STUDIES ON POPULATION AND ACTIVITY OF MICROORGANISMS ASSOCIATED WITH POTATO CROP

By

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We certify that the thesis entitled : "STUDIES ON POPULATION AND ACTIVITY OF MICROORGANISMS ASSOCIATED WITH POTATO CROP" submitted by Mr. Awadhesh Kumar Shukla, M.Sc. for the degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under our supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree. This work has not been submitted for any degree of any other University.

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C O N T E N T S

GENERAL INTRODUCTION

The soil is a complex system wherein chemical, physical and biochemical factors are held in a dynamic equilibrium. The physico-chemical properties of soil determine the capacity of the soil to provide plant nutrients in proper amount for the growth of crops. In addition they also regulate the population and activity of microorganisms. The characteristics of soil constantly change organisms population. In agricultural soils, ploughing, tillage application of fertilizer and biocides and type of cultivation affect the microorganisms of soil. The analysis of factors regulating the temporal dynamics of microbial population and their activities in soils provide an insight to the structure and function of the soil ecosystem. In soil, fungi and bacteria are responsible for breakdown of organic matter and release of nutrients.Fungi and bacteria are also known to be responsible for nutrient transformations, particularly in the case of nitrogenous and phosphatic minerals. Soil microflora thus exert considerable influence on the soil fertility and plant growth. Therefore, for better management of agricultural lands knowledge on microbial population and its activity is a fundamental requisite.The measurements of population and biological activities of microorganisms provides an index of various metabolic process of the soil.During recent years more emphasis is laid on the functional attributes of the microorganisms in the ecosystems. These are generally determined by the estimation of the rates of various biochemical pro-

cesses involving microbial enzymes viz., dehydrogenase, urease and phosphatase and CO_2 evolution. To obtain better insight into the ecology of soil microorganisms and for better understanding of the role of microbial communities in the soil ecosystem, quantitative and qualitative studies must be performed on the distribution of microorganisms and their biochemical activities in different type of cultivation.

Generally, enzymes accumulated in soil have a biological significance as they participate in the cycling of elements and thus play a very important role in the initial phase of the decomposition of organic residue (Kiss et al. 1975). Dehydrogenase activity in soil is frequently studied because of its relation to the total range of oxidative activity of the soil micro-flora (Ladd, 1978). Dehydrogenase activity appears to be more dependent upon the metabolic rate of microbial population of the soil than upon the activity of specific free enzyme. Thus, the estimation of dehydrogenase activity in soil provides correlative information on the biological activity and microbial population. Urea is unique among commonly used synthetic nitrogen fertilizers as its efficiency is greatly affected by the soil enzyme-urease. Mashtakov (1954) reported that urease is an indicator of total biological activity and fertility of soil. Generally, urease activity correlates with organic matter content due to its existence as a complex with

organic constituents. Phosphatase activity is directly related to the level of organic phosphorus in soil. As phosphatase mediates the release of inorganic phosphates from its inorganic and organically bound states. The release of phosphorus is fundamental to the maintenance of phosphorus cycle. Phosphatase activity has been found to be related to soil physico-chemical characters and microbial population. Soil respiration is also one of the factors which provide an index of microbial activity in soils. Enzyme assays, in conjunction with soil microbial respiration, can provide a clear picture of the microbial community metabolism (Nanniperi et al. 1978).

The use of fungicides and herbicides is becoming a common practice for the control of pathogens and weeds in modern agriculture. Application of fungicides and herbicides alter the number and activity of micro-organisms and thus influence the soil fertility and ecosystem function. On phyllosphere, microorganisms are held in dynamic equilibrium. There are evidences in support of the hypothesis that saprophytes play an important part in controlling the incidence of plant disease (Crosse, 1959; Tiwari and Mishra, 1976). The spray of these chemicals affects the non-target microorganisms of the phyllosphere and disturbs the microbial population and species composition. These chemicals directly or indirectly reach to the soil through run off from treated aerial system or from drifting spray. The rhizos-

phere is known for the intense biological activity of microorganisms. Generally, these chemicals affect adversely the microbial population of rhizosphere and soil. Application of various biocides also cause unfavourable alteration in biochemical process of soil. The biocides are generally inhibitory to most microbial processes, however, certain biocides are known to stimulate the microbial activity (Baruah and Mishra, 1986). Although, during recent times use of fungicides and herbicides has increased manyfolds; the effect of these biocides on the rhizosphere microflora has not received ample attention.

Alternaria alternata causes disease in leaf and tuber of potato. In field condition it affects the above ground parts of plant which causes loss in yield. During storage in godowns it causes blackpit disease in tubers. Generally, chemicals appear to be the plausible method for the control of A. alternata on potato.Very few studies are available on the effects of fungicides and herbicides on A. alternata (Mathur and Sarbhoy, 1983). The informations on the effect of these chemicals on the colony growth, spore germination and germ tube elongation would help in working out of the strategies for the control of the pathogen.

In potato cultivation, after harvesting of tubers, stem, root and leaf litters are left in the field which are incorporated in the soil before sowing of the next crop.

Thus, crop plant residue and its decomposition products become important component of the soil, which play an important role in maintaining the soil fertility through affecting both the physical structure and nutrient status of soil. The decomposition of litter is carried out by microorganisms in soil. Decomposition rates of litter are frequantly considered to be regulated by the interaction between soil organisms environmental condition and litter quality. Though a number of studies are available on the decomposition of crop residues in agricultural soils (Christensen, 1985; Baruah and Mishra, 1986; Weissen and Berg,1986). the decomposition of potato litter has not been studied. It was therefore, thought desirable to study the process of decomposition of the potato crop litter in order to better understand the role of the litter in nutrient generation in soil and also the role of microorganisms in the process.

The present study has been divided into following headings :

1. Physico-chemical characters, soil microflora and their their activities.
   (a) Physico-chemical characters of soil
   (b) Isolation of fungi and bacteria.
   (c) Dehydrogenase, urease, phosphatase and CO_2 evolution
2. Influence of fungicides and herbicides on phyllosphere microflora of potato.

3. Influence of fungicides and herbicides on rhizosphere microflora of potato.

4. Influence of fungicides and herbicides on colony growth, spore germination and germ tube of Alternaria alternata.

5. Study of microflora, weight loss and nutrient loss in decomposing litter of potato.

CLIMATE AND SEASONS OF THE STUDY AREA

CLIMATE AND SEASONS OF STUDY AREA

The three potato fields were situated at Upper Shillong (altitude 1540 m, latitude 25°34"N, longitude 91°56"E). The ambient temperature rainfall and relative humidity data of fields are giveniin fig.1. Study sites experience heavy annual rainfall. The rainfall varied from 279.0 mm to 4.0 mm. Most of the rainfall occurs during the months of April to September. Months of October to March are dry although a few occasional showers of rain may occur during this period as well. High annual rainfall, cloud cover of the sky and thick vegetation of the region keep the atmosphere humid during most period of the year. The maximum temperature goes upto 23°C and minimum 0.5°C. Similarly, the humidity is very high ranging in between 92% and 44%.

The typical summer season is not found at Shillong. However, based on the meteoroligal condition the year can be divided into the following seasons .

Spring season : The period from the middle of February upto middle of April covers the spring season which experiences very high wind velocity with less humidity and moderate temperature.

Rainy season : The rainy season extends from the middle of April to the middle of October. However, the early period of the rainy season is a bit warm representing summer,while

Fig.1. Rainfall, ambient temperature and relative humidity of the study area (September 1985 - November 1986). Histograms : rainfall, closed circles : Maximum temperature, open circles : Minimum temperature, open triangles : Morning h. humidity, closed triangles : evening h. humidity.

FIG.1.


30
15
0
TEMPERATURE (°C)
300
200
100
0
RAINFALL (mm)
100
50
0
RELATIVE HUMIDITY (%)
S O N D J F M A M J J A S O N
1985
1986
1986

later period of the season is comparatively cool.

Winter season : Winter season starts at the end of October and continues upto middle of February. In this season rainfall is very low.

CHAPTER - I

PHYSICO CHEMICAL CHARACTERS SOIL MICRO-FLORA AND THEIR ACTIVIES IN POTATO FIELD SOILS

INTRODUCTION

Soil, a nonrenewable resource, is depleting with a fairly rapid rate due to its over exploitation and poor management resulting ultimately into accelerated rate of erosion.The problem is more serious in hill agro-ecosystems particularly in areas where shifting cultivation is practised.Development of appropriate strategy for management and conservation of soil is posing a great challenge to the soil conservationists during recent years.Any attempt to restore this vital resource and also for its optimum utilisation knowledge on structure and function of soil ecosystem is a prerequisite.

Soils are impregnated with a variety of heterotrophic microorganisms which largely derive their nutrition from organic substances reaching to the soil in the form of dead plant and animal remains and their excretory products. The microorganisms perform a vital role in the soil as they are responsible for the decomposition of the organic matter and they play an important role in transformation of various nutrients from nonavailable to available forms. Thus microorganisms hold a key position in the nutrient cycle and functioning of soil ecosystem. That microorganisms play an important role in soil was recognised long back (Adametz, 1886; Jensen, 1931) and since then a large number of workers have contributed towards our

knowledge on the subject (Warcup, 1951; England and Rice, 1957; Mishra, 1966; Widden, 1979; Clarke and Christensen, 1981; Abouheilah, 1985; Acea and Carballas, 1986; Thomas, 1987). For a long time microbial populations estimated by dilution plate method or by soil plate method were used as an index of microbial activity in soil. Much emphasis was laid on the microflora of soil. Most studies on ecology of soil microbes emphasised on the effects of ecological factor and seasonal and spatial variations in the microflora (Moubasher and Dohleb, 1970; Maltby, 1984; Klein et al., 1986). What really these microbes do was generally tested in laboratory cultures (Skujins et al., 1970; Ingham and Klein, 1984). Of late various techniques have been evolved that give to a fairly reliable degree of precision an index of microbial activity in soils (Oedes and Jenkinson, 1979; West et al., 1986). Among these techniques estimations of activities of various enzymes provide a measure of microbial activity (Ross et al. 1982; Frankenberger and Dick, 1983; Nannipieri et al., 1983; Kanzawa and Filip, 1986; West et al., 1986). Dehydrogenase, urease and phosphatases estimations provide an index of microbial activity and they also give a measure of oxidative-reductive reactions, rate of urea degradation and of phosphate regenerations in soil (Skujin, 1976; Tyler, 1976; Mulvaney and Bremner, 1978; Frankenberger, 1983; Trevors, 1984). Estimations of the activities of above enzymes give an indication of poten-

tial capacity of soil to carry out biochemical processes.

Soil respiration is another index of microbial activity (Chaney et al., 1978), as most of the CO_2 evolved from soil comes from microbial respiration (Smith and Brown, 1932). It also gives an indication of the rate at which soil organic matter is broken down. Measurements of enzymes activity in conjunction with soil respiration and microbial number provides the most reliable index of microbial activity in soils (Casida, 1977; Stroo and Jencks, 1982; Ross and Cairns, 1982; Frankenberger and Dick, 1983; Nohrstedt, 1985; West et al., 1986).

A perusal of literature reveals that our knowledge on the ecology of soil microorganisms is largely based on research in forest and grassland soils (Roy and Dwivedi, 1962; Saksena et al. 1965; Mishra, 1966; Christensen, 1969; Lewis et al. 1971; Redman, 1975; Widden, 1979). Microbiological studies of agricultural soils have received less attention because soil microbes could not be manipulated so profitably to improve crop-yield as were the soil nutrient, soil moisture and crop variety and therefore, this area did not receive proper attention of agricultural scientists. Studies available on the subject are mainly concerned with the effects of various agricultural practices namely, tillage, and compaction, manuring, fertilizer application and types of crops on the soil microbes

(Jensen, 1931; Singh, 1937; Khan, 1970; Nair, 1973; Verstraete and Voets, 1977; Martyniuk and Wanger, 1978; Soderstrom et al. 1983; Bolten et al. 1985; Weker et al., 1985).

The potato crops grown on high altitudes of Meghalaya provide an unique feature because of the fact that the crop is grown under three different types of soil system. These systems represent age old practice of shifting cultivation on hill slopes· permanent type of modern cultivation found in valleys and cultivation on bench terraces recently introduced by the departments of agriculture. All the three systems are found within a very small area thus climatological and soil type variations are non-existent. The three cultivation types are described in the head site characteristics.

The present work was carried out with twin objectives : (i) To see how various methods of microbial activity estimation correlate with each other and with physico-chemical characteristics of potato field soil.(ii) To compare the potato field soils under three systems with respect to the microbial community structure, their activities and their physico-chemical characteristics. For this purpose, temporal and depth-wise distribution of fungi and bacteria, enzymes activities (dehydrogenase, urease, phosphatase), Co_2 evolution and various physico-chemical

characteristics of soil have been measured in the three soil systems for two crop cycles of potato.

REVIEW OF LITERATURE

Microbial population and physico-chemical characters :

Adametz (1886) was the pioneer to isolate fungi from the soil. Since then considerable attention was paid by a number of workers. Waksman (1916) reviewed the literature on soil fungi. He concluded that fungal flora changed with soil habitat and distribution is influenced by abundance and nature of organic matter in soil. Jensen (1931) reported that Penicillium and Trichoderma species were common in acidic soil while Mycogone niger and Cercospora agricola were common in alkaline soil. According to Warcup (1951) edaphic factors such as acidity and temperature play a vital role in the distribution of fungal species. Saksena (1955) did pioneer work in India on the ecological factors governing the distribution of fungi. He found a positive correlation between fungal population and nitrate content of soil. England and Rice (1957) determine qualitative and quantitative difference in fungal population between grassland and abandoned soil. Roy and Dwivedi (1962) made comparative study of soil fungal flora of three grassland soils and reported that change in vegetation site is accompanied by similar change in fungal population both qualitatively and

and quantitatively. Griffin(1963) pointed out that moisture content, soil texture and structure, which, affect soil aeration have a profound effect on fungal activity and it is postulated that aeration is the effective agent. He noticed that excess of carbon dioxide and insufficiency of oxygen are implicated as inhibitors. Dwivedi (1965) observed that physico-chemical characters like moisture content, water holding capacity, organic matter, nitrate, phosphate, exchangeable calcium magnesium were positively correlated with fungal population, while soil pH do not have any effect.) Mishra (1966 a,b) in his study on fungal flora of grassland soils of Varanasi noticed that the most common species throughout the year were Thiepaviaturicola, Chaetomuim globosum, Aspergillus terreus and Paecilomyces fusisporus. He examined that fluctuation in fungal population is due to minor change in root habitat and Physico-chemical characters of soil, Mukerji (1966) could not find relationship between fungal population, bacterial population and soil pH in usar soil. He also reported that surface profile harboured more population as compared to low profile. Gujrati (1968) observed that pH, organic matter, calcium, magnesium, phosphate and nitrate did not have any correlation with fungal population, but moisture content was directly responsible for the variation in microbial population. Moubashir and El-Dohleb (1970) found Aspergillus, Penicillium and Fusarium throughout the study period

and dominant in cotton field and clover field soils. Singh and Kamal (1970) found highest bacteria, fungi and actenomycetes population in surface soil and along depth microbial population decreased. Prakash and Khan (1971) noticed that moisture of the soil was an important factor governing population of soil fungi which are profoundly influenced by seasonal fluctuation. They also noted a number of dominant fungi which were Aspergillus niger, Aspergillus flavus, Aspergillus terreus and Fusarium chlamydosporum. Mishra and Kanaujia (1972,1973) made a comparative study on fungal flora of forest, grassland, usar and cultivated soils, and found that highest fungal population was in cultivated soil, they pointed out that soil depth and physico-chemical characters of soil affected the distribution and population of fungi. According to Hattori (1973) agricultural activities of man greatly modify the distribution of bacteria, and fungi in soil. Allison (1973) reported that cultivation has marked influence on bacterial population and in cultivated soil bacterial population was 20-30 time higher than the uncultivated soil. Morrall (1974) reported that fungal population was affected by physico-chemical characters of soil and ground vegetation. Dedalauri (1975) indicated that the distribution of fungi is determined by the combined effect of moisture, temperature and organic carbon. Wong (1975) reviewed the literature on soil fungi and suggested that distribution of soil fungi is mainly governed by various

soil factors. According to him moisture and pH were the most important factors. Widden (1979) reported that the effect of different of the soils which change the number of fungi and species composition. Clark and Christensen (1981) estimated fungal flora of grassland soil and found that Aspergillus spp., Penicillium sp. and Fusarium spp. dominated the fungal community. Orchard and Cook (1983) observed that the microbial population and respiration rate is positively correlated with moisture content, the microbial activity decreases with decrease in water potential. Deka and Mishra (1984) reported dominant fungi Trichoderma viride, Penicillium chrysogenum, Aspergillus niger, Cladosporium herbarum, Cephalosporium corenioides, Fusarium solani and Pythium sp. in soils under shifting cultivation. They also found that fungal, bacterial and actenomycetes population were highest in surface soil than the deeper soils. Lynch (1984) suggested that microbial activity should be considered in soil management and it may be possible to manipulate the soil population balance towards beneficial organisms. Back (1984) reported significant correlation between the microbiological index and the total organic carbon of eleven different agricultural soils. Theodorou (1984) recorded that bacterial population was maximum under pine planted soil and fungal propagules were maximum in Eucalyptus planted soil. Shuji and Takao (1985) found that the number of bacteria in 0-2 cm soil layer was high and in

deeper layers it was small and constant. Behera and Mukerji (1985) isolated the highest microbial population on surface soil and species numbers gradually declined with depth increase and they concluded that the surface vegetation and edaphic and environmental factor have a profound influence on the occurrence and distribution of fungi at various depth of soil. Abouheilah (1985) reported 103 fungal species from forest soil, out of which 10 belong to phycomycetes, 4 to ascomycetes, 1 to basidiomycetes and 88 to deuteromycetes. The most prevalent genera were Penicillium, Aspergillus, Fusarium, Trichoderma, Dreschslera, Ulocladium, Torula, Humicola, Alternaria and Helminthosporium. Valikanov et al. (1985) observed that deeper the soil horizon more significant difference between individual horizon with respect to species composition and the number of microorganisms. They also noticed that abundance of soil mycoflora decreased as the absolute altitude above sea level increased. Schnurer et al. (1986) pointed out that moisture changes the bacterial, fungal, protozoa and nematode population and oxygen consumption. In comparative study on rainfall and irrigation, they observed that the rainfall, doubled bacterial number within three days and which declined during the following period of drought while in irrigated plot bacterial population increased by 50% and remained constant.

