DISCUSSION
The study is concerned with the different pathological aspects of certain forest trees in two different forested regions of Meghalaya. Due to the extreme favourable climatic conditions prevailing in the forests, a number of tree species are infected. Once the infection is established, the climatic conditions being quite conducive the diseases spread very fast over the area. The fungi are found to attack leaf, stem, root and cause decay both on living and dead trees.

A number of fungi is reported to attack the leaves of many forest trees. Altogether 32 species of fungi, one species of alga are found parasitic causing leaf-spot, leaf-rust, powdery mildew, sooty mold and red rust.

The fungal infection begins in the rainy season and continues till winter in the field. Host plants are generally free of fungal infection during the summer. This may be due to the high temperature and low rainfall which are normally not favourable for the growth and development of the fungi (Fig. 1). Laboratory studies also reveal that high temperature inhibits the growth of the fungi and water is essential for conidial germination (Fig. 4). This explains why infection normally starts in the rainy season and reaches its climax in autumn and winter when both temperature and humidity are ideal for the growth of the fungi (Tables 1-18).

In the case of algal infection caused by Cephalaleuros virescens, it is found that temperature and sunlight have a
great effect on the growth of the parasite. The algae is abundant in summer and rainy seasons when temperature is quite high and it is almost absent during winter when the temperature is low (Tables 19-22). Shaded leaves develop less number of spots while the leaves exposed to direct sunlight possess more spots. It indicates that the algae prefers sunlight for its growth. Rangaswami (1979) also stated that the algae can best survive when bright sunlight is available.

Germination and growth of the conidia are best at the temperature range of 20 - 30°C for most of the foliage pathogens (Fig. 6-7). This correlates with the observation of other workers on certain leaf-spot pathogens (Hasija, 1970; Verma, 1970; Misaghi et al., 1978 and Chandrashekar and Ball, 1980). The optimum temperatures coincide with the range of the temperature prevailing during rainy and autumn seasons. The disease is correlated with sufficient moisture content, suitable temperature (20 - 30°C) in the atmosphere which provide favourable conditions for the growth and reproduction of the foliage pathogens.

The fungal infected leaves contain less amount of total sugar than healthy ones (Table 25). Many of the fungal infections are low sugar diseases and they could be inhibited by high sugar level in the host plants (Horsfall and Dimond, 1957). The healthy leaves contain high concentration of sugar which could inhibit pathogens by blocking enzyme synthesis (Mandelstam, 1961; Bateman and Miller, 1966). The total sugar decreases in
the infected tissues and it is likely that hydrolysis of sugars occurred rapidly during pathogenesis by hydrolases secreted by the pathogens. It has been reported by many workers (Samborski and Shaw, 1956; Korg et al., 1961 and Swamy, 1964) that the reduction in sugar content may be due to the increased respiration of the infected leaves and the respiratory pathway is different in the infected leaves than that in healthy ones (Shaw and Samborski, 1957). The high amount of sugar in healthy tissues and their relative decrease in the infected leaves indicates the utilization of the sugars by the pathogens. In the advanced stages of infection, the fungi have to depend on the hydrolytic products of sugar and this may be the reason for the fall in level of the sugar in the infected leaves.

The algal infected leaves contain more total sugar than healthy ones (Table 25). There is a great deal of evidence which indicates that the dark metabolism of photosynthetic algae is essentially similar to that of non-photosynthetic organisms (Danforth, 1962). Since chlorophyll is present in the algae, this parasitic alga, C. virescens, may not depend upon the host for its carbon nutrition. The increase in total sugar in the infected tissues may be due to the accumulation of algal fructose. du Merac (1953) reported that certain algae are characterized by the formation of fructose and polymers of fructose as reserve materials. Neish (1951) and Samejima and Myers (1958) found that green algae utilize glucose, fructose, galactose and sucrose as the energy source. The present findings also support
the observations of Vidhyasekaran and Parambaramani (1971a) who stated that the infected algal leaves of mango, guava and sapota contain more total soluble sugar than healthy ones.

As a result of both fungal and algal infection, the natural organic composition of host substrates gets affected. A perusal of data (Table 25) shows that the amount of total amino acid is more in both algal and fungal infected leaves (Table 25). In the infected leaves, the enzymes involved in the amino acid synthesis are also activated and as a result the level of various amino acids increases. A parallel proteolysis and protein synthesis has been reported in rust disease (Rudolph, 1963). A similar situation may also be expected in case of fungal and algal infections. It could be expected that excess of amino acids may be of the pathogenic origin. Tandon (1967) suggested the synthesis of amino acids by the fungi during pathogenesis.

The concentration of the nitrogen is higher in the fungal infected tissues (Table 25). Higher nitrogen content delays maturity of plants and promotes succulency, conducive to disease development. Higher nitrogen content in the susceptible leaves might enhance rapid degradation of phenols (Kirkham, 1954) while in the resistant leaves the degradation is minimal. Ali and Roy (1981) also observed that the carrot leaves infected by *Alternaria alternata* contain more nitrogen.

The algal infected leaves contain less amount of total
nitrogen (Table 25). There is no evidence for nitrogen fixation by algae belonging to group other than Cyanophyta (Fogg, 1956). Hence the alga has to depend upon its host for the nitrogen supply. Fogg (1959) stated that if nitrogen deficiency developed, the amount of chlorophyll in the algal cell decreases rapidly. Van Oorschot (1955) reported that the rate of photosynthesis in the algae is also affected by the nitrogen deficiency.

