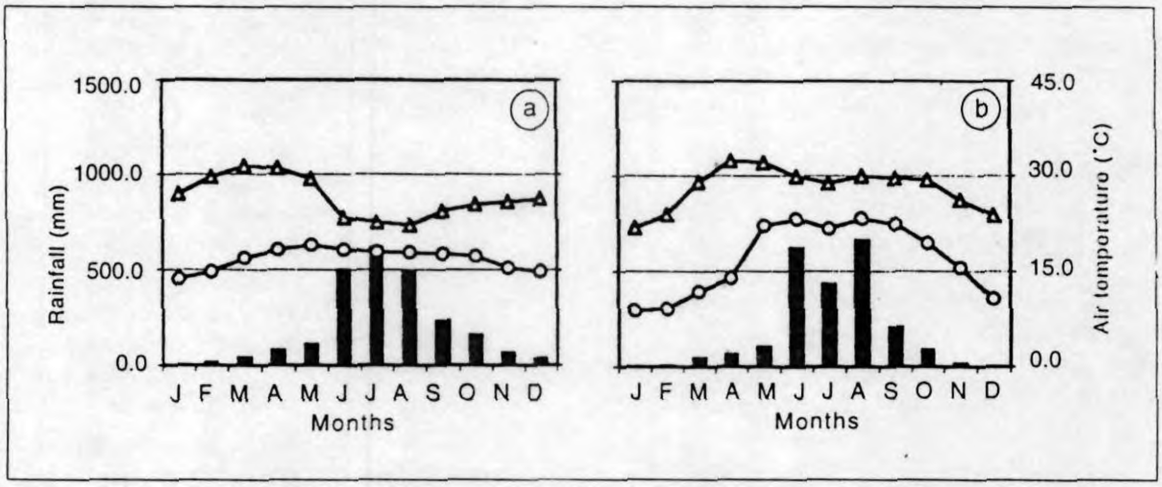

Fig. 4. Rainfall and temperature pattern in subtropical high altitude region

■ Rainfall   △ Maximum temperatrure   ○ Minimum temperature

a : Mudigere, Karnataka   b : Tura, Meghalaya

Establishment and growth of rubber planted in the high altitude farm (1100 m) is poor (RRII, 1996). It is not feasible to plant rubber at such altitudes in this region. At 500 m above msl, the clones PB 235, RRII 203 and RRIM 600 are performing better than other clones. The growth of plants was found to be comparable to that in the lower altitudes of the same region.

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