Soil enzymes :

Dehydrogenase :

Levels of dehydrogenase activity of soils are con-

sidered to give some guide to the microbiological activity of the soils and have been investigated increasingly since the introduction of a method for the estimation of this activity (Lenhard,1956). Stevenson (1956) modified Lenhard's technique and presented evidences for the reliability of the dehydrogenase as a means of estimating total microbial activity in soils. However, he did not find relationship between dehydrogenase activity and bacterial numbers, unless organic amendments were added to the soil. Casida et al. (1964) detected relatively constant dehydrogenase activity regardless of small fluctuations in microbial numbers. On addition of nutrients, it paralleled with the rapid multiplication gram-positive bacteria and decreased markedly when the metabolic activity of these bacteria slackened. Skujins and McLaren (1968) compared the dehydrogenase activity of geologically preserved soils with freshly collected desert and cultivated soils and concluded that the activity did not reflect the microbial numbers but was thought to reflect the rate of overall metabolism. Ross (1970,1971) reported that formazan production was significantly greater in systems incubated anaerobically than in systems incubated without complete anaerobioses. He studied factors limiting levels of dehydrogenase activity. The addition of glucose and NAD together did not prevent decline in rates of formazan formation on prolonged incubation. Pancholy and Rice (1972) found that there were no significant decrease in the

activities of urease and invertase after 30 days storage at 4°C. Skujins (1973) reported that dehydrogenase activity did not correlated with microbial numbers and also did not correlated with phosphatase activity showed scattered activity values throughout the profiles. Casida (1977) modified the dehydrogenase activity estimation technique for measuring the metabolic activity of microorganisms in soil and he proposed 6 h incubation at 37°C with an electron donating substrate. He found that in the modified technique the rate of formazan production remained constant during that time and cellular multiplication apparently did not occur. Schinner and Gurschler (1978) reported that higher values for enzyme activity, soil organic matter and moisture were found in the top layers of soil. These parameters decreased with increasing depth. Smith and Pugh (1979) demonstrated that the dehydrogenase assay can provide a valid indicator of soil microbial activity. Chendrayan et al. (1980) reported that dehydrogenase activity increased upon flooding while invertase activity decreased considerably under the same situation. Frankenberger and Dick (1983) found positive correlation of dehydrogenase activity with soil respiration. Dkhar and Mishra (1983) in their comparative study of dehydrogenase activity, microbial population and physico-chemical characters in maize field soils under different agricultural management showed that enzyme activity microbial population as well as physico-chemical characters followed a

trend plain valley land) terrace land) slash and burn type of shifting agriculture. Trevors (1984) reported that there was a high positive correlation between dehydrogenase activity and substrate concentration, incubation, temperature and soil pH. A highly negative correlation between dehydrogenase and O_2 content was noted. Rao and Ghai (1985) reported that alkali soil have low amount of organic carbon, nitrogen and low level of dehydrogenase activity and found that enzyme activity was positively correlated with organic carbon and nitrogen. Shuji and Takao (1986) found that dehydrogenase activity was positively correlated with soil pH and bacterial population. Tiwari et al. (1987) reported higher dehydrogenase activity from surface soils and also noticed positive correlation of dehydrogenase activity with bacterial population in pineapple field soil.

Urease :

Sumner (1926) first isolated and purified the enzyme urease in crystalline form from jack bean meals. Availability of urease in soil and enzymatic nature of urea decomposition in soil was first reported by Rotini (1935). Conrad (1940, 1944) reviewed the literature on presence of urease and its enzymatic characteristics in soils. Kuprevich (1951) considered urease enzyme as an indicator of total biological activity and fertility of the soil. Drobnik (1955) reported that although enzyme tests are suitable for qualitative

studies of various soil processes, they are not applicable for the quantitative estimation of microbial activity. Stojanovic (1959) reported that urease enzyme activity is not a stable indicator of the biological activity of the soil. Effect of soil properties on urease activity have been studied in upland soil by McGarity and Myers (1967) and Dalal (1975). Bremner and Douglas (1971) tested 100 compounds to evaluate the inhibitors of urease activity in soils they found that the dihydric phenol and thinones were the most effective organic inhibitors and Silver and murcury salts were the most effective inorganic inhibitors. Pancholy and Rice (1972) did not find any significant effect on urease and invertase activity after storage at 4°C for 30 days while significant loss in dehydrogenase activity was noted after 30 days. Zantua and Bremner (1976) reported that addition of urea to Iowa soils did not induce urease activity, however, increased urease activity was observed on addition of glucose that promotes microbial activity. Zantua and Bremner (1977) further reported that no loss of urease activity could be detected when field moist soil were air dried and stored at 105°C for 24 hours or autoclaved (120°C) for 2 hours. However, in moist soils in activation was detected at temperature above 60°C. Mishra et al. (1979) studied amylase, cellulose, invertase, protease and urease activities in eleven pasture soils of Orissa (India) and noted significant positive correlation between urease and

cellulose activity. Sahrawat (1980) estimated the urease activity and physico-chemical characters viz., pH, organic carbon and nitrogen of soils, He pointed out that in alkaline soil the rate of urea hydrolysis is more rapid and this increased N loss through NH_3 volatization. Speir et al. (1980) found more urease activity in planted soils as compared to fallow soil and suggested that temperature dependent denaturation could have caused the decrease in urease activity in fallow soil. Moller (1981) found positive correlation of urease activity with C/N ratio and soil pH values. They regarded urease activity as an indicator of biological activity of the soil. Das et al. (1981) could establish a positive correlation between urease activity and organic carbon and total nitrogen. They further suggested that organic carbon was chief positive factor determining urease activity. Nor (1982) reported that inhibition of urease activity was effectively achieves using silver ion. Urease inhibitors have potential application in reducing volatilization losses of ammonia derived from urea applied to soils. Stroo and Jencks (1982) reported a significant correlation among soil respiration, enzymatic activities and organic matter. Sahrawat (1963) reported that urease activity significantly correlated with total N and organic C but was not correlated with clay content, pH, active Fe or active Mn content. Singh and Nye (1984) found that on rewetting, air dry soil urease activity

increased rapidly within a 24 h. and after 4 days it declines. Dormaar et al. (1984) reported highest urease activity in ungrazed field soil compared to grazed field soil. Carcedo and Marcos (1984) found a correlation of urease activity with organic matter and ureolytic microorganisms in soil. Kaszubiak (1986) reported significant positive correlation between urease activity and bacterial population, however, correlation had disappeared after amendments of soil by organic matter.

Phosphatase :

Phosphatase activity in soils has been studied by many workers since its detection by Rogers (1942).

Golebiewska (1956) found that highest phosphatase activity was in surface layer soil and the activity decreased in low profile soil. Keilleng et al. (1960) and Hoffman and Elias-Azar (1965) reported the correlation of phosphatase activity with organic carbon, moisture content and total nitrogen. Khazier and Burangulova (1965) found positive correlation between phosphatase activity and soil organic phosphorus content. Dixon and Webb (1966) found positive relation of phosphatase activity with magnesium and suggested that it is due to magnesium ions being natural activators of the majority of enzymes activity on phospherylated substrates. Parkinson et al. (1968) stated that phosphatase activity decreased along depth due to

decreasing in the concentration of microbial population along depth. Dudchenko et al. (1974) reported that type of plants grown on soil were found to have an effect on soil phosphatase activity. Ladd and Butler (1975) suggested that the positive relationship with organic carbon content is probably associated with the fact that phosphatase like other enzymes become bound in humo-protein complex which possibly protects the enzyme from degradation. Tyler (1976) observed that industrial copper and zinc pollution reduces the phosphatase activity and P mineralization rate in the soil of conifer forest surrounding a brass mill. Verstraete and Voets (1977) reported that yield of winter wheat was positively related to soil phosphatase activity while sugar beet yield were negatively related to soil urease activity. Respiration and phosphatase activity were found to be correlated in reclaimed stripmine soils by Herksman and Temple (1979). Spiers and McGill (1979) reported that increasing in nitrogen supply increased the microbial synthesis of phosphatase. Ross (1982) reported that in maize field, carbon dioxide production, net production of mineral N, microbial biomass and phosphatase activity and some other enzymes (urease, sulphatase, amylase and invertase) had all declined appreciably more with cropping. He suggested that these characters would provide more sensitive indicator than organic matter to change in soil with management. Kulinska et al. (1982) could not find correlation between

microbial population and phosphatase activity. They also did not find correlation between soil water holding capacity and enzyme activities. Stroo and Jencks (1982) reported significant positive correlation of phosphatase activity with soil respiration. Frankenberger and Dick (1983) found significant positive correlation of alkaline phosphatase with respiration but in case of acid phosphatase he did not find correlation with microbial respiration. Dormaar et al.(1984) found highest phosphatase activity in grazed field as compared to ungrazed field of grassland soil. Nohrstedt (1985) reported that the concentration of organic carbon was the strongest predictor of phosphatase activity. Trasar and Stores (1987) found that maximum phosphatase activity was at the pH of 5-6 and also suggested that phosphatase activity was appeared to dependent on the concentration of organic matter content in soil.

Carbon dioxide evolution :-

Smith and Brown (1932) studied the Co_2 evolution and stated that 90 percent of soil respiration could be attributed to the activity of soil microorganisms. Katznelson and Stevenson (1956) studied the evolution of carbon dioxide from forest floor and showed that a number of environmental factor viz., temperature, moisture, pH,and the substrates have been found to affect the evolution of carbon dioxide from the soil. Stotzky (1960) established a corre-

lation between carbob-dioxide evolution and microbial biomass. Dobson and Wilson (1963) studied the soil activities from a stripmine spoil areas in west Virginia and observed a decreased rate of respiration along with low bacterial numbers. Volk (1972) measured Co_2 evolution, from soil column under varying water tables. He observed that Co_2 evolution was proportional to the depth of the water table. Ross et al. (1975) studied respiration activity and their relationship with temperature, moisture soil properties in tussock grassland in New Zealand. They found significant correlation of Co_2 evolution with soil moisture, organic carbon and total nitrogen. Nannipieri et al. (1978) noted that Co_2 evolution and urease activity were related to bacterial and fungal biomass. Ross and Cairns (1978) studied the influence of temperature on biochemical processes in some of grassland soils. They found that the pattern of Co_2 evolution at different temperature and incubation periods varied with the different soils and that Co_2 evolution increased with increase in temperature. Kowlenko et al. (1978) stated that below the optimum water content for microbial activity increasing moisture results in increasing carbon dioxide evolution. Cleve et al. (1979) reported that the estimation of Co_2 evolution provides an insight into the rate of growth organic matter breakdown and mineralization. Sato (1981) reported that the rate of Co_2 evolution correlated with number of gram-negative bacteria, while it did

not correlate with the number of cellulose decomposing microorganisms. He believed that main locus where this reaction takes place may be the surface area of soil crumbs. Upadhyay et al. (1981) reported that soil temperature and moisture were linearly related with carbon dioxide evolution. Gupta and Singh (1981) reported maximum rate of Co_2 evolution in the rainy summer month and lowest during winter months. Stroo and Jencks (1982) reported close relationship of soil respiration with phosphatase and amylase activity and to oxidizable carbon and nitrogen. Frankenberger and Dick (1983) found correlation of Co_2 evolution with alkaline phosphatase activity but the same was not found with acid phosphatase and urease activity. Baruah and Mishra (1983) noticed correlation of Co_2 evolution, with organic carbon, nitrogen and phosphorus and microbial population. Nohrstedt (1985) reported that the organic *C* was strongest predictor of soil respiration. He did not find any correlation between soil respiration and dehydrogenase activity. West et al. (1986) reported that in the summer season's soil samples, respiration doubled within one day of incubation but then gradually declined, however, in winter season's soil samples, respiration declined significantly after incubation. Dkhar and Mishra (1987) found a significant positive correlation of Co_2 evolution with fungal biomass, microbial population, organic carbon and total nitrogen.

MATERIALS AND METHODS

Study Area :

The study was carried out at Upper Shillong (altitude 1706-1730m latitudes 25°34'N and longitude 91°56'E. Three different cultivation methods are prevalent which are adapted by the farmers depending on the topography and availability of land.

In one type, farmers adapt slash and burn type of shifting cultivation. This is more in practice on the hillocks. Under this type the vegetation is cut and after it is dried the layer boles and removed while other plant parts are burnt after putting it in rows parallel to the hill slopes. Afterwards the ash is covered with adjoining soil and a band is made which maybe 1.0 to 1.5 m wide 10 to 15 m in length and 0.20 to 0.25 m high. On these bands the potato tubers are shown randomly, however, plant to plant distance is maintained between 0.15 to 0.20 m. Distance between two adjacent bands is generally 30 to 40 cm. Farmers do not use any manure or fertilizers. As the cultivation is done on hill slopes they prone to severe erosion and run off. As a result the soil moisture is generally low and the fertility of soil diminishes with time.

During recent years due to non-availability of lands for shifting cultivation permanent type of cultivation on hill slopes has started. This is done on bench

SLOPE LAND

TERRACE LAND

VALLEY LAND

terraces. The terraces check soil erosion and run off, thus fertility is maintained and soil moisture is retained. The width and length of terrace depends on the degree of slopes. In this cultivation the measurement of bands are length approx. 3 m; width 0.3 m and height 0.15 to 0.20 cm and a distance of approx. 0.30 m is left between two adjacent rows. This type of cultivation has been introduced by Central Potato Research Station and in this type of cultivation manure fertilizer and pesticides etc. are used.

Between the hillocks some plain land are found and on these lands permanent type of cultivation is done and farmers grow potato on bands similar to the shifting cultivation lands however, in these fields the width of band are lesser in width (0.75 m) and the height (0.50 m) are generally more. The height of band prevents water logging. In this type of cultivation farmers use fertilizers and manures. Being in valleys these are low lying areas and thus soil moisture remains high throughout the year.

For convenience, the three cultivation types have been named as slope cultivation, terrace cultivation and valley cultivation. Potato crop sown under the three cultivation types were situated within a radius of one kilometer.

Soil samples were collected from three potato fields namely, Jhum lands on hill slopes, bench terraces

made on hill slopes and plain lands situated in valleys. Sampling was done at 10 days interval for two crop cycles from 10th September, 1985 to 20th November, 1985 and 10th September, 1986 to 20th November, 1986. Soil samples were collected from three depths (0-10 cm, 10-20 cm and 20-30 cm). The samples were collected from five random sites from each field. These samples were thoroughly mixed in a sterile polythene bag to form a composite sample. This was done with an aim to minimize local variation in the microbial population. The samples were brought to the laboratory and were stored in fridge at a temperature of $4^{\circ}C$. All the estimations concerned with microbial population and activity were carried out within 24 hours of collection. Soil temperature was noted using soil thermometer at the time of collection.

Moisture content :

Moisture content of soil was assessed by oven dry weight method. 10 g of freshly collected soil was dried at $105^{\circ}C$ in a hot air oven to constant dry weight and from the resulting weight loss the percentage moisture content was calculated.

pH :

20 g of soil was saturated with 100 ml of distilled water and was subjected to constant stirring for 20 minutes with the help of a magnetic stirrer. The suspension

thus prepared was used for recording the pH using an electrical pH meter.