Total phenol content is found to be depleted both in the algal and fungal infected leaves (Table 25). Accumulation of phenolic compounds in host-parasite reaction is a general phenomena of disease resistance and the rate of accumulation and breakdown of phenolic compounds determine the degree of resistance (Farkas and Kiralay, 1962; Tomiyama, 1963; Mahadevan, 1966; Jayapal and Mahadevan, 1968 and Jamaluddin et al., 1981). The breakdown of the phenolic compounds is rapid in the infected leaves while in the healthy ones the degradation rate of such substances is usually slow. Phenolics have a wide range of toxicity to various microorganisms (Cruichshank et al., 1964 and Nemec, 1976).

The dry weight of the fungal infected leaves is found to be less (Table 25). Obviously the dead cells and shot holes were responsible for the reduction in weight. The algal infected leaves on the other hand contain more dry weight (Table 25). The presence of algal cells might have increased the dry weight.
The foliage pathogens survive in plant debris and on soil (Table 23-24). *Alternaria alternata*, *Curvularia lunata*, *Myrothecium roridum*, *Phyllosticta* spp., *Colletotrichum gleosporioides* and *Helminthosporium* spp. thrive in mycelial form on leaf debris of host and non-host plants which provide substrate for fungal colonization. Since the addition of plant litter is a continuous process in the natural forests such fungi lead a saprophytic life on organic plant debris and also in soil and survive till the oncomming of favourable conditions for disease development.

Although quite a good number of fungi infect a wide variety of plants, the diseases they cause are of not much serious nature since the percentage infection is not very high and mortality due to defoliation is also not much (Table 1-18).

In stem diseases, only canker is observed. *Corticium salmonicolor* and *Fusarium solani* infect a wide variety of forest trees and cause much damage. *C. salmonicolor* has a broad host range than *F. solani*. Sharples (1936) recorded more than 141 species belonging to 104 genera of *C. salmonicolor*. In India, it is indigenous and occurs on a wide range forest trees (Bakshi, 1976). Among all the hosts, *Eucalyptus* spp. is the most susceptible. The fungus causes heavy mortality of *E. globulus* and *E. tereticornis* from India (Bakshi et al., 1970). High incidence of the disease is reported either due to proximity of the plantations in natural forests or to plantations
like tea and coffee where the inoculum of the fungus is present.

The present study shows that the inoculum of both fungi is present in different forests of Meghalaya (Table 26-29; Fig. 8-9). *Terminalia bellirica* is found to be the most susceptible to *Cyphon salmonicolor* and *Albizia lebbeck* to *Fusarium solani*. Canker size in the stem and trunk is quite broad and sometimes it girdles the stem (Table 26-29). The association of the two fungi is frequently noticed when isolations are made from the cankers.

Laboratory and field inoculations show that both the fungi when inoculated in wound produce canker, whereas in uninjured and vertical slits no canker development is observed (Table 30-31). This suggests that both the fungi gain entrance through the wounds. The pathogens move through the pith of the shoots into the subcortical tissue of the stem.

The prevalence of *Cyphon salmonicolor* and *Fusarium solani* and their widespread distribution in two widely separated localities in the area suggests that they might be indigenous in the forests. This may account for the attainment of large size by some of the older cankered trees (Plate 7). In the forest, both the fungi invade xylem tissues for an appreciable distance beyond the visible limits of the cankers. Evidences available indicate that the fungi develop primarily in sapwood which is acidic in nature (Table 32). This is also supported by the fact that artificial inoculations were successful when the wound in.
bark is extended to the xylem. Similar results were obtained by Gruenhagen (1945) and Shea (1963) with Hypoxylon canker on poplar and aspen respectively. Once established in the sapwood, the cambium is eventually killed and the dying bark is invaded by the fungi.

Artificial inoculation of various forest trees with C. salmonicolor suggests that Eucalyptus sp., Sterculia villosa and Hibiscus macrophyllus are also susceptible to this fungus (Table 32). The susceptibility of Eucalyptus to C. salmonicolor is important because it is planted in the different forests of Meghalaya. Enterolobium saman, Albizia odoratissima and Populus deltoides are also found to be susceptible to F. solani (Table 32).

Both the fungi cause perennial cankers. They kill the living tissue either by direct hyphal penetration or by secreting some substances toxic to cells in their vicinity, so that the entry of hyphae in the dead cells may be facilitated. The mycelium grows primarily in the inner bark and cambium. The mycelium being perennial spreads slowly from cell to cell.

It is seen that trees with one to many cankers of the persistent type commonly maintain their position in the stand, showing no apparent reduction in height or diameter, even though only a small portion of the trunk is left alive. Such trees may break off at the point of canker, or decay fungi may enter through the open wounds. Branch cankers are not serious
unless many branches are involved and killed, so that the crown is considerably reduced.

