Organisms of any community, besides interacting among themselves, always have functional relationship with the external world or the environment. The environment is a complex whole of many interacting factors that influence every organism. It is widely recognized that in the field of ecology there are fundamental principles that apply to most organisms. Workers investigating a particular type of organism can define processes and formulate principles of application to ecology generally. Conversely, works in a restricted field can often benefit from the application of ideas deriving from work of very different organisms. Fungi, because of their small size and their rapid activity, permit a study on a smaller scale than do many more traditional ecological materials, partly because, fungi have certain special features of somatic morphology, of physiology and of genetics. Besides large surface to volume ratio, inherent in the hyphal growth-form, gives a large contact with environment and greatly affects fungal biology. Over and above, larger area of contact between the fungus and the environment, there is a closer proximity between any point in the fungal protoplasm itself and the environment. For these reasons, the environment plays a much more immediate and direct part in fungal behaviour as compared to other organisms.

The study of the ecology of *phytophthora infestans* (Mont) de Bary is of special interest as the fungus encoun-
ters three different environments - soil or edaphic, host or biotic and climatic during its life span. The edaphic, biotic and climatic factors, which constitute a part of the environment, affect organisms, their survival, growth and dynamics in a holistic manner. Unlike most other fungi, P.infestans is very susceptible to environmental variations, which consequently affect its geographical distribution. The potato crops in regions of very high humidity and low temperature usually suffer from severe attack of blight, while crops of the warm and dry areas very often escape infection.

In India, the climatic conditions vary from region to region. Variations in the incidence of blight, corresponding to the variations in the climatic conditions of different parts of the country, have been reported by various workers (Dastur, 1917; Chattopadhyaya, 1952; Choudhuri and Pal, 1959; Dutt, 1964; Mukhopadhyaya and Sengupta 1967). The district of Lakhimpur in Assam, situated at the foot hills of Arunachal Pradesh, receives comparatively heavier rainfall than other parts of the state, even during the winter months when potato season is on. With the appropriate climatic pattern, conducive to disease development prevailing in the region and with the introduction of a number of potato cultivars, the presence of a wide spectrum of races of P.infestans can be expected from this area. It was observed in the present investigation that, a total of seven physiologic races of the fungus was available in the district of Lakhimpur. Phadtare et al. (1971) reported
the presence of nine different races namely, 0, 1, 4, 1.2, 1.4, 2.4, 3.4, 1.2.4 and 3.4.7 from the hills of Assam (now Meghalaya) and he attributed the occurrence of such a wide spectrum of races to the congenial environment including climatic conditions and wide host range of the fungus.

Isolation and culturing of a fungus from infected plant tissue is an essential prerequisite for the study of the nature and ecological behaviour of the fungus. Identification of isolated races of *P. infestans* on the basis of morphological characters was not found to be tenable. However, culturing of the three physiologic races of the fungus showed significant variations in the growth rate in artificial media. Among solid media, maximum growth of race 0 was observed in Hollomon's medium while races 4 and 1.4 grew best in Eckert and Tsao's medium. Likewise, of the three liquid media tested, Cuppett and Lilly's medium supported good growth of races 0 and 1.4 while race 4 grew best in Hwang's medium. It is to be noted that profuse growth as well as sporulation of all the races of the fungus was observed when cultured in potato tuber slices. Cultural variability among the three races in the present investigation was not unexpected. Variation among races and even isolates of the same race of *P. infestans* was earlier reported by French (1953), Thurston et al. (1959) and Golovin et al. (1961). The whole character complex of the races of the fungus may be attributed to the aggressiveness of the races as suggested by Castranovo et al. (1954). Specificity in the carbohydrate and nitrogen requirement of the races of
the fungus may also be a factor for cultural variation as suggested by Hall (1959) and Roncadori (1965).