Organic carbon :

Walkley and Black's (1934) rapid titration method was followed for the determination of organic carbon of the soil. 0.5 g of soil was taken after passing through 0.2 mm mesh and placed in a 500 ml conical flask. 10 ml of 1N $K_2Cr_2O_7$ solution was then pipetted onto the soil and mixed by swirling the flask. 20 ml of conc. H_2SO_4 was subsequently added and mixed by gentle rotation to ensure complete contact of the reagent with the soil. The mixture was allowed to stand for 30 minutes. A control blank (without soil) was run in the same way. The solution was diluted to 200 ml with distilled water and 10 ml of 85% phosphoric acid and 3 drops of diphenyl amine indicator were added. The solution was titrated with 1N ferrous sulphate. The percentage organic carbon present in the soil was then calculated as follows :-

Since 1 ml of 1N potassium dichromate corresponds 3 mg of carbon

$$\therefore \% C \text{ (organic)} = \frac{B - S \times 0.003 \times 100}{W}$$

where B = ml $FeSO_4$ in blank titration,

S = ml $FeSO_4$ in sample, W = weight of the soil sample in grams.

Total Nitrogen :

Nitrogen was estimated by semi-micro Kjeldahl method as described by Allen (1974). 0.5 g of sieved (< 0.2 mm) soil was taken in a Kjeldahl flask and 2 g K_2SO_4 - HgO mixture and 3 ml. conc. H_2SO_4 containing 5% salicylic acid were added and the mixture was digested on digestion rack till the solution became pale green in colour. 50 ml distilled water was added to the cooled solution and mixed carefully. The solution was filtered through Whatman No.1 filter paper and left to settle for 12 hours. 1 ml of the filtrate was taken in a 50 ml volumetric flask and 8 ml alkaline rochelle reagent (60 g sodium potassium tartrate dissolved in distilled water and diluted to 600 ml with distilled water) 1 ml 0.16% W/V sodium nitropruside, 2 ml fresh sodium phenate reagent (50 g phenol dissolved in 250 ml 40% NaoH and diluted to 100 ml with distilled water) and 1 ml sodium hypochlorite reagent containing 5% active chlorine were added and the volume was made upto 50 ml. Flasks were kept in a water bath at 40°C for 20 minutes. One blank sample was also run with it, after cooling, the O.D.(Optical density) was measured at 625 nm. Percentage nitrogen was calculated as follows :-

$$N\% = \frac{C\ (mg) \times \text{Solution volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample weight (g)}}$$

where C = NH_4^+ in mg obtained from the standard curve.

Available phosphorus :

Sulphomolybdic acid method was followed for the estimation of phosphorus (Jackson, 1973). 4 g of sieved (< 0.2mm) soil was taken in a 250 ml conical flask. 50 ml of Brays extraction solution (1.11 g of ammonium fluoride dissolved in 1 litre of 0.1N HCl) was added and stirred for 15 minutes with the help of a magnetic stirrer. The solution was filtered through a Whatman No.44 filter paper. One ml of the filtrate was taken in a test tube and to it 5 ml sulphomolybdate solution (25 g of ammonium molybdate in 250 ml distilled water, 275 ml conc. H_2SO_4 in 650 ml water mixed with the ammonium molybdate solution when cooled, 100 ml aquous solution of 5% antimony potassium tartrate was added and solution was made to 2 litre) and 5 ml 1.5% ascorbic acid solution was added and the volume was made to 50 ml. After 30 minutes O.D. was determined at 660 nm using blank (without soil).

$$P\% = \frac{C(mg) \times \text{Solution volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample weight (g)}}$$

where C = mg P obtained from the standard curve.

Exchangeable Potassium :

Exchangeable potassium was determined by flame photometer method using ammonium acetate as extraction solution (Jackson, 1973). 5 g of sieved (< 0.2mm) soil was taken in 500 ml conical flask and 125 ml of ammonium

acetate extraction solution (pH 7) was added and stirred for 1 h. on a mechanical shaker. The solution was filtered through a Whatman No.14 filter paper. 2 ml of filtrate was diluted with 10 ml distilled water and read in flame photometer.

$$K\% = \frac{C(mg/L) \times \text{Solution volume (ml)}}{10 \times \text{Sample weight (g)}}$$

where C = Mg/L of K obtained from standard curve.

Fungi :

Warcup's (1950) soil plate method was followed for isolation of fungi from the soil. A small amount (approx. 0.015 g) of soil was taken from the sample by means of a sterile nichrome spatula having a flattered tip. The soil was then dispersed in a few drops of sterile water at the bottom of sterile Petriplates. 15 ml of molted and cooled Martin's (1950) rose bengal agar medium supplemented with streptomycin sulphate was poured and the soil particles were dispersed throughout the medium by shaking and rotating the Petriplates. Three replicates were maintained for each sample. All isolation procedures were carried out in a sterilized laminar flow chamber. The plates were incubated at $25\pm1^{o}C$ for 5 days in a BOD incubator. The colonies were counted after 5 days and number of fungal propagules per g dry soil was calculated. For identification of the fungi the books consulted were those of Gilman (1951), Barnett and Hunter (1972), Subramanian (1971) and Domsch

et al. (1980).

Bacteria :

Dilution plate method (Waksman, 1921) was followed for the enumeration of bacteria. 1 g soil was taken and transferred to 250 ml conical flask which contained 100 ml of sterilized distilled water. The solution was thoroughly hand-shaken for about 15 minutes.Subsequent dilutions were prepared by transferring 10 ml of this solution to 90 ml of sterile distilled water. 0.5 ml aliquot of the 1:10000 dilution soil water suspension was transferred onto nutrient agar medium. The petriplates were shaken gently to disperse the inoculum uniformly over the surface of the agar medium. All isolation procedures were carried out in a sterilized laminar flow chamber. Three replicates were maintained in each case. The petriplates were incubated at $30\pm1^{\circ}C$ in a BOD incubator for 24 hours. Number of bacterial colonies was counted and their population per gram dry soil was calculated by taking into consideration the moisture content of the soil. In this study only the bacterial population was considered and no attempt was made to identify the species.

Composition of the media used for isolation of fungi and bacteria

Medium for fungi :

Peptone-dextrose-rose bengal agar (Martin, 1950).

Agar	-	20.0 g
KH_2PO_4	-	1.0 g
$MgSO_4 7H2O$	-	0.5 g
Peptone	-	5.0 g
Dextrose	-	10.0 g
Rose bengal (1%)	-	3.3 ml
Distilled water	-	1000.0 ml
Streptomycin sulphate	-	30.0 mg

Medium for bacteria :

Nutrient agar medium (Johnson and Curl, 1972).

Agar	-	15.0 g
Beef extract	-	3.0 g
Peptone	-	5.0 g
NaCl	-	8.0 g
Distilled water	-	1000.0 ml

Dehydrogenase activity :

Dehydrogenase activity of soil was determined by 2,3,5 triphenyl tetrazolium chloride (T.T.C.) reduction technique as suggested by Casida (1977). Freshly collected soil samples were taken but when storage was necessary, the soils were stored at $4^{\circ}C$. The stability of enzyme is good at $4^{\circ}C$ (Lloyd and Sheafee, 1973). 1.0 g of soil sample taken in a dry test tube, was treated with 0.1 g $CaCO_3$ and 1 ml of 1% T.T.C. The content of each tube was mixed

well, plugged with a rubber stopper and incubated at 30°C for 24 hours. As a result of dehydrogenase activity the T.T.C. was reduced to triphenyl formazan which was extracted with methanol. The soil from each tube was quantitatively transferred to a Whatman No.1 filter paper with the help of methanol and washed down into 50 ml volumetric flask, with a small portion of methanol till the volume of filtrate was made upto the 50 ml mark. Three replicates were maintained in each case. The O.D. of the pink coloured filtrate was determined at 485 nm by spectrophotometer using methanol extract from the control (without soil) as the blank. The dehydrogenase activity per gram dry soil was calculated from the standard curve prepared by using different concentrations of triphenyl formazan.

Urease activity :

Urease activity was determined by the method of McGrarity and Mayers (1967). 1.0 g of soil was placed in 100 ml volumetric flask and to this was added 1 ml of toluene. The mixture was allowed to stand for 15 minutes to permit the complete penetration into the soil. 10 ml of buffer (pH 7) and 5 ml of 10% urea solution were subsequently added. The flask was shaken and incubated for 3 hours at 37°C. Controls where urea solution was replaced by 5 ml

distilled water were run for each soil sample. After incubation the content of the flask was made upto 100 ml with distilled water. The flask was thoroughly shaken and their content filtered through a Whatman No.5 filter paper. Ammonia released as a result of urease activity was assessed by indophenol blue method. 0.5 ml of filtrate was placed in a 25 ml volumetric flask and to this was added 4.5 ml distilled water 2.5 ml of phenolate solution (20 ml phenol solution made by dissolving 62.5 g phenol in 20 ml of methanol; 28.5 ml acetone and 20 ml of 27%. NaOH were added and the mixture was made upto 100 ml with ethyl alcohol) and 1.5 ml of sodium hypochlorite solution containing 0.9% active chlorine. The whole mixture was thoroughly mixed and after 20 minutes the volume was made upto 25 ml by adding distilled water. The O.D. of blue coloured solution was measured spectophotometrically at 630 nm. The amount of ammonia-N formed was calculated by reference to a standard curve. Three replicates were maintained in each case.

Phosphatase activity :

Phosphatase activity was measured by the method of Tabatabai and Bremner, 1969). 1.0 g sieved ($<$ 2 mm) soil was taken in a 50 ml conical flask and to this 4 ml of modified universal buffer (pH-6.5) 0.25 ml toluene and 1 ml 0.115M disodium P-nitrophenyl phosphate hexahydrate were added. The flasks were stoppered and incubated at 37^{o}C

for 1 hour. After incubation 1 ml of 0.5M CaCl, and 4 ml of 0.5M sodium hydroxide were added to each flask and mixed well. The soil suspension was filtered through a Whatman No.1 filter paper and O.D. of the filtrate was measured in a spectophotometer at 420 nm.Controls (without soil) were also run for each soil. The amount of P-nitrophenol released as a result of phosphatase activity was calculated using a standard curve.

Carbon dioxide evolution :

The CO_2 evolution was measured by absorption and titration method (Macfadyen, 1970). Roots were hand-picked from the soil. 1 kg of the soil was placed in a glass jar. A glass beaker of 100 ml capacity containing 50 ml of 0.1N KOH solution was placed inside the jar. The glass jars were then sealed and made air tight. A suitable control jars with equal volume of sterilized sand was also used for the substraction of the atmospheric CO_2. After 24 hours incubation at room temperature, the amount of CO_2 fixed by KOH solution was measured by titrimetric method using 0.1N HCl as titrant and phenolphthelin as an indicator. Three replicates were used for each soil. Carbon dioxide evolution was expressed in mg CO_2 evolved per Kg dry soil, by taking into consideration the moisture content of the soil.

RESULTS

Soil temperature :

Generally, soil temperature was lower in valley land cultivation than that of the hill slope and terrace cultivations. With increasing depth the soil temperature decreased in all the fields as well as on all the sampling dates. During winter the soil temperature dropped considerably and a lowest temperature was recorded at 30 cm depth of valley land soil. Almost similar trend of variation was noted during both the years (Fig.1.1).

Soil moisture :

Moisture content of soil was higher in valley lands than the fields on hillocks. Maximum moisture content (50.50%) was recorded in valley land field at the depth of 20-30 cm and the minimum (10.10%) was in hill slope cultivation soil at 0-10 cm depth. In all the three agricultural systems higher moisture content was recorded in deeper layers of the soil (Fig.1.2).

pH :

In valley land soil pH ranged between 4.0 to 5.22, while in terrace land it ranged between 4.0 and 5.28 and in slope land between 3.64 and 5.64. No marked temporal variation in pH was observed (Fig.1.3).

Organic carbon :

Organic carbon content was maximum in valley land

soil followed by terrace land and slope land soil. Surface (0-10 cm) soils contained higher organic carbon which decreased with increasing soil depth. In all the three practices organic carbon was higher at the sowing and harvesting periods (Fig.1.4).

Total nitrogen :

Maximum nitrogen content was found in valley land soil followed by terrace land soil and the minimum in slope land soil. Upper layer of soil always contained higher percentage of nitrogen. The percentage of nitrogen decreased along soil depth. Peak was observed in the month of October during both the year (Fig.15).

Available phosphorus :

General trend of variation of available phosphorus in soil was similar to that of the nitrogen. Higher values were obtained during the month of October and a decline was observed during following months. In valley land soil phosphorus was higher as compared to the terrace land and slope land soil. In slope land soil phosphorus content was nearly half of the valley land soil. Generally, with increasing depth, the phosphorus content decreased in all the three fields (Fig.1.6).

Exchangeable potassium :

Maximum potassium was found in terrace land soil

followed by slope land soil while minimum was obtained in valley land soil. There were no marked variation in potassium among the three depths (0-10 cm, 10-20 cm and 20-30 cm) in all the three agricultural systems. The growth of crop and season did not have any effect on the exchangeable potassium content of soil except in the terrace land soils where a drop was noted during the month of October (Fig.1.7).

Fungi :

Temporal and depth-wise variation in fungal population of soils of the three fields is depicted in fig.1.8. The number of fungi per gram dry soil was maximum in valley land soil and minimum in hill slope land soil. In depth-wise studies the population was always highest in surface soil and it decreased along depth. In valley land a maximum of 3672 propagules/g dry soil was recorded in the surface soil and a minimum of 1252 propagules/g dry soil was recorded in the 20-30 cm deep soil. In terrace land soil surface layer (0-10 cm) contained maximum 760 propagules/g dry soil was recorded in 20-30 cm deep soil. In hill slope land the fungal population ranged between 3093 and 930 propagules/g dry soil. In all the three agricultural systems highest fungal population was found in the month of October, which was followed by a sharp decline. In valley land fungal population is significantly correlated with soil temperature, nitrogen, phosphorus, bacterial population, dehy-

drogenase activity, urease activity, phosphatase activity and CO_2 evolution. In terrace land it is correlated with soil temperature, organic carbon, nitrogen, phosphorus, potassium, dehydrogenase activity, urease activity, phosphatase activity and CO_2 evolution. In hill slope land soil it is correlated with moisture content, soil pH, organic carbon, nitrogen, phosphorus, dehydrogenase activity, urease activity, phosphatase activity and CO_2 evolution.

The fungal species isolated from different depths of the soil in different systems are given in table 1.1 - 1.18. A total number of 26 species were isolated from valley land soil. In valley land soil Absidia glauca, Rhizopus oryzae and Emmonsiella capsulata were isolated only from the surface layer (0-10 cm) of soil, while Alternaria alternata and Phoma sp. were isolated only from the middle layer (10-20 cm). Monilia sp., Penicillium funiculata and Trichoderma harzianum were recorded only from 20-30 cm depth soil. Mucor racemosus, Penicillium brevicompactum and sterile forms were dominant in middle layer (10-20 cm) soil while Mucor racemosus, Penicillium chrysogenum and Trichoderma viride were dominant fungi in 20-30 cm depth soil. Fusarium sp., Mucor hiemalis, M. racemosus, Penicillium brevicompactum, P. chrysogenum and Trichoderma viride were common in all the three depths of valley land soil. Absidia glauca, Emmonsiella capsulata, Aspergillus niger, Fusarium solani, Fusarium poae, Alternaria alternata, Mucor mucedo, Mucor

circenelloides, Aspergillus flavus, Monilia sp., Penicillium funiculata and Trichoderma harzianum appeared only for a short time during the study period.

A total number of 21 species were isolated from terrace land soil Alternaria alternata, Humicola fuscoatra and Penicillium fellutanum were isolated only from surface (0-10 cm) soil. Penicillium canescens and Pythium sp. were isolated only from 20-30 cm depth soil. Mucor plumbeus, Penicillium chrysogenum and Trichoderma viride were dominant in surface soil while Trichoderma viride was dominant in the middle layer soil. Penicillium brevicompactum was the dominant fungi in 20-30 cm depth soil. Aspergillus flavus, Fusarium poae, Mucor hiemalis, M. plumbeus, M. racemosus, Penicillium chrysogenum, P. brevicompactum and Trichoderma viride were common fungi in all the three depths of terrace land soil. Alternaria alternata, Aspergillus niger, Humicola fuscoatra, Monilia sp., Mucor circinelloides, M. hiemalis, Mortierella minutissima, Absidia corymbifera and Trichoderma harzianum appeared twice or thrice during the study period.