Stem-growth of the trees commences during March-June and progresses rapidly during June-September. Canker development seems to reflect this pattern of stem growth in an inverse relationship, the advancement rate of both *longitudinal* and lateral margins declines from March to June and drops sharply from June-September. During June-September the greatest swelling around the canker occurs. The increase in swelling and decrease in canker enlargement indicate that host activity exerts an influence on canker development, which corresponds to the observation of other cankers (Willison, 1938; Heldebrand, 1944; Helton and Moisey, 1955; Chilton, 1955; Helton, 1956; Luerschen, 1965 and Dharvantari, 1968). It can be concluded from the experiment that canker development in the summer is restricted by the growth activities of the host. The summer cessation of canker enlargement associated with host growth activities may be expressed as a healing reaction. Laboratory studies show 20 - 25°C as the optimum temperature for the growth of both the fungi and above this range growth is considerably reduced (Fig. 10-11). This may be correlated with the canker development in the natural fields. High temperature during summer months has also been implicated as an environmental factor affecting a reduction in the rate of canker enlargement. The only time the mean monthly temperatures in the field are near optimum for mycelial growth is during rainy and autumn season.
In winter also, the temperature is favourable for the canker development. The combination of these two factors are most likely responsible for the greatest canker enlargement. During the winter months the fungi remained active enough to advance the canker margins even though the average temperature in the winter is below optimum for fungal growth.

It is found that trees with DBH class more than 80 cm were not affected by the pathogens whereas those with 41 - 60 cm were affected (Fig. 8-9). However, artificial inoculations show that canker development occurs in trees with more than 80 cm. This suggests the influence of the wounds of the host on canker development rather than the age of the trees.

_C. salmonicolor_ cankers may become perennial and weaken the trees. However, in case of vigorous trees, _C. salmonicolor_ and _F. solani_ canker do not appear to be a major disease. Although infection may occur in these trees, it seems to be not effective as soon as the host begins to grow in the spring. The inactivation of cankers in healing trees is supposed to be associated with the wound healing process.

In wilt, _Fusarium oxysporum_ infects _Albizia lebbeck, A. procera_ and _Cassia tora_, and _F. solani_ to _Dalbergia stipulacea_ and _D. assamica_ (Table 41). Only seedlings are found to be infected.

Both the fungi are soil-borne and they invade the trees
through the roots, usually the laterals, subsequently travel into the tap root and then proceed along the stem. Within the wood, the hyphae of both the species of *Fusarium* are abundant in the tissues particularly in the xylem. Death of the affected seedlings is rapid and occurs within a few months after the symptoms. *F. oxysporum* and *F. solani* are constantly associated with seedling wilt. Isolations are attempted from roots and basal parts of the stem of the wilted seedlings, both from stained and unstained sapwood. 100% of the isolations from stained wood yield *F. oxysporum* and *F. solani* from their respective hosts. No fungi could be isolated from the unstained wood. In the laboratory, it is seen that the healthy roots after colonization by *Fusarium* spp. exhibit the characteristic pink stain which proves that *F. oxysporum* and *F. solani* which are present in the soil infect the healthy roots and cause pink stain in the wood.

In pathogenicity tests, *Schima wallichii* and *Albizia odoratissima* were found to be resistant to *F. solani*, whereas *Schima wallichii*, *Quercus serrata*, *Dalbergia tamarindifolia* and *D. sissoo* proved resistant to *F. oxysporum* (Table 42). Both the fungi are isolated from soil in the immediate vicinity of other non-host trees (Table 44). It may be inferred that both the fungi are pathogenic to certain plants and not to others.

The disease is observed only in the rainy season with more than 20% moisture content in acidic soil (Table 43). Heavy infection is found in clay soil which indicates that the fungi
are favoured in the acidic soil. In sandy soil with nearly neutral pH the fungi are isolated in less number and disease is also not observed. This suggests that the sandy soil is unfavourable for the growth and activities of the fungi. In the laboratory, it is found that the growth and conidial germination of both the fungi are maximum at 25°C (Fig. 12-14) which coincides with the range of soil temperature during rainy season. In summer when the temperature is quite high, the disease is not observed. In case of wilt disease, soil temperature, soil texture and suitable moisture content are the important factors for disease development.

_Fusarium_ spp. causing wilt disease belong to the group of soil inhabiting fungi as classified by Garrett (1950). The organisms are widely distributed in the soil bearing both healthy and wilted plants. The fungus may occur in the soil in absence of host plants or bearing other trees. Fusaria possess wide ability of saprophytic colonization on dead host roots (Table 46-47). Due to their wide ability of saprophytic survival in the infected host tissue and also in soil, it is not amenable to control the disease by crop rotation. The fungus may persist indefinitely as a soil saprophyte even in the absence of host plants. Bagchee (1952) suggested that in the case of wilting of shisam caused by _F. solani_, the fungus can be eliminated from the soil by a wide spacing of the two susceptible shisham crops. Although _Fusarium_ spp. can not be reduced below a certain level by crop rotation, they may be increased
above normal level by growing the susceptible host continually since the fungus multiplies much more rapidly in the parasitic phase than in the saprophytic phase and the dead tissues of the host plants are more favourable for saprophytic survival than those of non-host plants.

The results indicate that under laboratory conditions, both the *Fusarium* spp. grow and survive well in sterile loam soil containing up to 40% moisture (Table 45). Above this level, there is a sharp decline of the fungus in the soil. When the infested soils contain free water the fungi are eliminated. Bakshi (1957) suggested that in the case of shisham wilting, control may be possible by increasing the moisture content of the soil through irrigation. High moisture content in the soil, as afforded by irrigation, is correlated with the lowering of the fungal population to a degree which is harmless to the crop. During irrigation, the land should not be under water continuously since aeration is necessary for the health of roots. Stover (1953, 1956) also found that *Fusarium oxysporum* f. *cubense*, the cause of banana wilt, is favoured by light textured soil with low moisture.