An understanding of the physiologic basis of plasticity of the races of *P. infestans* should furnish a clue to the ecological nature and behaviour of the fungus. The nutritional responses of the three virulent races of the fungus showed a remarkable range of diversity. Significant variations have been observed among the races and even among the isolates of the same race in their requirement of essential compounds for growth. Similar conclusions were also drawn by French (1953). Fehrmann (1971) studied the growth of *P. infestans* and obtained a yield of 176.7 mg/culture with one isolate and 0.2 mg with another isolate of the fungus when both isolates were cultured in a liquid glucose/glutamic acid medium. In the present investigation; among different carbon sources, glucose and sucrose supported good growth of *P. infestans*, the former being the better source. Among nitrogen compounds none of the inorganic nitrogen sources supported satisfactory growth of the fungus. Asparagine was found to be best utilized by majority of the isolates of the three races. The present findings are in agreement with the results of workers like Sakai (1955), Hall (1959) and Child and Fothergill (1967). Among sulphur sources, magnesium sulphate was found to be the best sulphur source for growth of the fungus. This substance has been reported to support growth of a large number of fungi (Baishya, 1965; Chakraborty, 1980; Thakuria, 1982). Utilization of magnesium sulphate may be attributed to the presence
of Mg-ion which has its principal essential function in the
activation of enzymes necessary for normal metabolism and
growth. Among different phosphorus sources, potassium dihy-
drogen phosphate was found to be the appropriate phosphorus
source for the races of \textit{P. infestans}, a finding which is in
agreement with the work of Jones et al. (1912). Regarding
the requirement of trace elements, it is revealed from the
present investigation that \textit{P. infestans} requires iron, zinc,
copper and managanese for its growth. It was further obser-
ved that growth of the fungus was more when all the trace el-
ements were added together than tested individually.

\textit{Phytophthora infestans} has two distinct habitat sites
on the potato plant for their initial growth and development,
one on the haulm and other on the tuber. The establishment
of the fungus on the haulm and its subsequent development
depends largely on environmental conditions besides other
host factors. In vitro studies on the influence of tempera-
ture and humidity on the growth of \textit{P. infestans} revealed that
the fungus is very sensitive to these factors. High tempera-
ture (beyond 25\(^\circ\)c) as well as low humidity (less than 80 per-
cent) did not favour good growth of any of the races of the
fungus. Very low temperature (less than 10\(^\circ\)c) also had an
adverse effect on the growth of the fungus. It is revealed
from the present investigation that a temperature range be-
tween 15 - 20\(^\circ\)c and a humidity level of more than 80 percent
is suitable for growth and development of all the three races
studied.
Field studies on the course of development of *P. infestans* on potato crop revealed two possible ways of establishment of the fungus on the haulm - from infected tubers and from airborne inoculum. The growth of the fungus from diseased potato tubers into sprouts was first demonstrated by de Bary (1863) - an important discovery that was not achieved easily. The phenomenon was later reported by Limasset and Godard (1943), Peterson (1947) and Korolov (1981). Mycelium overwintering in diseased tubers is generally thought to be the most important source for start of epidemics. Its importance will be better appreciated only when reliable evidences on both the frequency of lesions development on aerial stem from fungus disseminated from diseased potato tuber, and the area over which the fungus can spread from such primary lesions are available. Experiments on plantation of both inoculated and healthy seed tubers and measuring the intensity of subsequent disease development showed that initial stem lesions occurred near the ground level in most of the plants of the inoculated plot, which proved to be connected with direct underground infection. Closer inspection of the plants bearing initial stem lesions revealed gradual extension of the infected portion to the upper region of the stem, viz. petioles and leaves. Subsequent spread of the disease in the whole plot was probably due to aerial infection.

The second possibility of spread of the disease through air borne inoculum can not also be ruled out. Experimental results show that blight also appeared in the plot where heal-
thy seed tubers were planted but it started with the initial infection on the terminal leaflets rather than on the stems. It is probable that the initial infection source in the form of sporangia was contributed by a foreign source through aerial dissemination and deposition on the terminal leaflet, and subsequent development and spread to the plants in the vicinity took place.

While perennating in soil in association with tuber or other remains of potato plants, *P. infestans* encounters various soil factors, both abiotic and biotic, affecting their survival and subsequent growth and development on the potato cultivars of the next season. Studies relating to the effect of various edaphic factors on the survival, growth and development of the fungus revealed that *P. infestans* was available in field soil under potato crop only during the period of haulm infection. The fungus could be traced up to 6 inches in depth in soil, though in very small proportion, maximum being on the surface soil. The sporangia were obviously washed down by rain water to the deeper layer of soils which, after coming in contact with tubers, established on the surface and subsequently developed on fresh tubers. In vitro studies on the persistence of the fungus in soil revealed that a number of soil factors such as soil type, soil temperature, soil moisture and soil pH influence growth of the fungus in soil besides the influence of soil microorganisms. In the present investigation, *P. infestans* could be detected in clay and sandy
loam soil up to 40 days when soil temperature was maintained at 20°C along with low soil moisture (25%) and pH of the soil at 6.0. Persistence of the fungus in soil was found to be reduced when these levels were altered. It is thus obvious from the present findings that increase in temperature and moisture content of the soil along with alteration in the soil acidity during the summer months suppressed growth of the fungus in soil. Further, it was observed that soil microorganisms isolated from the tuber surface, such as Penicillium sp., Trichoderma sp. and Rhizoctonia sp. inhibited the growth of the fungus and Aspergillus sp., Mucor sp. and Fusarium sp. overgrew the fungus quickly when grown in culture media with these fungi. All these microorganisms might have hindered the persistence of the fungus in soil for longer periods.