A total number of 27 species were isolated from hill slope land soil. Arthorobotrys arthrobotryoides, Oidiodendron echinuatum, Penicillium canescens, P. citrinum and Phoma sp. were isolated only from middle layer (10-20 cm) of soil, while Rhizopus oryzae, Trichoderma koningii and

Verticillium chlamydosporum were isolated only from (20-30 cm) of soil; Trichoderma viride and Mucor racemosus were dominant fungi in surface soil, while Mucor racemosus was dominant in middle layer soil. Mucor racemosus and Trichoderma viride were dominant fungi in 20 - 30 cm depth soil. Aspergillus flavus, Mucor hiemalis, M. plumbeus, M. racemosus, Fusarium oxysporum, Penicillium chrysogenum, P. brevicompactum and Trichoderma viride were common in all the three depths. Absidia corymbifera, Aspergillus niger, Mucor plumbeus, Monilia sp., Oidiodendron echinulatum, Penicillium canescens, Trichoderma hamatatum, T. harzianum, T. koningii and Verticillium chlamydosporium were isolated sporadically.

Mycoflora of the three fields did not differ significantly. Fusarium oxysporum, Mucor plumbeus, M. racemosus, Penicillium brevicompactum, P. chrysogenum and Trichoderma viride were the common fungi in all the fields.

Bacteria :

Temporal and depth-wise variation in the population of bacteria of three field soils is given in fig.1.9. The number of bacteria per gram of dry soil was maximum in terrace land soil which was followed by the valley land and hill slope land soil. In terrace land the maximum population was in surface soil (8.16×10^5/g dry soil) and minimum (8.45×10^5/g dry soil) in the 20-30 cm depth soil. In valley land soil surface layer harboured maximum (17.75×10^5/g

dry soil) population and the minimum (7.76×10^5/g dry soil) was noted in the 20-30 cm depth soil. In hill slope land the bacterial population ranged between 17.10×10^5 and 5.69×10^5/g dry soil. In all the three systems highest population was recorded in the month of October and the lowest was recorded in November. Bacterial population decreased with increasing depth in all the three systems, however, the decrease in population was most prominent in hill slope land soil. The trend of seasonal variation was similar in all the three field soil. In valley land soil bacterial number is significantly correlated with soil temperature, nitrogen, phosphorus, fungal population, dehydrogenase activity, urease activity, phosphatase activity and CO_2 evolution. In terrace land soil it is correlated with phosphatase activity. In hill slope land soil it is correlated with soil temperature, nitrogen, phosphorus, urease activity, phosphatase activity and CO_2 evolution.

Dehydrogenase activity :

Dehydrogenase activity of soil is expressed as ug Triphenyl formazan/g dry soil 24 h. (fig.1.10). Maximum dehydrogenase activity was assayed in valley land soil which was followed by terrace land and hill slope land soil. In all the three agricultural systems maximum activity was found in the surface layer (0-10 cm) and as depth increased the activity decreased. In terrace land soil activity

ranged from 16.6 to 70.0 µg TPF/g dry soil per 24 h, while in valley land soil it ranged between 10.0 and 83.8 µg/TPF/g dry soil per 24 h and in hill slope land soil it ranged between 17.6 and 52.6 µg TPF/g dry soil per 24 h. During the first year (1985) of study, in terrace land soil the highest activity was estimated in the month of November, while during second year the highest activity was recorded in the month of October. In valley land and in hill slope land soil general trend of variation during the study period was similar in both the years and the maximum activity was noted in the month of October. In valley land soil the activity was significantly correlated with organic carbon, nitrogen, phosphorus, potassium, fungal population, bacterial population, urease activity and phosphatase activity. In terrace land soil it was correlated with organic carbon, nitrogen, phosphorus, potassium, fungal population, urease activity, phosphatase activity and CO_2 evolution. In hill slope land the activity was correlated with fungal population and phosphatase activity.

Urease activity :

The urease activity of the potato fieldssoils under three different agricultural systems expressed as µg NH_4^+/g dry soil per 3 h. is depicted in fig.1.11. Valley land soil harboured maximum activity followed by terrace land and hill slope land soil. Maximum activity was recorded from surface

soil and with increasing depth the activity decreased. In valley land soil the activity ranged from 26.9 to 137.8 µg NH_4^+/g dry soil per 3 h; in terrace land soil it ranged between 22.8 and 109.8 µg NH_4^+/g dry soil per 3 h. and in hill slope land soil between 20.8 and 94.9 µg NH_4^+/g dry soil per 3 h. In both the years highest activity in all the three agricultural systems was found in the month of October, which was followed by a decline, but in valley land soil in 1986 activity was maximum in the first week of November. In valley land soil the activity was significantly correlated with organic carbon, nitrogen, potassium, fungal population, bacterial population, dehydrogenase activity and phosphatase activity. In terrace land soil the activity was correlated with nitrogen, phosphorus, potassium, fungal population and CO_2 evolution. In hill slope land soil it correlated with nitrogen, phosphorus, fungal population, bacterial population, phosphatase activity and CO_2 evolution.

Phosphatase activity :

Phosphatase activity expressed as µg p-nitrophenol/g dry soil per h is depicted in fig.1.12. The phosphatase activity followed a trend of variation similar to the urease activity. Maximum activity was found in valley land soil followed by terrace land and hill slope land soil. In valley land soil the activity ranged from 263.3 to 295.0 µg p-nitrophenol/g dry soil per h and in hill slope land

soil varied from 244.6 to 291.0 µg p-nitrophenol/g dry soil per h. Surface soil showed highest activity and as soil depth increased the activity decreased, however, in hill slope land soil in the year 1985 at the depth of 10-20 cm the activity was greater than the surface soil. In all the agricultural systems the highest activity was recorded in the last week of September or first week of October. In valley land soil the activity was significantly correlated with soil temperature, moisture content, organic carbon, nitrogen, phosphorus, fungal population, bacterial population, dehydrogenase activity and urease activity. In terrace land soil it was correlated with soil temperature, organic carbon, nitrogen, phosphorus, potassium, fungal population, dehydrogenase activity and CO_2 evolution. In hill slope land soil the activity was correlated with soil temperature, moisture content, soil pH, organic carbon, nitrogen, phosphorus, fungal population, bacterial population, dehydrogenase activity, urease activity and CO_2 evolution.

CO_2 evolution :

The CO_2 evolution expressed as mg CO_2/g dry soil/ 24h is given in fig.1.13. Maximum output of CO_2 was from valley land soil followed by terrace land and hill slope land soil. In valley land soil CO_2 output ranged from 34 to 104 mg CO_2/g dry soil per 24 h. While in terrace land soil it ranged between 31 and 97 mg CO_2/g dry soil per 24 h and

Fig. 1.1. Temporal variation in temperature (^{o}C) of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 1·1

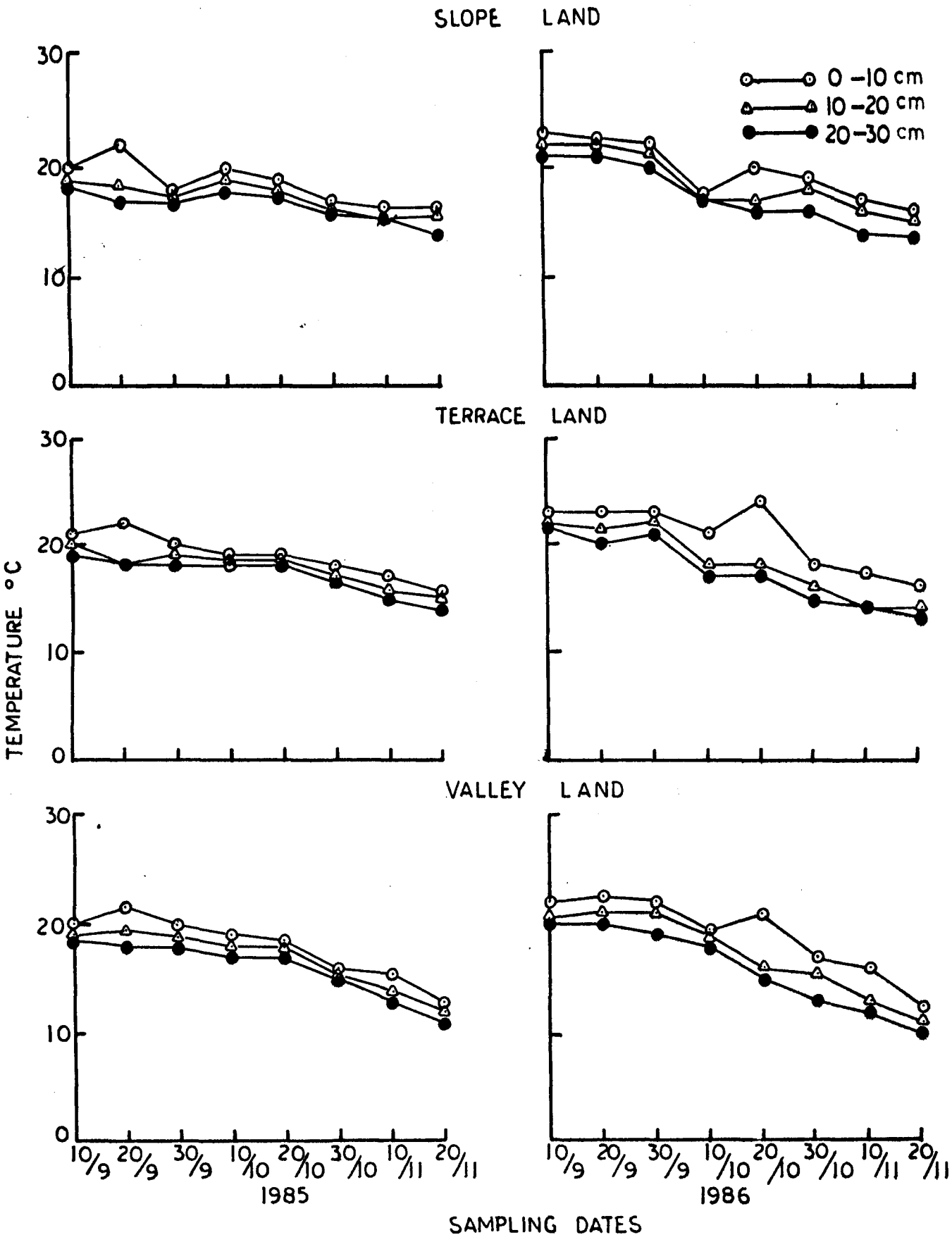

SLOPE LAND
TERRACE LAND
VALLEY LAND
0 -10 cm
10 -20 cm
20-30 cm
TEMPERATURE °C
30
20
10
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
1986
SAMPLING DATES

Fig. 1.2. Temporal variation in moisture content (%) of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 12

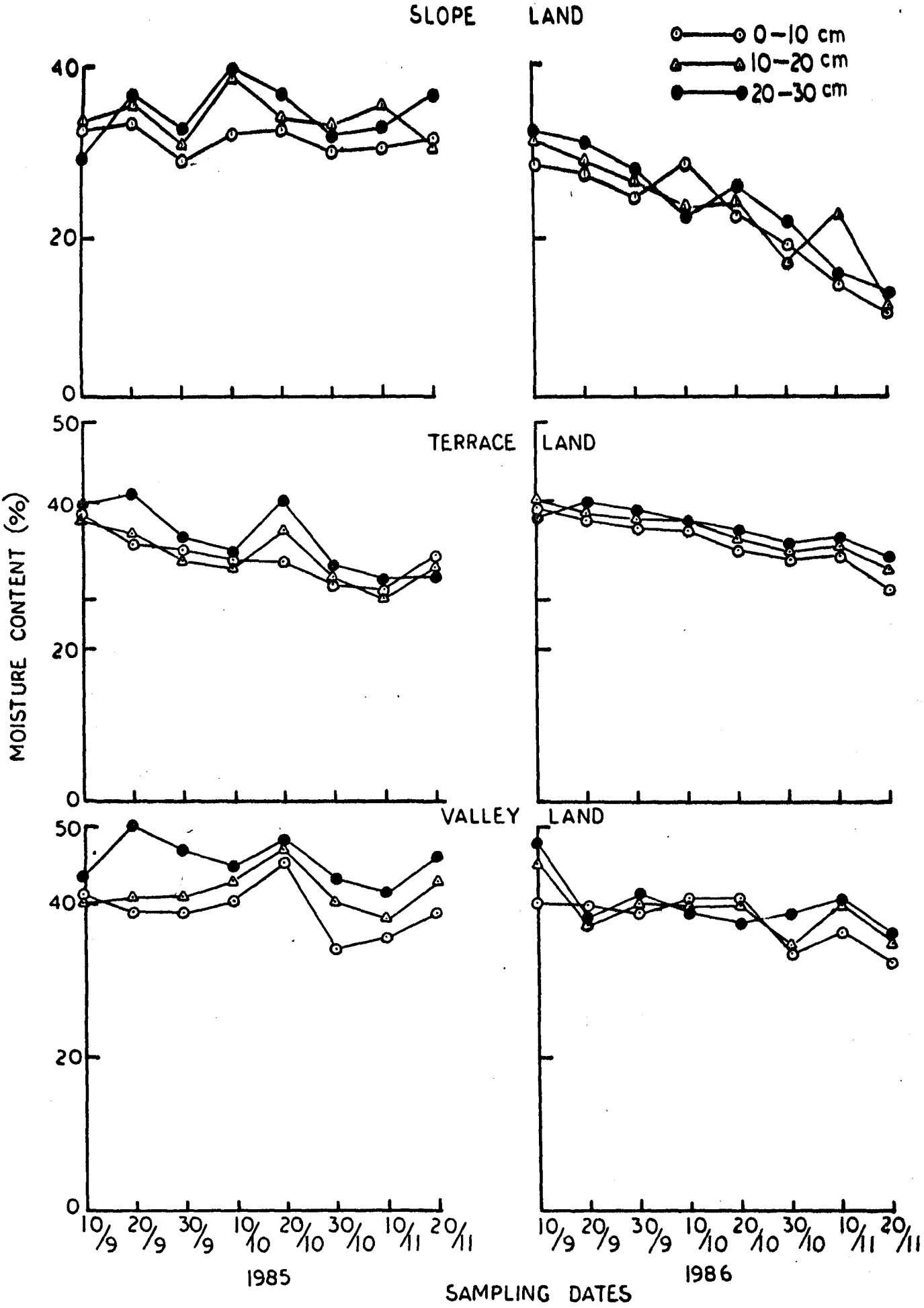

SLOPE LAND
0–10 cm
10–20 cm
20–30 cm
TERRACE LAND
VALLEY LAND
MOISTURE CONTENT (%)
0
20
40
50
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
1986
SAMPLING DATES

Fig. 1.3. Temporal variation in pH of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 13

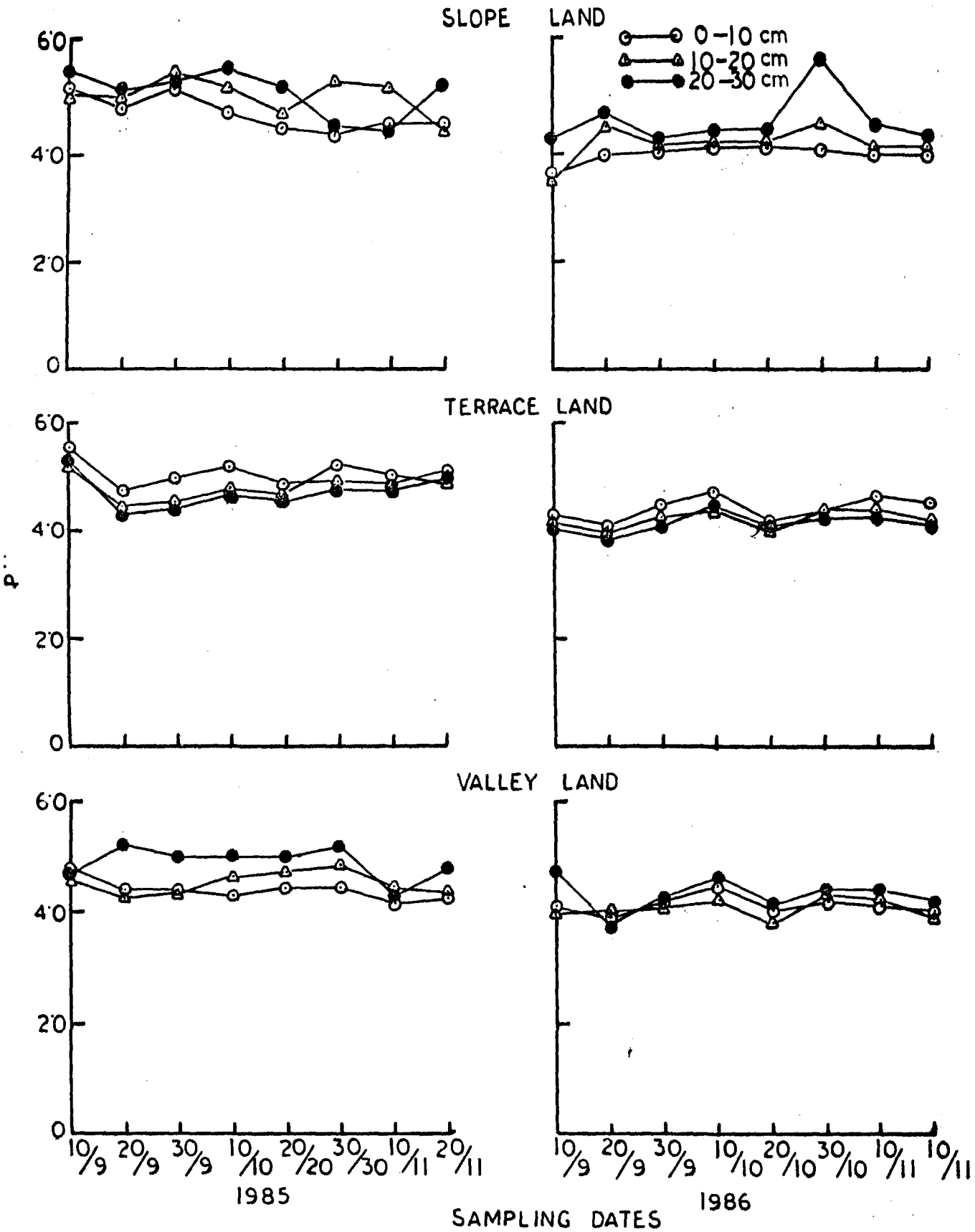

SLOPE LAND
0-10 cm
10-20 cm
20-30 cm
TERRACE LAND
VALLEY LAND
6·0
4·0
2·0
0
10/9 20/9 30/9 10/10 20/20 30/30 10/11 20/11
1985
10/9 20/9 30/9 10/10 20/10 30/10 10/11 10/11
1986
SAMPLING DATES