The data from the wilt diseases shows that the activity of *F. oxysporum* and *F. solani* in their saprophytic phase is likely to reach their optimum during periods of wet, warm weather, an environment which is also favourable for infection (Table 41-46).
In the case of root rot, *Rhizoctonia solani* is pathogenic to *Quercus serrata*, *Phyllanthus emblica* and *Citrus* sp. (Table 35). *R. solani* is generally known to be an ubiquitous soil saprophyte, capable of being parasitic at times on roots and aerial parts of crop plants, producing diseases. According to Garrett (1960), root-inhabiting fungi possess an expanding parasitic phase on the living host and a decline saprophytic phase after its death.

The present study indicates that the incidence of *R. solani* is associated with high rainfall and poor soil drainage. The fungus is isolated frequently from wet sites with poor drainage (decline areas) whereas it is normally absent from dry sites with good soil drainage (non-decline areas). High incidence of disease is recorded mostly from May to August when both the rainfall and temperature are quite high. These two factors are important in the disease development. In the laboratory also the growth of the fungus is very fast over the temperature range of 20–35°C whereas below and above this range, growth is considerably reduced (Fig. 15).

The disease is prevalent in both the evergreen and mixed deciduous forests, the incidence of the disease, however, is low in sandy soil where the moisture content is below 20%. In silt and clay soil with slightly acidic pH and above 20% moisture content the disease is quite prevalent. Kannaiyan and Prasad (1981) also reported that *R. solani* survives better in clay soil and the fungal population was much reduced in sandy
soil.

Disease is found only in the seedling stage and is almost absent in the older plants. In the root rot diseases, seedling phase is an important factor for disease development. Bateman et al., (1969) have shown that the cell wall of young bean seedlings could be degraded by \textit{R. solani} enzymes whereas the cell walls of older plants were not susceptible to destruction. Although \textit{R. solani} is present in the soil in the immediate vicinity of other forest trees, the disease is not observed in them. In pathogenicity test, plants of five other tree species could not develop disease (Table 37). The parasitic specialization of \textit{R. solani} is important, because in the two tropical forests where resistant and susceptible species are in mixture, the pathogen remains in an endemic state, rather than becoming epidemic.

\textit{R. solani} is isolated with high frequency on agar plates from the infected roots and also from soils. The organism possesses quick and wide powers of saprophytic colonization of dead roots and also the soil. In isolations from healthy root-pieces buried in the soil for a short duration (one week), \textit{R. solani} is obtained from near the cut ends of the root pieces and not from the central portions away from the cut ends (Table 39). This indicates that the fungus penetrated through the cut ends of roots more freely than through the bark.

In the forest, the seeds which germinate in the summer,
rainy season or in winter (i.e. seedling age six months or less) become infected, while the germinated seeds of autumn (seedling age more than six months) grow healthier and the disease is reduced to a great extent.

*R. solani* causing root-rot disease of *Phyllanthus emblica* and *Quercus serrata* is hitherto unreported from India (Butler and Bisby, 1960; Tandon and Chandra, 1963-64 and Mukerji and Juneja, 1975). Thus, this appears to be the first authentic report from India on the two plants.

In decay, the wood-rotting fungi are observed both from living and dead trees (Table 48-51). Two types of decay are observed, i.e. white and brown rot. In the living plants, only white rot is noticed and ten decay fungi are recorded. Except *Merulius eurocephalus*, which occurs only in Balphakram forests, other nine fungi are common in both the forests. The white rot fungi are noted both from older and younger plants, but the disease severity is more in younger plants. Plants with DBH class ranging from 36 - 40 cm are found to be most susceptible to infection, while DBH class more than 50 cm plants are free from infection. Rishbeth (1957) also observed that the older plants were resistant to certain decay fungi.

Among all the decay fungi, *Fomes annosus* has a broad host range and is also most dominant species which attacks many hardwoods. It causes both stem and root decay. The fungus kills young plants by decaying the bark and wood of roots and
root collar.

In oxidase reaction, eight white rot fungi show rapid blue colouration which indicates the presence of an extra cellular oxidase with gallic and tannic acid except for *Hexagonia tenuis* and *Merulius eurocephalus* (Table 56). In case of gum guaiac, all the ten species show positive reaction. This applies directly to cultures of wood-rotting fungi that are associated with white rots while no colour change follows their application to the cultures that cause brown rots. It is found that gum guaiac test give more satisfactory result. In Baven-damm test, *Fomes annosus, F. pachyphloeus, Polyporus gilvus, P. versicolor* show weak reaction.

The pH of the substrate for decay fungi is found to be acidic which explains the colonization of the fungi on such acidic media. The moisture content ranging from 20.1 to 31.3% is more favourable for the growth of the fungi (Table 48-51) which supports the observation of other workers (Boyce, 1961 and Bakshi, 1971) that decay fungi can not grow in wood if the moisture content is below 15%.

The white rot fungi are present in rainy, autumn and winter seasons and are absent during summer (Table 48-51). This is due to the fact that in summer, the temperature is quite high and moisture content is low, both of which are unfavourable for the growth of the fungi. Findlay (1950), Findlay and Badcock (1954) also found that fungi can survive for longer periods (as
many as nine years) in air-dried wood. Just after the rain, the fungi gradually appear and reach the climax in autumn when both temperature and moisture are suitable for them. In winter also, the two factors are ideal for the growth of decay fungi.

The decay in the living trees is progressive, so that more and more wood is decayed with age. As the trees grow, opportunities for decay also multiply and the rate of wound healing becomes slow. With age, the increment for new wood slows down while decay increases so that at a certain stage, the volume of wood decay overtakes the new wood added to the tree. From this stage, the tree suffers from an increasing net loss year after year. The average decay is greater in slow growing than in the fast growing trees which has an important bearing on the management of forest trees.