The spread of the disease within the crop depends primarily upon the microclimate which is, of course, closely linked up with the prevailing weather conditions. A comparative study of meteorological data and disease records, provide sufficient clues for deducing the pattern of disease development. Studies on the course of development of blight and its subsequent spread in uninoculated as well as inoculated plots revealed maximum number of lesions on the plants on the days preceding rainfall. The temperature becomes lower with subsequent increase in the humidity level which rendered easy sporulation and subsequent development of the fungus on the haulm.
It is an accepted fact that considerable variation in the level of blight occurs in different seasons, and in different places in any one season, due primarily to differences in climatic patterns in relation to rainfall and humidity. There are however additional variations to be noted within a single crop, which are probably attributable to the mechanism of dispersal, deposition as well as infectivity of sporangia within the crop, although varying individual susceptibilities dependent upon the growth status of the host, may also be involved (Grainger, 1956). It is revealed from the present studies that the mode of dispersal, deposition as well as infectivity of sporangia of *P. infestans* follows a definite pattern as the day advances. Higher rate of dispersal as well as deposition was observed during the morning hours. It is obvious that during night hours temperature decreases with increase in humidity level which favours easy sporulation of the fungus on the host surface. The sporangia thus formed get themselves detached from the sporangiophores in the relatively higher wind currents of the morning hours resulting in higher rate of dispersal and deposition on the surface of other host plants. Infectivity of sporangia trapped during late afternoon hours was higher than those trapped during early hours of the day. It is assumed that sporangia produced during morning hours loses viability earlier, being unable to resist the hot dry condition of the noon hours, while those formed in the late afternoon hours were not exposed to such unfavourable conditions and thus retained infectivity for a longer period.
Host variety as well as growth status of the host plant are very important factors which influence the intensity and spread of the disease to a great extent. The resistance exerted by a host plant to attack by plant pathogens varies according to the age of plants and maturity of leaves. In the experiments carried out on the reaction behaviour of potato plants to infection by *P. infestans* it was revealed that the young plants are generally easily attacked by the fungus than the old plants. In case of leaf maturity, however, the young upper leaves are generally less susceptible than the more matured lower leaves. This type of reaction behaviour was not confined only to the susceptible cultivar, but the more resistant cultivar Kufri-Jyoti was also found to behave in the same manner, though to a lesser extent. Variations in the intensity of growth of the fungus have also been observed on the two surfaces of the leaves. Lesion growth was found to be higher on the abaxial surface, irrespective of cultivar, plant age and leaf position. Variation in growth pattern of the fungus in relation to plant age and leaf position is attributable to the changes in host physiology at different stages of growth or the presence of a chemical mechanism either inhibiting or stimulating hyphal growth at different stages of host development, as suggested by Lowing and Acha (1959). Variation in growth pattern of the fungus on the two surfaces of leaves may be due to morphoanatomical characteristic of the two surfaces or the changing microclimate of the leaf surface, as suggested by Burrage (1971).

The extent of infection of host plants by *P. infestans*
also depends on the quantity of inoculum. Higher inoculum concentration resulted in higher rate of lesion growth. In the present investigation, higher inoculum concentration (50,000 sporangia/ml) was even found to be associated with increased lesion growth on the leaves of the resistant cultivar Kufri-Jyoti.