Fig. 1.4. Temporal variation in organic carbon (%) of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

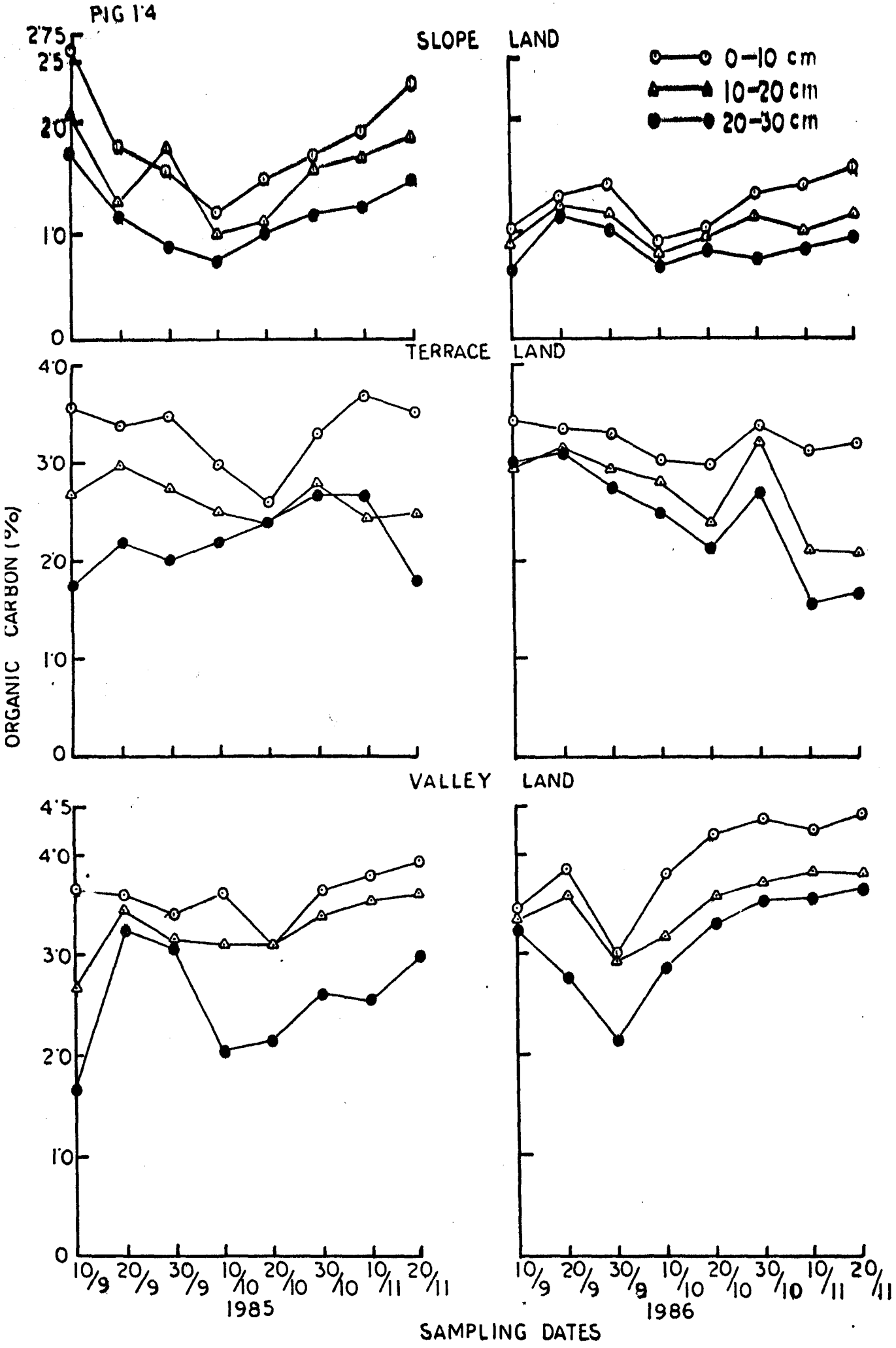


FIG 1·4
SLOPE LAND
TERRACE LAND
VALLEY LAND
0–10 cm
10–20 cm
20–30 cm
ORGANIC CARBON (%)
2·75
2·5
2·0
1·0
0
4·0
3·0
2·0
1·0
0
4·5
4·0
3·0
2·0
1·0
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1986
SAMPLING DATES

Fig. 1.5. Temporal variation in total nitrogen (%) of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 15

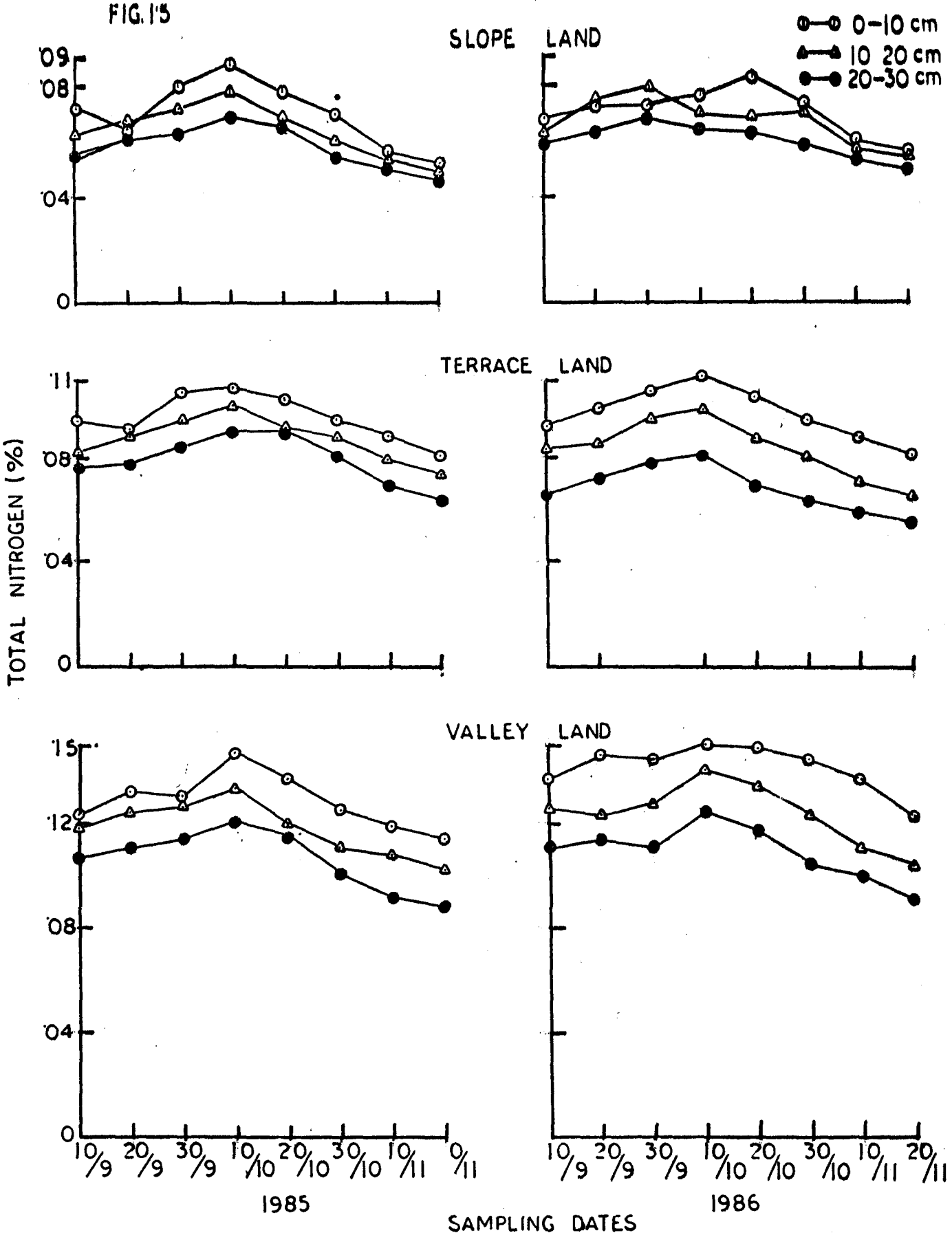

SLOPE LAND
TERRACE LAND
VALLEY LAND
0-10 cm
10 20 cm
20-30 cm
TOTAL NITROGEN (%)
.09
.08
.04
0
.11
.08
.04
0
.15
.12
.08
.04
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 0/11
1985
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1986
SAMPLING DATES

Fig. 1.6. Temporal variation in available phosphorus (%) of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 1'6

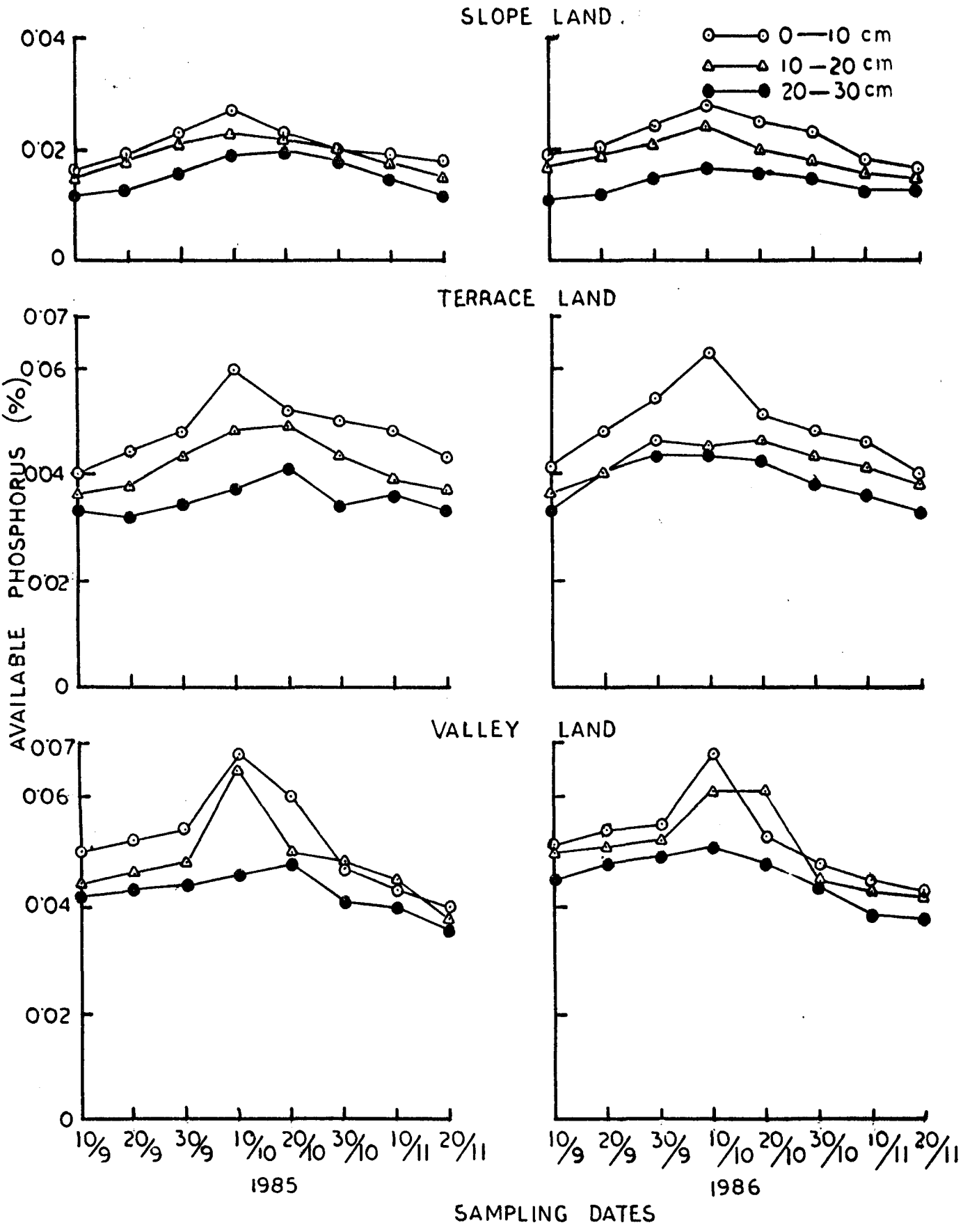

SLOPE LAND
0—10 cm
10—20 cm
20—30 cm
TERRACE LAND
VALLEY LAND
AVAILABLE PHOSPHORUS (%)
0·04
0·02
0
0·07
0·06
0·04
0·02
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
1986
SAMPLING DATES

Fig. 1.7. Temporal variation in exchangeable potassium (%) of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 17

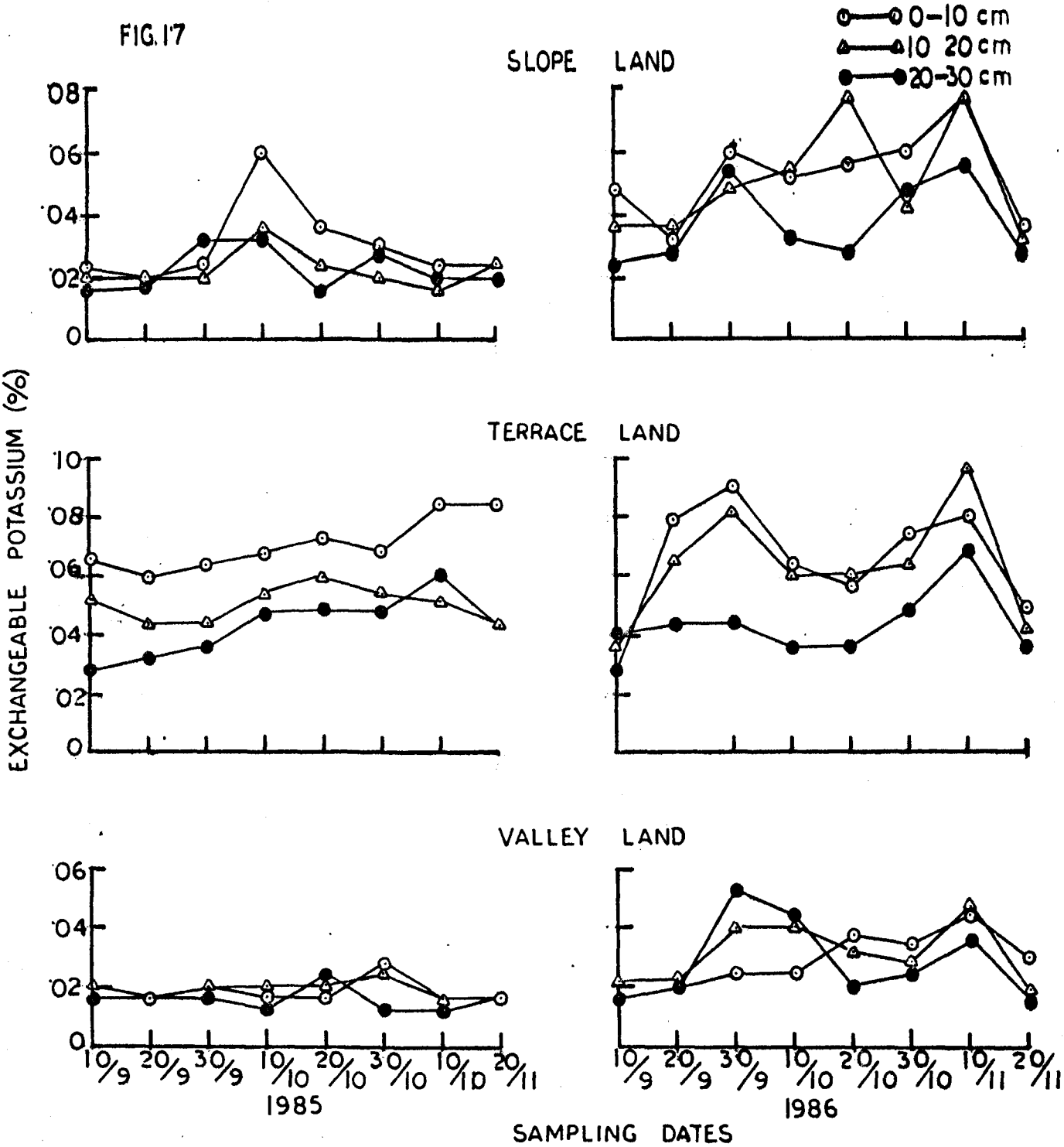

0-10 cm
10 20 cm
20-30 cm
SLOPE LAND
TERRACE LAND
VALLEY LAND
EXCHANGEABLE POTASSIUM (%)
08
06
04
02
0
10
08
06
04
02
0
06
04
02
0
10/9 20/9 30/9 10/10 20/10 30/10 10/10 20/11
1985
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1986
SAMPLING DATES