The white rot fungi which occur in the two different forested regions of Meghalaya with high rainfall and suitable temperature cause extensive root and stem decay, but no evidence is found that they kill the trees.

From dead trees, altogether 38 decay fungi are recorded which cause both white and brown rots (Table 52-55). They occur primarily on dead wood including dead standing and fallen trees, stumps, logging slash, other dead wood on the ground and wood in service. White rot fungi are dominant and only five brown rot fungi are recorded. The percentage relative abundance
is maximum in the case of *Daedalea flavida* and *Polyporus xanthopus* which are recorded with high frequencies. The number of species is more in Balphakram than Pong Tung forest throughout the year (Fig. 19-21). This is due to the fact that development and growth of decay fungi require different temperatures for different species and even the different parts of the same species, i.e. mycelium growth, production of fruiting bodies and spore germination differ in their temperature requirements. Falck (1926) found that in *Gloeophyllum sepiarium*, the optimum temperature for the germination of spores was 30—34°C, whereas its mycelial growth was best at 36°C. The decay fungi differ in their minimum, optimum and maximum temperature required for growth and development. In the laboratory studies, it is found that the optimum temperature for *Polyporus hirsutus* is at 35°C, *P. gilvus* at 15-25°C, *Poria eurora*, *Lenzites betulina* and *Fomes nanfordii* at 20-25°C, while for *F. annosus*, *F. badius*, *Polyporus versicolor*, *P. semipileatus* and *P. glomeratus* at 15-20°C (Fig. 24-26). The other 36 species of decay fungi have their optimum temperature between 20-30°C (Fig. 24-26). This may be one of the reasons for the occurrence of the decay fungi in different seasons.

The moisture content of the substrate suitable for growth of the decay fungi is 20-32.3% and they prefer acidic pH (Table 52-55). This explains the colonization of such fungi on acidic substrata with suitable moisture content in the different seasons of the year. Germination of spores takes
place on humid substrata, whereas at lower humidities, the spore germination is relatively poor. Zeller (1920) observed that maximum germination of certain decay fungi was at 98% humidity. Such a degree of saturation may be attained naturally in the different seasons of the year depending on the weather condition. Bondartsev (1971) stated that the wood humidities in the range of 30-70% are the most suitable for development and activities of wood-rotting fungi.

Although wood is almost the sole substrate for the penetration and the growth of decay fungi, the environmental conditions also play an important role in the colonization. The selectivity of the decay fungi is apparently determined by their biochemical properties including their ability to secrete various enzymes. Certain anatomical characteristics, such as thickness of the bark, cell size and the proportion of spring wood to summer wood of the hosts, the presence and distribution of resins, gums, tannins and other substances are also probably responsible for preventing the development of decay fungi.

In oxidase reaction, all the white rot fungi from dead plants show positive reaction whereas five brown rot fungi show negative reaction with gum guaiac which is found to be more efficient than gallic or tannic acid media (Table 57). These results show that the direct application of alcoholic gum guaiac to actively growing cultures gives a reliable test for extracellular oxidase. In standard procedure used in this experiment to identify the cultures of wood-rotting fungi, it has proved
more satisfactory than Bavendam test.

The rate of wood decomposition by the activation of different species of decay fungi is quite high in the laboratory conditions (Fig. 22). The rate of decomposition is mainly affected by temperature and moisture. When the six species of fungi are in mixture the rate of decomposition is very fast. This may be due to the fact that all the decay fungi are active and as a result the degradation is maximum. The total dry weight loss of the wood under laboratory conditions indicates that different fungal species have different decomposing ability under similar conditions. The variation in the percentage loss of different wood components suggests that the rate of decomposition is closely linked with the activity of the organisms involved. The rate of decomposition of any substrate is generally proportional to the growth rate of the decomposers (Parnas, 1975).

The ability of fungi to attack various components of wood is determined by the type of enzymes secreted. In fungi causing brown rots, the dominant exoenzymes are hydrolytic which attack cellulose and related polysaccharides but very little, if any lignin. Such wood after decay appears more brown than normal wood due to greater percentage of lignin. On the other hand, fungi causing white rot, the primary decomposition of wood involves a combination of oxidation and hydrolysis. Oxidising exoenzymes are necessary for the breakdown of lignin. The fungi,
therefore, attack all constituents of wood including cellulose and lignin. The present studies show that Daedalea flavida, Fomes annosus, Polyporus biennis and Irpex vellereus are white rot fungi, since they decompose lignin at a faster rate, whereas Lenzites striata and Tremetes cubensis are brown rot fungi and they decompose cellulose faster than lignin (Fig. 23). When all the six species of both white and brown rot fungi are in mixture, the lignin and cellulose decomposition is quite high. This is due to the fact that in the mixture, both white and brown rot fungi are active and all of them are able to degrade cellulose and lignin simultaneously. However, when they are alone, the decomposition of cellulose or lignin is comparatively slow because only one fungus is involved in the process. From this experiment it may be inferred that in the fallen trees, if many fungi, including both white and brown rot attack, the wood would decay at a very faster rate since both cellulose and lignin of the wood would be decomposed simultaneously. The wood loss in the form of total weight loss will include both cellulose and lignin.

The impact of forest diseases is assessed not only by the actual damage caused, but also by the cost of preventive and control measures. In the present study, attempts have been made to control the leaf, stem, root diseases and also decay both in the laboratory and in the natural forest.