Host plant nutrition is another important factor which influences the susceptibility of potato plants to infection by *P. infestans*. It has been observed in the present investigation that both nitrogen and potassium when applied singly to the plants, increases susceptibility of the plants to infection by the fungus, maximum being observed with potassium application. Treatment of plants with phosphorus increased the resistance of plants to attack by *P. infestans*. The fact that susceptibility of plants increases with the application of nitrogen and potassium is well established (Diwakar and Payak, 1980; Bedi and Dhiman, 1980; Panduranga and Hiremath, 1985). Increase in susceptibility of plants as a result of nitrogen and potassium application may be due to anatomical changes in leaf and stem (Dwivedi and Shukla, 1981), or to changes in the biochemical content of the plants (Bedi and Dhiman, 1983).

The importance of phyllosphere in the incidence and development of infection by fungi has received much attention during these days. The organisms in the surface of plants as well as in the air have a profound influence on the course of
events to the infection of hosts and are ultimately related to the formulation of methods of disease control. In the present investigation intensity of \textit{P. infestans} has been found to vary in the phylloplane as well as phyllosphere during different periods of growth of the plants. Experimental results show that \textit{P. infestans} was present in the air from the month of December while in the phylloplane in January, which indicates that initial infection occured from an airborne inoculum and subsequent development took place. Maximum population of the fungus was observed both in the air as well as on the plant surface during the month of February. It is interesting to note that population of other microorganisms on the phylloplane of potato was maximum during the month of January. It is thus probable that these organisms hindered deposition as well as growth of \textit{P. infestans} resulting in lower population during January in comparison to other microorganisms in general. Decrease in population of the fungus, both in air as well as phylloplane may directly be correlated with higher temperature and low humidity. In the air, the fungus was found in higher amount at lower heights i.e. around the plant canopy. Population of the fungus decreased with increasing heights.

The physiological and biochemical aspects of resistance of host tissue to attack by plant pathogens have received sporadic attention since the middle of this century. Workers on this line emphasized resistance to be due to biochemical changes in the components of host tissue in relation to infection
by the pathogens and also varying quantities of certain com­ponents of host tissue which were supposed to inhibit the es­tablishment of pathogen in the host tissue. Results of the present investigation on the biochemical aspects of pathogene­sis and resistance of potato plants to infection by P. infestans revealed a number of biochemical factors involved in the mecha­nism.

Alterations in the level of chlorophyll as a result of fungal infection have been reported by a number of workers for different plant pathogens (Tayal et al., 1981; Reddy et al., 1983). In the present investigation also a gradual depletion in the chlorophyll level in potato leaves as a result of infection by P. infestans was observed. This may be attributed to the de­struction or inhibition of chlorophyll synthesis caused by de­velopment of the fungus. Further, it is revealed from the in­vestigation that chlorophyll content of leaves of potato plants varies according to host variety and maturity of leaves. The leaves of the resistant cultivar Kufri-Jyoti contained higher proportion of the substance than the susceptible cultivar Up­to-date. Further the less susceptible young upper leaves con­tained more chlorophyll than the susceptible lower leaves. As such, a direct correlation may be expected between chlorophyll level and resistance of tissues to infection. It is not known how chlorophyll influences the mechanism of resistance, but it is possible that chlorophyll may act through dry matter accu­mulation creating carbohydrate status, less favourable to the
spread of the fungus in such tissues as suggested by Szczotka et al. (1973).

The carbohydrate status of the host plant as a result of infection by *P. infestans*, revealed that considerable depletion occurred in the total soluble sugar content and lesser depletion in the starch level in the infected tissues. The decreased carbohydrate level in the tissues after infection was not unexpected. Under pathogenesis, enhanced respiratory rates (Swamy, 1964) and movement of photosynthetic products to the site of infection (Gauman, 1950; Holligan et al., 1974) are the most frequently observed phenomena. The activation of carbohydrate hydrolyzing enzymes in the infected tissue, as observed by Schipper and Mirocha (1969) could also result in a carbohydrate depletion.

Association of carbohydrate status of potato plants in the mechanism of resistance has been emphasized by Grainger (1968) and Warren et al. (1973). Grainger stated that if the host has an adequately high 'exploitable' level of carbohydrate, a pathogen can attack, but it cannot start to do so if the Cp/Rs ratio is sufficiently low. In the present investigation also higher amount of total sugar and starch content was obtained in the susceptible plant parts, a finding, which stands in conformity with the above workers.