Fig. 1.8. Temporal variation in fungal population of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 18

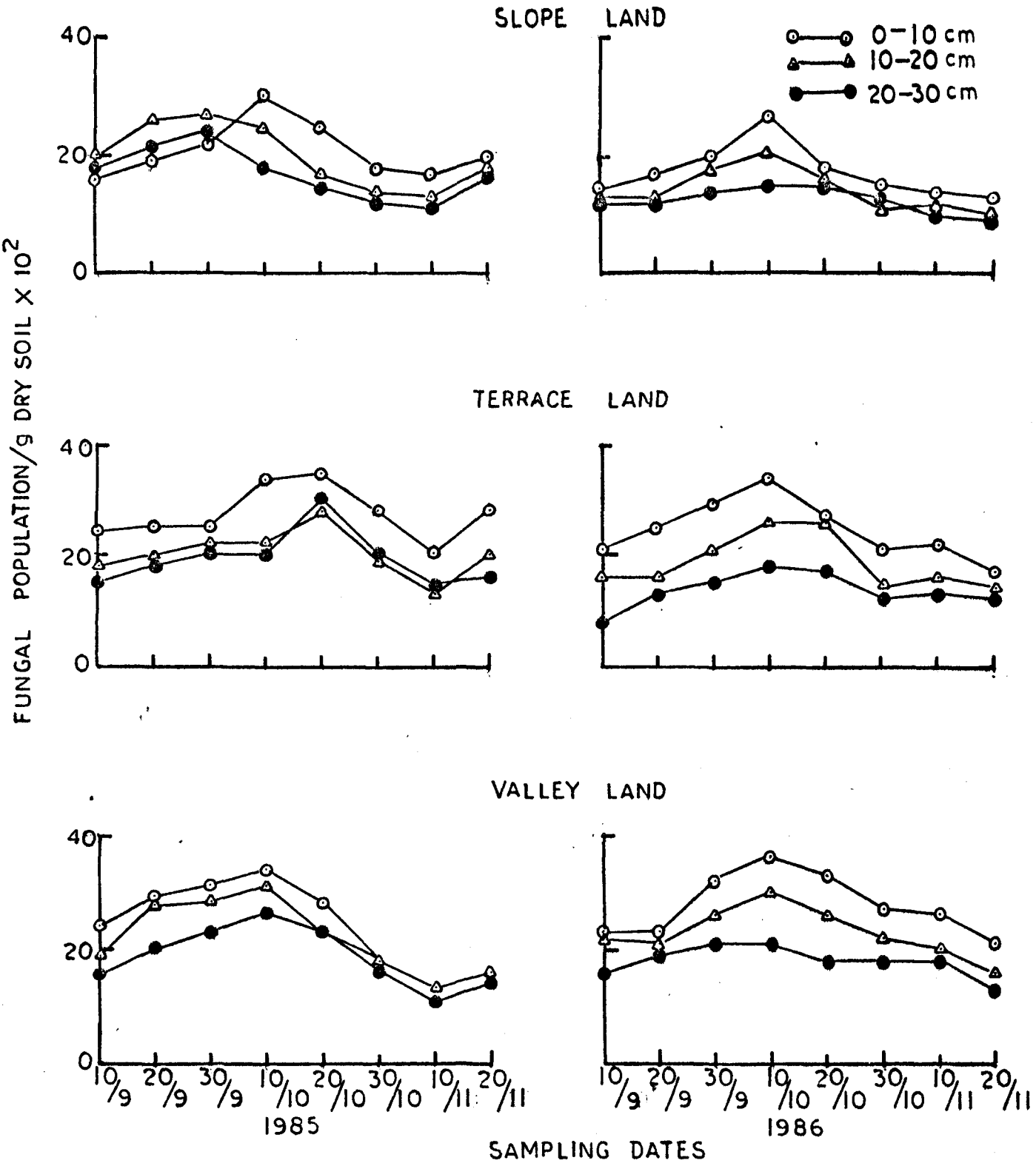

SLOPE LAND
TERRACE LAND
VALLEY LAND
0–10 cm
10–20 cm
20–30 cm
FUNGAL POPULATION/g DRY SOIL X 10^2
40
20
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
1986
SAMPLING DATES

Fig. 1.9. Temporal variation in bacterial population of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November and 10 September 1986 to 20 November 1986.

FIG.19

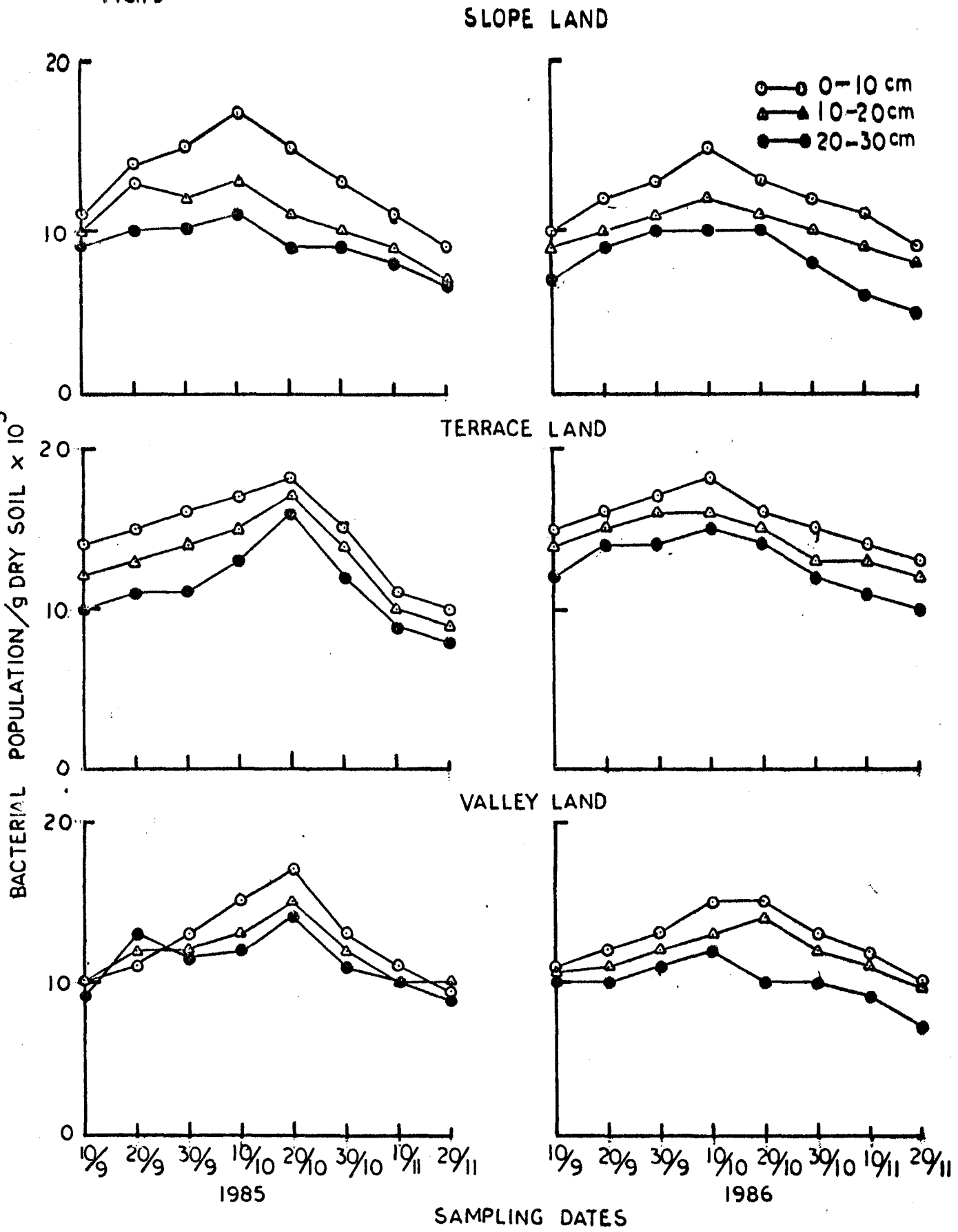

SLOPE LAND
TERRACE LAND
VALLEY LAND
0-10 cm
10-20cm
20-30cm
BACTERIAL POPULATION/g DRY SOIL x 10^5
20
10
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
1986
SAMPLING DATES

Fig. 1.10. Temporal variation in dehydrogenase activity of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG.1'10

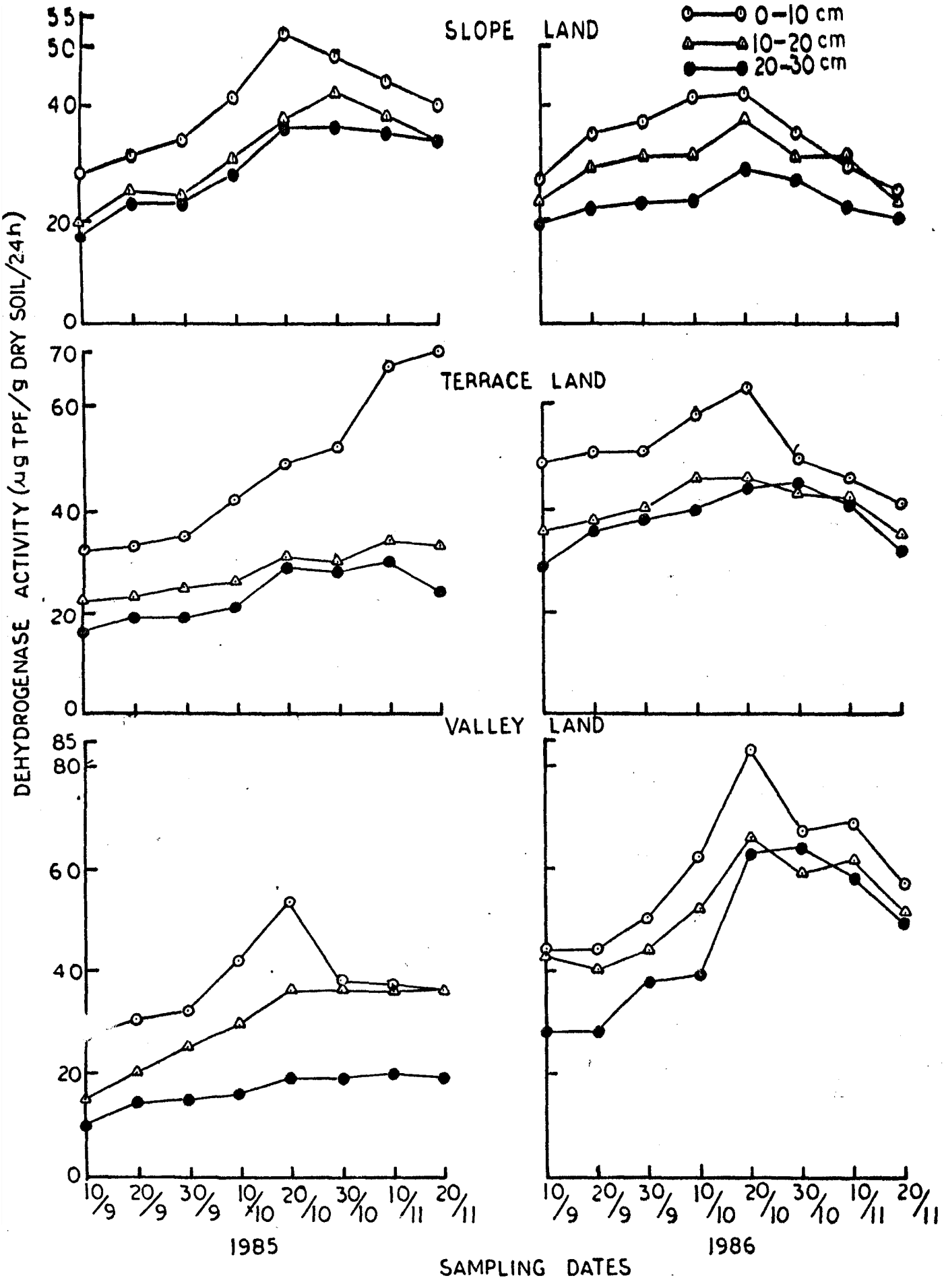

SLOPE LAND
TERRACE LAND
VALLEY LAND
0-10 cm
10-20 cm
20-30 cm
DEHYDROGENASE ACTIVITY (μg TPF/g DRY SOIL/24h)
55
50
40
20
0
70
60
40
20
0
85
80
60
40
20
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1986
SAMPLING DATES

Fig. 1.11. Temporal variation in urease activity of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 1'11

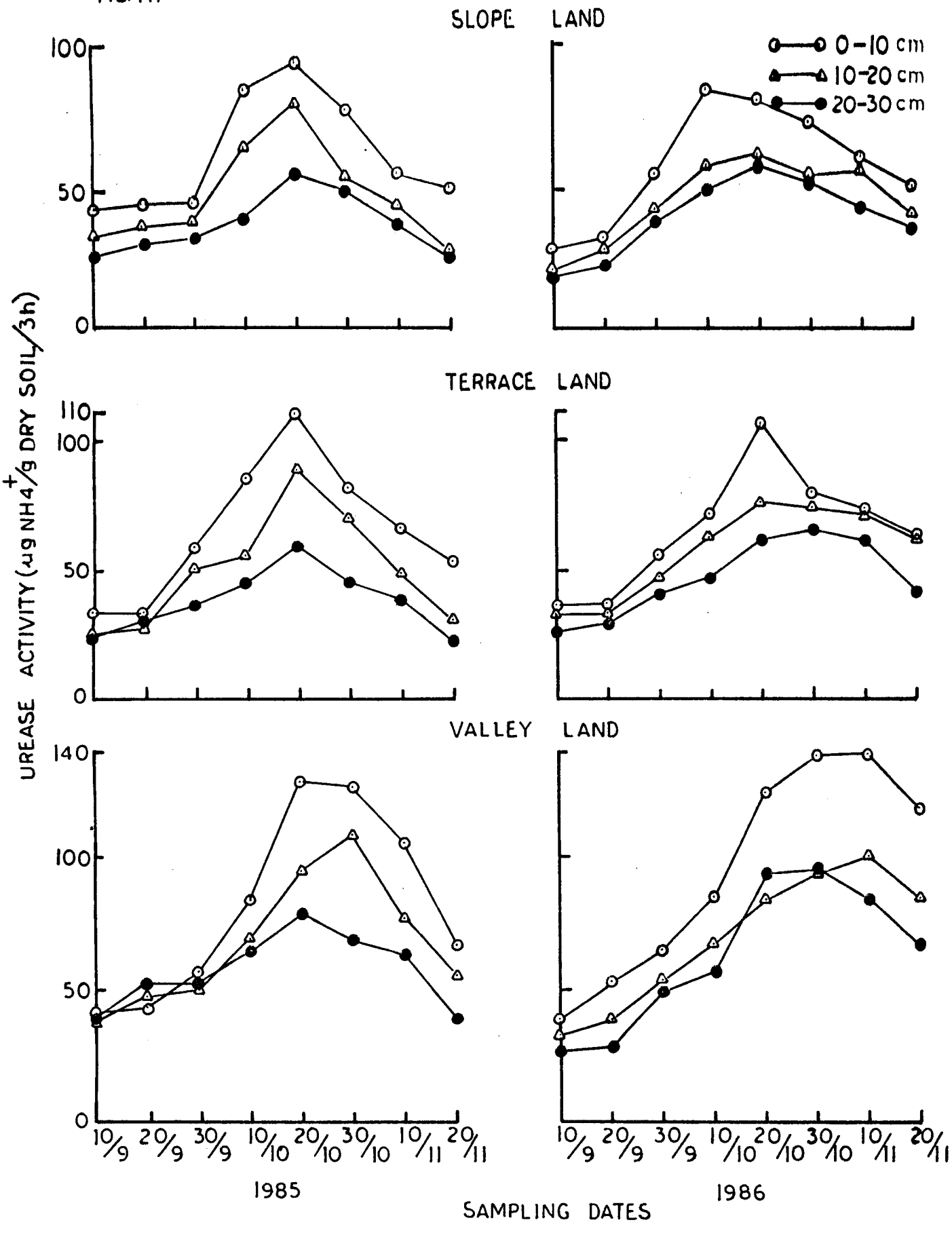

SLOPE LAND
TERRACE LAND
VALLEY LAND
0-10 cm
10-20 cm
20-30 cm
UREASE ACTIVITY (μg NH4+/g DRY SOIL/3h)
100
50
0
110
140
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
1986
SAMPLING DATES

Fig. 1.12. Temporal variation in Phosphatase activity of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November 1985 and 10 September 1986 to 20 November 1986.