In controlling leaf diseases, no fungicides are applied. From the trees, infected leaves are removed, pruned off and
burnt along with the infected litter. The method, however, failed to give control measure, since the percentage infection is not significantly reduced in the affected plants (Table 58). This is due to the fact that most of the foliage pathogens produce air-borne spores which disseminate the fungal propagules. Although by removing and burning of the infected leaves, the inoculum is reduced to some extent from the ground surface of the forest floor, the propagules, which are already present in the air, germinate on the foliage and produce diseases under suitable environmental conditions. As a result, the intensity of disease is not reduced. Although quite a good number of plants are affected, the disease is not serious since defoliation and mortality due to fungal infection are not observed in any of the affected tree species.

In the stem disease, canker clean up method give fairly good result (Table 59). New callus formation is observed from the affected trees. There is no evidence of stem weakening in the trees where the affected bark is removed around the cankered part. Laboratory studies show that the entry of the canker pathogens is through the wound (Table 30-31). As such the best control could be achieved if the wound formation may be prevented.

In in vitro studies, PCNB, Copper sulphate and Benomyl are effective for inhibition of mycelial growth of *Corticium salmonicolor* and *Fusarium solani* (Table 60). Among the three fucigides, PCNB is found to be most effective. Based on this information,
it could be suggested that the fungicides may be further tested in the field to determine their relative efficacies in protecting plants from infection by *C. salmonicolor* and *F. solani*.

For the control of root diseases, only glass house experiments are done. Among PCNB, Vitvax and Captan 50, the latter give good control measure in the case of *Fusarium oxysporum* wilt of *Albizia lebbeck* and *A. procera* in *vitro* (Table 61). PCNB successfully controlled *F. solani* on *Dalbergia sissoo* and *D. stipulacea* in *vitro* (Table 62). Vitvax and PCNB are found to be effective in the control of *Rhizoctonia solani* root rot of *Phyllanthus emblica* and *Quercus serrata* in *vitro* (Table 63). It is found that PCNB has broad host range which inhibits the mycelial growth of both *F. solani* and *R. solani*. Benomyl, Captan 50, Choroneb, PCNB and Vitvax are also inhibitory for mycelial growth of *F. oxysporum*, *F. solani* and *R. solani* in *vitro* (Table 64). Although the fungicides are successful in controlling the root diseases in *vitro*, their application in natural field is limited, except in nurseries, because of the cost. In the forest condition, therefore, proper silvicultural method should be adopted for controlling the root diseases. In the case of plantation trees, light textured soil with adequate soil moisture and good drainage may minimize the damage caused by many root diseases (Bakshi, 1976).

In the case of decay on living trees, caused by *Fomes annosus*, cleaning up wounds and trimming away injured bark from
the affected trees give a good result in the field. New callus formation is observed after one year of trimming the injured bark (Table 65). Since the entry of the fungus is through wounds that may lead to decay, prevention of wound can give a good control measure. Powers and Hodges (1970) suggested silvicultural method for controlling annosus root rot by planting the susceptible species in mixture with other resistant species.

Once the fungi are established in the stumps and in the crop, there is usually little that can be done to control them. It is, therefore, important to prevent the fungi from entering crops by means of primary stump infections. This may be done by treating freshly-cut stumps with a suitable chemicals. The present investigation shows that stump treatment with 20% urea, coal tar and keeping the stumps under water give a very good result in the natural fields (Table 66). Both urea and coal tar are poisonous for decay fungi and as a result the pathogens could not colonize the treated stump. Since decay fungi are not aquatic, the stumps which are kept under water remain free from infection. Where eradication of decay through stump removal is not possible or justified, the methods described in this study may be taken into account to reduce the damage caused by the decay fungi. Greig and Redfern (1974) also suggested that stump protection and removal may give control measure for decay.

For the control of root diseases by mycorrhizal fungi, it is apparent from the results (Table 67-71) that root rot and
wilting caused by _Rhizoctonia solani_ and _Fusarium_ spp. respectively is minimized or there is no affect by the presence of VA mycorrhizal fungi. _Glomus tenuis_ successfully controlled the _Fusarium oxysporum_ wilting on _Albizia lebbeck_ (Table 67), _G. tenuis_ and _G. fasiculatus_ to _Rhizoctonia solani_ root rot of _Quercus serrata_ (Table 71) and _Fusarium oxysporum_ wilt of _Albizia procera_ (Table 68). Although _G. tenuis_ and _G. fasiculatus_ failed to control the wilting of _Fusarium solani_ on _Dalbergia sissoo_ (Table 70) and _F. oxysporum_ on _Cassia tora_ (Table 69), and _G. tenuis_ to _R. solani_ root rot of _Quercus serrata_ (Table 71), the disease development is much delayed. Zak (1964) suggested four methods by which ectomycorrhizae could afford protection to roots which include, by using surplus carbohydrates, by providing a physical barrier, by secreting antibiotics or by favouring protective rhizosphere organisms. All these phenomena could be expected to operate in case of VA mycorrhizal fungi except that of providing a physical barrier since no hyphal mantles are formed over the root surface. In addition, VA mycorrhizal fungi in some instances may affect plant pathogens by inducing morphogenic and biochemical changes in host tissue which are unfavourable to pathogens (Baltruschat _et al._, 1973 and Becker, 1976). The prior colonization phenomena as suggested by Wilhelm (1973) could also be operative in antagonistic interactions. Besides controlling the root diseases, all the mycorrhizal plants show better shoot and root length and also the total biomass. This may primarily be due to the enhancement of phosphate uptake by mycorrhizal plants.
The present observation also shows that the mycorrhizae operates even in the presence of root pathogens which supports the findings of Davis (1980) on *Glomus fasciculatus* to *Thielaviopsis basicola* root rot of citrus. From this experiment it may be concluded that mycorrhizae offer an alternative approach to control certain root diseases rather than with expensive physical or chemical soil treatments. This field of investigation, is, however, still in its infancy and needs detailed study.
SUMMARY
Due to our inadequate knowledge of forest pathology in the North-Eastern India, the present study was undertaken in the different forests of Meghalaya. The object of the present investigation was to locate the different pathogens on their host in relation to the seasonal variation, mode and time of infection, biochemical changes of the infected foliage, loss estimation, decay fungi both on living and dead trees and certain control measures both in the laboratory and field condition.