Results of the experiments of amino acid content suggest no definite correlation between single amino acid and re-
sistance of potato plants to infection by \textit{P. infestans}. Differences have, however, been observed in the concentrations of few amino acids in healthy and infected and also in resistant and susceptible plant tissues. Reduction in the concentration of asparagine and proline and complete disappearance of methionine and alanine after infection might be due to their utilization by the fungus. The possibility of arginine and cysteine to be associated in the mechanism of resistance, can not be ruled out, because concentrations of these amino acids were found to increase in the tuber tissues of the resistant cultivar after infection. It is also worthy to mention here that these two amino acids did not support growth of \textit{P. infestans} in culture media. This view is further supported by the fact that arginine and cysteine were found in higher concentrations in the young leaves of the resistant cultivar.

The association of phenolic substances in the mechanism of resistance of plants is an well established fact. In the present investigation, chlorogenic acid, an ortho dehydroxy phenol, was found to increase in the tissues of both resistant and susceptible cultivar after infection by \textit{P. infestans}, which supports the findings of Friend \textit{et al.} (1973). Higher amount of this substance has also been found in the leaves of the resistant cultivar than the susceptible one. Further, the young leaves of both cultivars contained significantly higher amount of chlorogenic acid than the susceptible lower leaves. However, when attention is confined to tuber tissues, no signifi-
cant variation in chlorogenic acid content was obtained in the tuber tissues of both resistant and susceptible cultivars. As such, no direct correlation has been found between chlorogenic acid content and resistance of tuber tissues of potato. These observations stand in conformity with the findings of Fehrmann and Dimond (1967). So far leaf tissues are concerned, a correlation was found in the present investigation, between chlorogenic acid content and resistance of tissues to infection by P. infestans.

Experimental results indicate that a definite correlation exists between the activity of enzyme peroxidase and resistance of potato plants to infection by P. infestans. Activity of the enzyme rapidly increased at the initial stage of infection and then gradually declined. Both tubers and leaves of the resistant cultivar exhibited higher peroxidase activity than the susceptible cultivar. Moreover, the young leaves, which are resistant to infection showed higher activity of the enzyme than the lower leaves. Increased peroxidase activity may be attributed to deposition of suberin in the peripheral cell walls and accumulation of quinone type compounds as suggested by Schober (1971).

In the present investigation, activity of enzyme polyphenoloxidase has been found to be associated with resistance so far leaf tissues are concerned. No significant variation in the activity of the enzyme was obtained with tuber tissues. However, increase in the activity of the enzyme was obtained in
all tissues after infection.

The chemical content of plants have been found to be influenced by factors like host plant nutrition and light. In earlier experiments, treatment of plants with potassium has been found to increase susceptibility of plants to infection. Attempts were therefore made to find if potassium influences the chemical content of plants. Results of the present investigation indicate increase in the level of sugar and starch and decrease in the level of chlorogenic acid as a result of potassium application. Activity of enzymes peroxidase and polyphenoloxidase decreased in plants treated with potassium. No significant variation was, however, found in the contents of chlorophyll and amino acids in plants in relation to treatment with potassium.

The influence of light on production and composition of chemical constituents has been emphasized by Vickery et al. (1937). In the present investigation, no significant effect of light in the chemical composition of tuber tissue of potato was obtained except that total sugar increased in the tissues exposed to continuous light. Activity of enzyme peroxidase was also found to increase considerably in tissues exposed to light.

Finally, in addition to the effect of various biochemical constituents of the host plant that regulate growth, development and population dynamics of Phytophthora infestans, it comes across some inorganic chemicals, in the form of fungicides, applied during plant control operations. These fungicides have
been found to play important part in the control of growth and development of the fungus, though not all the well known fungicides were found to have equal effectiveness in this regard. Results on the comparative effectiveness of test fungicides on the growth of *P. infestans* revealed significant effect of Bordeaux mixture, among non-systemic fungicides, in the control of foliar damage in both the crop seasons. Among systemic fungicides, both Ridomil and Benomyl were found to be highly effective against the attack of the fungus. Variations in the intensity of disease development in the fungicide sprayed plots during the two crop seasons may be attributed to the influence of the varying climatic pattern of the two seasons. The comparatively heavier rainfall during the crop season of 1982-83 might have washed away or diluted the fungicides from the plant surface resulting in increased plant infection. Further, the surface temperature of leaves decreased with increase in humidity during rainy days favouring easy sporulation of the fungus. It is obvious that overall affect of various climatic factors coupled with the affect of fungicides play important role on the ecological life cycle of *Phytophthora infestans*.

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