FIG. 1·12

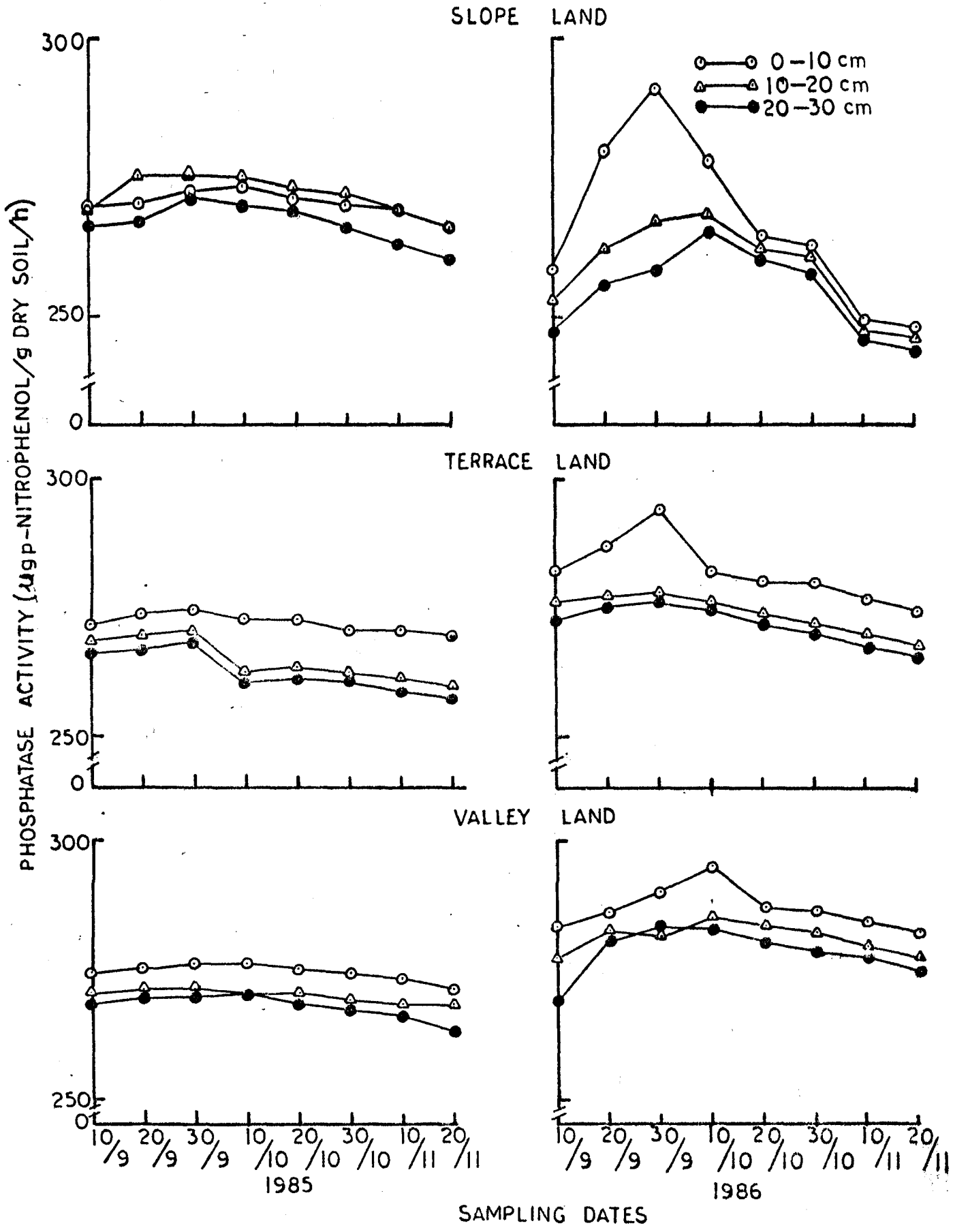

SLOPE LAND
TERRACE LAND
VALLEY LAND
0–10 cm
10–20 cm
20–30 cm
PHOSPHATASE ACTIVITY (μg p-NITROPHENOL/g DRY SOIL/h)
300
250
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
1986
SAMPLING DATES

FIG. 1·12

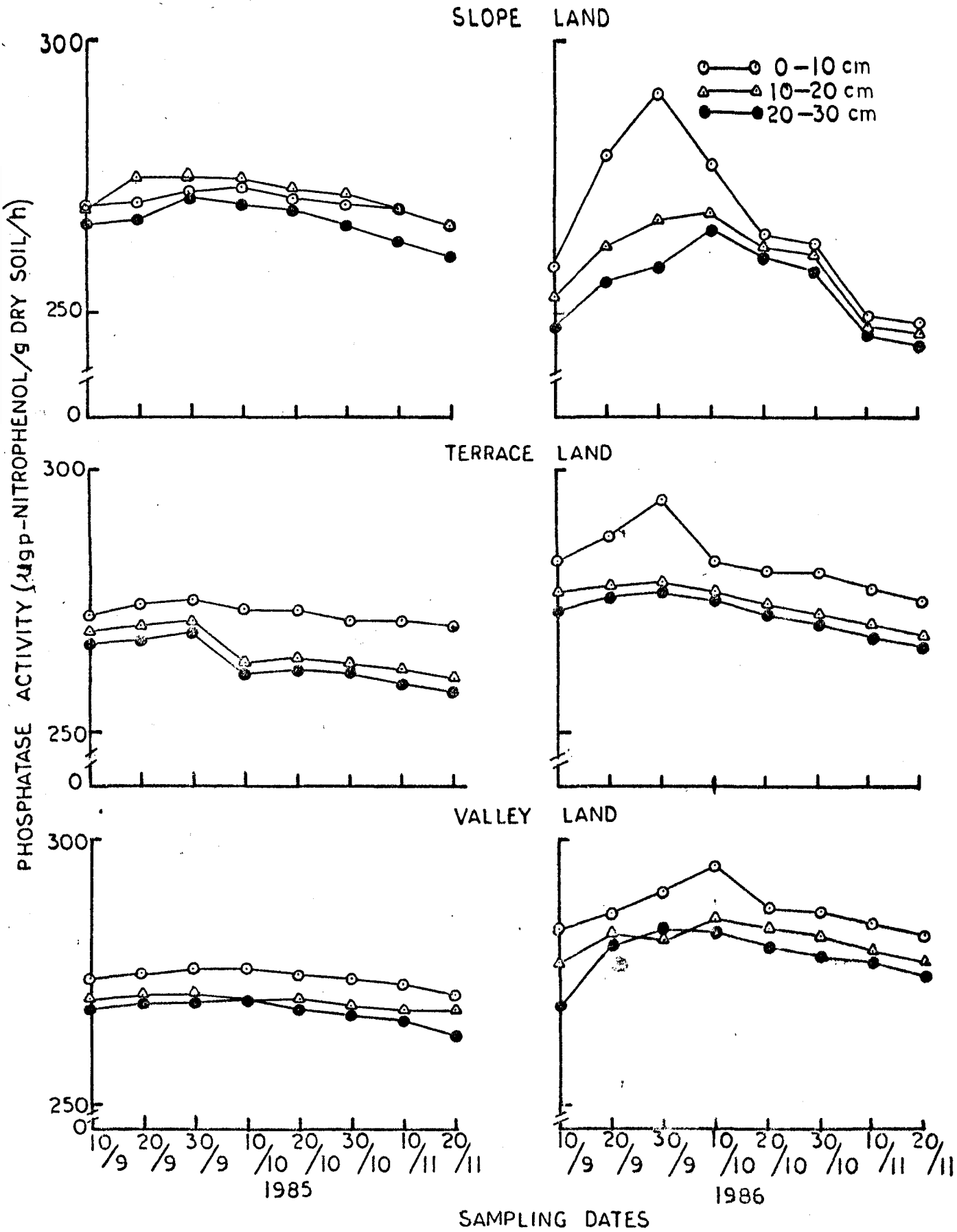

SLOPE LAND
TERRACE LAND
VALLEY LAND
0–10 cm
10–20 cm
20–30 cm
PHOSPHATASE ACTIVITY (μg p-NITROPHENOL/g DRY SOIL/h)
300
250
0
10/9 20/9 30/9 10/10 20/10 30/10 10/11 20/11
1985
1986
SAMPLING DATES

Fig. 1.13. Temporal variation in soil respiration of valley land, terrace land and slope land agricultural field soils from 10 September 1985 to 20 November and 10 September 1986 to 20 November 1986.

FIG. 113

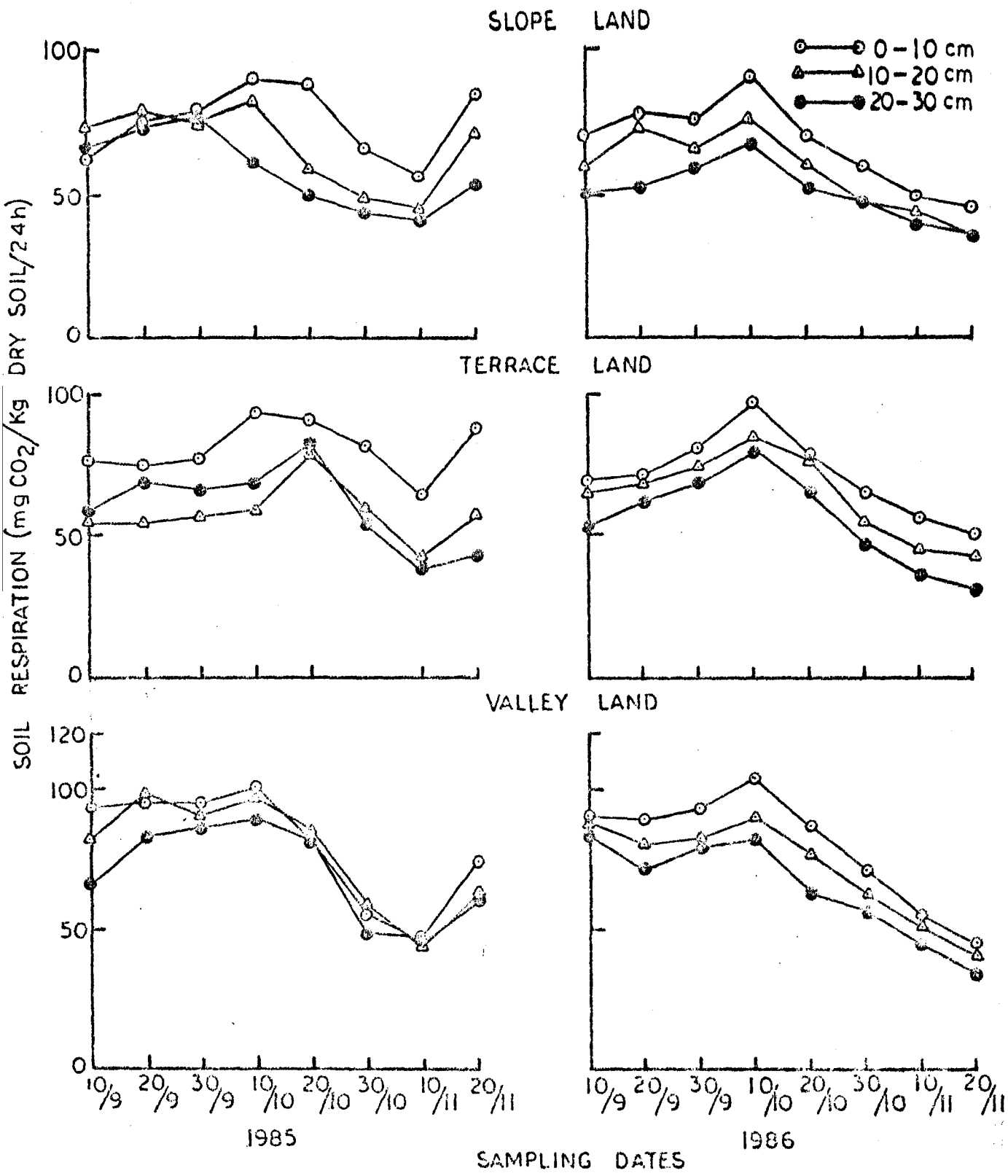

SLOPE LAND
TERRACE LAND
VALLEY LAND
0-10 cm
10-20 cm
20-30 cm
SOIL RESPIRATION (mg CO2/Kg DRY SOIL/24h)
100
50
0
120
10/9
20/9
30/9
10/10
20/10
30/10
10/11
20/11
1985
1986
SAMPLING DATES

Table 1.1. Temporal variation in the population of fungal species per gram dry soil x 10^2 in slope land field soils at 0-10cm depth for the period of 10 September, 1985 to 20 November, 1985. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus niger	-	-	-	-	62.9 (16.8)	-	-	-
Fusarium oxysporum	23.5 (3.9)	21.0 (3.9)	24.9 (5.6)	28.1 (8.7)	-	-	-	-
Fusarium solani	-	-	-	-	-	21.0 (3.8)	36.8 (6.6)	-
Mucor hiemalis	-	-	-	-	18.5 (4.9)	15.7 (2.8)	21.0 (3.8)	38.0 (7.8)
Mucor plumbeus	-	36.8 (6.9)	16.6 (3.7)	21.8 (6.8)	-	-	-	-
Mucor racemosus	17.6 (1.9)	42.1 (7.9)	24.9 (5.6)	25.0 (7.8)	-	15.7 (2.8)	31.5 (5.7)	38.0 (7.8)
Penicillium brevicompactum	-	-	-	-	18.5 (4.9)	47.3 (8.5)	-	-
Penicillium chrysogenum	35.2 (3.9)	-	-	-	-	-	-	-
Trichoderma viride	25.5 (3.9)	-	33.3 (7.4)	-	-	-	10.5 (1.9)	-
Sterile	-	-	-	25.0 (7.8)	-	-	-	23.8 (4.8)

Table : 1.2. Temporal variation in the population of fungal species per gram dry soil x 10^2 in slope land field soils at 0-10cm depth for the period of 10 September, 1986 to 20 November, 1986. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Absidia corymbifera	-	10.5 (1.8)	13.0 (2.6)	-	9.0 (1.7)	15.5 (2.4)	-	-
Aspergillus flavus	-	-	-	-	4.5 (0.8)	10.5 (1.6)	-	-
Fusarium oxysporum	25.0 (3.2)	31.5 (5.5)	-	-	-	-	-	-
Monilia sp.	-	-	-	-	13.5 (2.5)	15.5 (2.4)	11.0 (1.5)	22.0 (2.9)
Mortierella minutissima	-	-	-	-	18.0 (3.4)	10.5 (1.6)	-	-
Mucor plumbeus	-	-	-	-	-	21.0 (3.2)	27.5 (3.8)	28.0 (3.7)
Mucor racemosus	-	-	-	20.0 (5.6)	13.5 (2.5)	-	-	-
Penicillium chrysogenum	18.5 (2.7)	15.5 (2.7)	13.0 (2.6)	10.0 (2.8)	13.5 (2.5)	16.0 (2.5)	33.0 (4.6)	16.5 (2.2)
Trichoderma harzianum	12.5 (1.8)	-	21.5 (5.4)	20.0 (5.6)	-	-	-	-
Trichoderma viride	25.0 (3.2)	31.5 (5.5)	26.0 (5.3)	26.5 (7.4)	27.0 (5.1)	11.0 (1.7)	11.0 (1.5)	22.0 (2.9)
Verticillium sp.	-	-	13.5 (2.6)	13.5 (3.7)	-	-	-	-
Sterile	19.0 (2.8)	10.5 (1.8)	13.8 (2.6)	10.0 (2.8)	-	-	16.5 (2.3)	11.0 (1.4)

Table : 1.3. Temporal variation in the population of fungal species per gram dry soil x 10^2 in slope land field soils at 10-20cm depth for the period of 10 September, 1985 to 20 November, 1985. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus niger	-	-	-	8.6 (2.1)	17.6 (3.0)	-	-	-
Fusarium oxysporum	28.5 (5.9)	46.1 (12.4)	-	-	-	-	-	-
Fusarium solani	-	-	-	34.7 (8.6)	-	19.9 (2.9)	-	-
Monilia sp.	14.2 (2.9)	3.8 (1.0)	-	-	-	-	-	-
Mucor hiemalis	-	-	-	-	23.5 (4.0)	-	53.8 (7.2)	32.1 (7.7)
Mucor plumbeus	-	-	39.2 (10.6)	-	-	-	-	-
Mucor racemosus	9.5 (1.9)	34.6 (9.3)	-	30.4 (7.6)	29.4 (5.0)	19.9 (2.9)	46.1 (6.2)	36.8 (8.7)
Penicillium chrysogenum	28.5 (5.9)	15.3 (4.1)	28.5 (7.7)	26.0 (6.5)	29.4 (5.0)	33.3 (4.9)	-	-
Trichoderma viride	19.0 (3.9)	-	32.1 (8.6)	-	-	13.3 (1.9)	-	-
Sterile	-	-	-	-	-	13.3 (1.9)	-	21.0 (3.8)

Table : 1.4. Temporal variation in the population of fungal species per gram dry soil x 10^2 in slope land field soils at 10-20 cm depth for the period of 10 September 1986 to 20 November 1986. Values in parentheses are percentage relative dominance.