An extensive survey of the diseases has been made and it was observed that leaf, stem and root were infected by the pathogens. Decay was also recorded both on living and dead trees.

A number of fungi was found to attack the leaves of forest trees. Altogether 32 species of fungi and one species of alga were parasitic on many forest trees causing leaf-spot, leaf rust, powdery mildew, sooty mold and red rust. Among the leaf-spot diseases, the important fungi were Alternaria alternata (Fr.) Keissler, Colletotrichum gloeosporioides Penz., Curvularia lunata (Wakker) Boedijn, Cercospora spp., Helminthosporium spp., Myrothecium roridum Tode ex Fr., Phomopsis bakeri Syd. and Phyllosticta spp. Four species of rust fungi were recorded which include Puccinia congeta Berk and Br., P. gracilenta Syd. and Butler, P. thumbergiae Cooke and Ravenelia sessilis Berk. In powdery mildew, Sphaerotheca lanestris Harkn. attacked Quercus spicata Sm. and Erysiphe
periyarensis Ramakrishnan on *Sterculia villosa* Roxb. and a species of *Erysiphe* on *Maesa ramentacea* A-DC. *Capnodium* spp. *Meliola* spp. were found to attack a wide variety of forest trees causing sooty mold. The parasitic alga, *Cephaloneuros virescens* Kunze was found to attack a number of forest trees causing red-rust. The fungal infection started in the rainy season and continued till winter, whereas the algal infection was abundant in summer and rainy seasons. Germination and growth of the conidia were best at the temperature range of 20-30°C for most of the foliage pathogens. Saprophytic survival of the leaf-spot pathogens was both in the soil and on leaf debris of host and non-host plants. Biochemical analysis of the infected leaves shows that total sugar, total phenol and dry weight were less in such leaves whereas total amino acid and total nitrogen were higher in the fungal infected leaves. The algal infected leaves on the other hand contained more total sugar, total amino acid and dry weight and less amount of total phenol and total nitrogen.

Amongst the stem diseases, only canker was observed. *Corticium salmonicolor* B. and Br. and *Fusarium solani* (Mart.) Appel et Wr. em Snyder et Hansen attacked a wide variety of forest trees that cause much damage.

*C. salmonicolor* had a wide host range than *F. solani*. Plants with DBH class more than 80 cm were not affected by the pathogens, whereas 41-60 cm, plants were susceptible. Laboratory and field studies shows that both these fungi gain entrance
through wounds. The maximum canker development was observed in the rainy and autumn seasons. The optimum temperature for *C. salmonicolor* was at 20-25°C, whereas for *F. solani* it was 25°C. In pathogenicity test, it was found that *Sterculia villosa* Roxb. *Hibiscus macrophyllus* Roxb. were susceptible to *C. salmonicolor*, whereas *Albizia odoratissima* (L.f.) Benth. *Enterolobium saman* Prain and *Populus deltoides* Mar. were susceptible to *F. solani*.

In root diseases, wilting and root rot were observed. In wilt, *Fusarium oxysporum* Schlecht attacked the seedlings of *Albizia lebbeck* Benth. *A. procera* Benth and *Cassia tora* Linn., whereas *Fusarium solani* (Mart.) Appel et Wr. em Snyder et Hansen was pathogenic to *Dalbergia stipulacea* Roxb. and *D. assamica* Benth. seedlings. The disease was observed only in the rainy season with more than 20% moisture content in acidic soil. Wilting was observed in silt and clay soil in mixed deciduous forest. Both *F. oxysporum* and *F. solani* were isolated from soil in the laboratory with 10-40% moisture content till 100 days period. In 50% moisture content, *F. oxysporum* was isolated upto 70 days period whereas *F. solani* was isolated upto 60 days period. Both of them possess quick and wide saprophytic ability on dead roots and in soil and they penetrated through the cut ends of roots more freely than through the bark. In pathogenicity test, it was found that *Dalbergia sissoo* Roxb., *D. tamarindifolia* Roxb. and *Quercus serrata* Thunb. were also susceptible to *F. solani* and *Albizia odoratissima* (L.f.) Benth.
to *F. oxyспорум*. In root rot, *Rhizoctonia solani* Kuhn was found to attack the seedlings of *Phyllanthus emblica* L., *Quercus serrata* Thumb. and *Citrus* sp. The incidence of root rot was associated with high rainfall and poor soil drainage. The disease was observed in both evergreen and mixed deciduous forests in silt and clay soil with slightly acidic pH. The optimum temperature for the growth of the fungus was at 20-30°C.

Decay was observed both in living and dead trees. In the living trees only white rot was observed and ten decay fungi were recorded. They were noted both from older and younger plants, but the disease severity was more in younger plants. Plants with DBH class ranging from 36-40 cm were found to be most susceptible to infection while DBH class more than 50 cm plants was free from infection.

*Fomes annosus* (Fr.) Cooke had a broad host range and it was one of the most dominant species which attack many hardwoods. The pH of the substrate was acidic with 20.1 to 31.3% moisture content. They were present in rainy season, autumn and winter and absent in summer. In oxidase-reaction test, except *Hexagonia tenuis* Hook ex. Fr. and *Merulius eurocephalus* (Berk and Br.) Petch, other eight decay fungi showed positive reaction with gallic and tannic acid. In gum-guaiac test, all the ten species showed positive reaction. In dead trees, altogether 38 decay fungi were recorded which caused both white and brown rot. White rot fungi were dominant and only 5 brown rot fungi were recorded. The percentage relative abundance was highest in the case of *Daedalea flavida* Lev. and.
Polyporus xanthopus Fr. The decay fungi occurred in the forests throughout the year. The optimum temperature for *Polyporus hirsutus* Wulf ex Fr. was at 35°C, *P. gilvus* (Schw.) 15-25°C, *Poria eupora* (Karst.) Cooke, *Lenzites betulina* (L. ex Fr.) Fr. and *Fomes sanfordii* Lloyd, 20-25°C while for *F. annosus* (Fr.) Cooke, *F. badius* (Berk.) Cooke, *Polyporus versicolor* L. ex Fr., *P. semipileatus* Peck. and *P. glomeratus* Peck 15 - 20°C. The other 36 species both from living and dead trees have their optimum temperature at 20 - 30°C. The moisture content of the substrate was 20 - 32.3% with pH 4.6 to 6.1. In extracellular oxidase test all the white rot fungi from dead trees showed positive reaction, whereas brown rot fungi showed negative reaction. The gum-guaiac test gave more satisfactory result. The rate of decomposition in the laboratory condition by decay fungi was quite high. *Daedalea flavida* and *Tremetes cubensis* (Mont.) Sacc. were fast decomposers among all the tested fungi. The rate of decomposition was maximum when the six species of decay fungi were kept in mixture. *D. flavida, Fomes annosus, Polyporus biennis* (Bull. ex Fr.) Fr. and *Irpepx vellereus* Berk and Broome decomposed lignin faster than cellulose whereas *Lenzites striata* (Swartz ex Fr.) Fr. and *Tremetes cubensis* decomposed cellulose faster than lignin. Lignin decomposition was also faster when all the six species were in mixture.

An attempt has also been made to investigate the control of certain diseases. Removal and burning of the infected leaves failed to give control measure in the natural field condition.
Canker clean-up method gave satisfactory results where callus formation was observed after one year. In in vitro studies, PCNB at 50 to 100 ppm and Benomyl at 100 to 1000 ppm inhibited the growth of *C. salmonicolor* and *F. solani*. Copper sulphate at 50 to 1000 ppm inhibited the mycelial growth of both these canker pathogens. In root diseases, PCNB at 1 ppm controlled the *Fusarium oxysporum* wilt of *Albizia procera* Benth.; Vitavax at 10 ppm to *Albizia lebbeck* Benth., Captan 50 at 40 ppm to both *A. procera* and *A. lebbeck*. In the case of *Fusarium solani*, PCNB at 10 ppm controlled the wilting of *Dalbergia sissoo* Roxb. and *D. stipulacea* Roxb., Vitavax at 20 ppm to *D. stipulacea*. In the case of *Rhizoctonia solani* root rot, PCNB at 1 ppm and Vitavax at 2 ppm controlled the root rot *Phyllanthus emblica* and *Quercus serrata*. Benomyl at 30 ppm was not effective. In in vitro studies, Benomyl at 50 ppm inhibited the growth of *Fusarium oxysporum* and *F. solani* and 30 ppm to *Rhizoctonia solani*, Captan 50 at 40 ppm to *F. oxysporum* and *F. solani* and 50 ppm to *R. solani*, Chloroneb at 100 ppm to *F. oxysporum* and *R. solani* and 80 ppm to *F. solani*. PCNB at 1 ppm to *F. oxysporum*, *F. solani* and *R. solani* while Vitavax at 10 ppm to *F. oxysporum* and *F. solani* and 20 ppm to *R. solani*. In the case of *Fomes annosus* infection on *Quercus serrata*, callus formation was observed after one year of cleaning up wounds and trimming away the injured bark. In the case of decay on dead trees, stump treatment with 20% urea, coal tar and keeping the stump under water gave very good result in controlling decay in the natural field condition. For controlling root
diseases by mycorrhizal fungi, it was found that *Glomus tenuis* (Greenhall) Hall and a mixture of *G. tenuis* and *G. fasciculatus* (Thaxter) Gerd. and Trappe successfully controlled the wilting of *Albizia lebbeck* caused by *F. oxysporum* and *G. fasciculatus* to *Quercus serrata* caused by *Rhizoctonia solani*. Although *G. tenuis* and *G. fasciculatus* failed to give control measure for *Fusarium solani* wilting of *Dalbergia sissoo*, *F. oxysporum* wilting of *Cassia tora* and *G. tenuis* to *Rhizoctonia solani* root rot of *Quercus serrata*, the disease development was delayed. Besides, all the mycorrhizal plants showed larger shoot and root length and total biomass.