Fungal species	September 10	September 20	September 30	October 10	October 20	October 30	November 10	November 20
Absidia coryncifera	-	13.0 (1.8)	10.0 (1.8)	16.0 (3.4)	-	-	13.0 (1.7)	23.0 (2.2)
Arthrobotrys arthrobotryoides	-	-	-	-	15.5 (2.6)	20.0 (21.1)	-	-
Aspergillus flavus	-	-	25.0 (4.5)	-	15.5 (2.6)	-	-	-
Aspergillus niger	-	6.5 (0.9)	-	-	15.5 (2.6)	13.0 (1.6)	-	-
Fusarium oxysporum	20.0 (2.9)	13.0 (1.8)	-	16.0 (3.4)	-	-	-	-
Monilia sp.	-	-	-	-	-	13.0 (1.6)	13.0 (1.7)	-
Mortierella minutissima	13.5 (1.9)	-	-	-	15.5 (2.6)	-	-	-
Mucor hiemalis	-	-	-	12.0 (2.6)	-	-	-	-
Mucor plumbeus	-	-	-	-	-	20.0 (21.1)	13.0 (1.7)	-
Mucor racemosus	-	-	-	8.0 (1.7)	-	-	-	-
Oidiodendron echinulatum	-	16.5 (0.9)	-	-	-	-	-	-
Penicillium breviconpactum	-	13.0 (1.8)	20.0 (3.6)	-	-	-	13.0 (1.7)	23.0 (2.2)
Penicillium canescens	13.5 (1.9)	-	-	-	-	-	-	-
Penicillium chrysogenum	-	-	-	-	-	-	20.0 (2.5)	15.5 (1.5)
Penicillium citrinum	20.0 (2.9)	20.0 (2.8)	20.0 (3.6)	-	-	-	-	-
Penicillium fellutanum	-	-	-	-	22.0 (3.5)	14.0 (1.6)	-	-
Phoma sp.	-	-	-	12.0 (2.6)	15.5 (2.6)	20.0 (21.1)	-	-
Trichoderma hamatum	6.5 (0.9)	13.0 (1.8)	10.0 (1.8)	-	-	-	-	-
Trichoderma harzianum	-	-	-	16.0 (3.4)	-	-	20.0 (2.5)	15.5 (8.5)
Trichoderma viride	20.0 (2.9)	20.0 (2.8)	10.0 (1.8)	20.0 (2.6)	-	-	7.0 (2.5)	7.5 (8.5)
Sterile	3.5 (1.9)	-	-	-	-	-	-	-

Table 1.5. Temporal variation in the population of fungal species per gram dry soil x 10^2 in slope land field soils at 20-30 cm depth for the period of September, 1985 to November, 1985. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Fusarium oxysporum	10.5 (1.8)	40.9 (9.3)	-	-	-	-	-	-
Fusarium poae	-	-	-	41.1 (7.5)	-	16.6 (1.9)	-	-
Monilia sp.	21.0 (3.7)	9.0 (2.0)	-	-	-	-	-	-
Mucor hiemalis	-	-	-	17.6 (3.2)	33.3 (5.2)	24.8 (2.9)	33.3 (3.9)	33.3 (6.3)
Mucor plumbeus	-	-	36.0 (8.8)	-	-	-	-	-
Mucor racemosus	5.2 (0.9)	36.3 (8.3)	-	29.4 (5.3)	26.6 (4.1)	8.3 (0.9)	49.9 (5.8)	49.9 (9.4)
Penicillium chrysogenum	31.5 (5.6)	13.6 (3.1)	32.0 (7.9)	11.7 (2.1)	-	-	-	-
Penicillium fellutanum	-	-	-	-	19.9 (3.1)	33.3 (3.9)	16.6 (1.9)	16.6 (3.1)
Trichoderma viride	31.5 (5.6)	-	32.0 (7.9)	-	-	8.3 (0.9)	-	-
Sterile	-	-	-	-	19.9 (3.1)	8.3 (0.9)	-	-

able : 1.6. Temporal variation in the population of fungal species per gram dry soil x 10^2 in slope land field soils at 20-30 cm depth for the period of September 1986 to November 1986. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Absidia corymbifera	-	23.0 (2.8)	-	-	-	-	14.0 (1.5)	16.5 (1.5)
Aspergillus flavus	-	7.5 ((0.9)	-	11.0 (1.7)	11.5 (1.7)	13.5 (1.7)	-	-
Fusarium oxysporum	16.5 (1.9)	7.5 (0.9)	-	-	23.5 (3.5)	-	-	-
Monilia sp.	-	-	13.5 (1.8)	-	-	-	-	-
Mortierella minutissima	-	-	20.0 (2.7)	5.5 (0.8)	13.5 (3.5)	20.0 (2.5)	-	-
Mucor hiemalis	-	-	16.5 (1.9)	11.0 (1.7)	6.0 (0.6)	13.5 (1.7)	14.0 (1.5)	-
Mucor plumbeus	-	-	-	11.0 (1.7)	-	-	21.5 (2.3)	-
Penicillium brevicompactum	16.5 (1.9)	7.5 (0.9)	-	-	-	-	14.0 (1.5)	25.0 (2.2)
Penicillium chrysogenum	25.0 (2.9)	7.5 (0.9)	20.0 (2.7)	-	-	-	21.5 (2.3)	33.5 (3.0)
Penicillium fellutanum	-	-	-	11.0 (1.7)	11.5 (1.7)	6.5 (0.8)	-	-
Rhizopus oryzae	-	-	-	16.5 (2.5)	11.5 (1.7)	20.0 (2.5)	-	-
Trichoderma hamatatum	16.5 (1.9)	-	-	-	-	-	-	8.5 (0.7)
Trichoderma harzianum	-	7.5 (0.9)	13.5 (1.8)	16.5 (2.5)	6.0 (8.8)	6.5 (0.8)	-	-
Trichoderma koningii	-	-	-	11.0 (1.7)	-	-	-	-
Trichoderma viride	16.5 (1.9)	-	13.5 (1.8)	11.0 (1.7)	6.0 (8.8)	20.0 (2.5)	14.0 (1.5)	16.5 (1.5)
Verticillium chlamydosporum	-	30.5 (3.8)	-	-	-	-	-	-
Sterile	16.5 (1.9)	7.5 (0.9)	13.0 (1.7)	-	-	-	-	-

Table 1.7. Temporal variation in the population of fungal species per gram dry soil x 10^2 in terrace land field soils at 0-10 cm depth for the period of 10 September, 1985 to 20 November, 1985. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus niger	-	-	-	13.8 (4.9)	16.6 (5.8)	-	-	32.1 (8.9)
Fusarium oxysporum	17.3 (4.3)	20.0 (5.0)	15.3 (3.9)	22.2 (7.8)	-	-	-	--
Fusarium poae	-	-	-	-	24.9 (8.7)	16.6 (4.6)	17.3 (3.6)	24.9 (6.9)
Monilia sp.	-	-	-	19.4 (6.8)	-	-	-	-
Mucor circenelloides	-	-	-	-	-	9.9 (2.7)	-	-
Mucor hiemalis	-	-	-	-	16.6 (5.8)	-	-	-
Mucor plumbeus	-	4.0 (1.0)	15.3 (3.9)	24.9 (8.8)	-	26.6 (7.4)	17.3 (3.6)	-
Mucor racemosus	39.1 (9.7)	8.0 (2.0)	19.2 (4.9)	-	-	-	21.7 (4.6)	-
Penicillium chrysogenum	30.4 (7.5)	32.0 (8.0)	15.3 (3.9)	-	-	-	-	-
Penicillium fellutanum	-	-	-	-	33.3 (11.7)	39.9 (11.1)	13.0 (2.7)	32.1 (8.0)
Trichoderma viride	13.0 (3.2)	36.0 (9.1)	34.6 (8.9)	19.4 (6.8)	-	-	17.3 (3.6)	10.7 (2.9)
Sterile	-	-	-	-	8.3 (2.9)	6.6 (1.8)	13.0 (2.7)	

Table : 1.8. Temporal variation in the population of fungal species per gram dry soil x 10^2 in terrace land field soils at 0-10 cm depth for the period of 10 September 1986 to 20 November 1986. Values in parentheses are percentage relative dominance

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Alternaria alternata	-	-	13.5 (1.0)	-	-	-	-	-
Absidia corymbifera	-	-	-	9.0 (3.1)	11.5 (2.9)	9.0 (1.9)	-	-
Aspergillus flavus	-	-	-	9.0 (3.1)	22.0 (5.9)	13.5 (2.9)	-	-
Aspergillus niger	-	-	-	-	-	-	17.5 (3.9)	26.0 (4.6)
Fusarium oxysporum	25.0 (5.4)	-	-	-	-	-	-	16.0 (2.7)
Fusarium poae	-	21.0 (5.3)	17.0 (5.2)	12.0 (4.1)	-	-	--	-
Humicola fuscoatra	-	12.5 (3.2)	-	-	-	-	-	16.0 (2.7)
Monilia sp.	-	-	-	-	-	18.0 (3.9)	17.5 (3.9)	21.0 (3.7)
Mucor hiemalis	20.0 (4.3)	-	10.0 (3.1)	9.0 (3.1)	-	-	-	-
Mucor mucedo	10.0 (2.1)	-	-	-	-	-	-	-
Mucor plumbeus	10.0 (2.1)	16.5 (4.2)	7.0 (2.0)	12.0 (4.1)	7.5 (1.9)	9.0 (1.9)	13.0 (2.9)	-
Mucor racemosus	-	4.5 (1.0)	10.0 (3.1)	6.0 (2.0)	15.0 (3.9)	-	-	-
Penicillium brevicompactum	-	-	20.5 (6.2)	18.0 (6.2)	22.0 (5.9)	13.5 (2.9)	22.0 (4.9)	-
Penicillium chrysogenum	-	21.0 (5.3)	10.0 (3.1)	15.0 (5.2)	22.0 (5.9)	19.0 (3.9)	22.0 (4.9)	21.0 (3.7)
Penicillium fellutanum	25.0 (5.4)	-	-	-	-	18.0 (3.7)	-	-
Trichoderma viride	10.0 (2.1)	8.0 (2.1)	21.0 (6.2)	12.0 (4.1)	-	-	7.0 (1.5)	-
Sterile	-	16.5 (4.2)	-	-	-	-	-	-

Table : 1.9. Temporal variation in the population of fungal species per gram x 10^2 in terrace land field soils at 10-20cm depth for the period of 10 September, 1985 to 20 November, 1985. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus niger	-	-	-	-	33.3 (9.3)	4.7 (0.9)	-	27.2 (5.7)
Fusarium oxysporum	29.4 (5.2)	-	21.7 (4.9)	26.0 (4.7)	-	-	-	-
Fusarium poae	-	-	-	-	14.8 (4.1)	19.0 (3.7	19.9 (2.7)	-
Monilia sp.	17.6 (3.1)	-	13.0 (2.9)	17.3 (3.8)	3.7 (1.0)	-	-	-
Mucor circenelloides	-	-	-	-	-	-	-	22.7 (4.8)
Mucor hiemalis	-	-	-	-	7.4 (2.0)	-	-	-
Mucor plumbeus	-	10.0 (2.0)	4.3 (0.9)	34.7 (7.7)	-	23.8 (4.6)	26.6 (3.6)	-
Mucor racemosus	23.5 (4.2)	15.0 (3.2)	8.6 (1.9)	-	-	-	-	-
Penicillium brevicompactum	-	-	-	-	40.7 (11.4)	38.0 (7.5)	33.3 (4.5)	31.8 (6.7)
Penicillium chrysogenum	17.6 (3.1)	30.0 (6.1)	30.4 (6.9)	13.0 (2.8)	-	-	-	-
Pythium sp.	-	-	-	-	-	-	-	9.0 (1.9)
Trichoderma viride	11.7 (2.1)	45.0 (9.1)	21.7 (4.9)	8.6 (1.9)	-	4.7 (0.9)	-	-
Sterile	-	-	-	-	-	9.5 (1.8)	19.9 (2.7)	9.0 (1.9)

Table : 1.10. Temporal variation in the population of fungal species per gram dry soil x 10^2 in terrace land field soils at 10-20cm depth for the period of 10 September, 1986 to 20 November, 1986. Values in parentheses are percentage relative dominance.

Fungal species	September 10	September 20	September 30	October 10	October 20	October 30	November 10	November 20
Absidia corymbifera	-	20.0 (3.2)	8.5 (4.1)	16.0 (2.2)	14.0	20.0 (2.9)	-	-
Aspergillus flavus	-	-	-	8.0 (2.1)	-	-	-	-
Fusarium poae	20.0 (3.2)	14.0 (3.1)	14.0	12.0 (3.1)	20.0 (4.0)	13.0 (1.9)	-	-
Monilia sp.	-	-	-	-	-	20.0 (2.9)	12.5 (2.0)	20.0 (2.8)
Mortierella minutissima	-	20.0 (3.2)	-	-	-	-	-	13.0 (1.9)
Mucor hiemalis	20.0 (3.2)	13.0 (2.1)	-	-	-	-	-	-
Mucor plumbeus	-	-	-	-	-	20.0 (2.9)	19.0 (3.0)	26.5 (3.8)
Mucor racemosus	-	13.0 (2.1)	14.0 (3.1)	-	-	-	6.0	13.0 (1.9)
Penicillium brevicompactum	13.0 (2.1)	-	-	-	-	13.0 (1.9)	13.0 (1.0)	13.0 (1.9)
Penicillium canescens	-	6.5 (1.0)	28.5 (6.3)	20.0 (5.2)	3.8 (8.5)	-	-	-
Penicillium chrysogenum	-	6.5 (1.0)	9.5 (2.1)	-	24.0 (5.0)	6.5 (0.9)	19.0 (3.0)	-
Trichoderma harzianum	13.0 (2.1)	-	-	-	-	-	-	-
Trichoderma viride	20.0 (3.2)	13.0 (2.1)	14.0 (3.1)	24.0 (6.3)	-	-	-	-
Sterile	13.0 (2.1)	7.0 (1.3)	9.5 (2.1)	20.0 (5.2)	4.0 (1.1)	6.5 (0.9)	12.5 (2.0)	14.0 (2.0)

Table : 1.11. Temporal variation in the population of fungal species per gram dry soil x 10^2 in terrace land field soils at 20-30 cm depth for the period of 10 September, 1985 to 20 November, 1985. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus flavus	-	-	5.0 (1.0)	-	-	-	-	-
Aspergillus niger	-	-	-	-	33.3 (10.0)	-	-	27.7 (4.7)
Fusarium poae	-	-	-	-	18.5 (5.5)	33.3 (6.7)	18.7 (2.7)	11.1 (1.9)
Fusarium solani	28.5 (4.3)	-	25.0 (5.0)	25.0 (4.9)	-	-	-	-
Monilia sp.	7.1 (1.0)	-	10.0 (3.0)	20.0 (3.9)	3.7 (1.1)	-	-	-
Mucor hiemalis	-	-	-	-	7.4 (2.2)	-	-	-
Mucor plumbeus	-	6.2 (1.1)	10.0 (2.0)	25.0 (4.9)	3.7 (1.1)	14.2 (2.8)	25.0 (4.6)	11.1 (1.9)
Mucor racemosus	35.7 (5.4)	12.5 (3.2)	15.0 (2.0)	30.0 (5.0)	-	-	-	-
Penicillium brevicompactum	-	-	-	-	33.3 (10.0)	42.8 (8.6)	21.2 (3.0)	27.7 (4.7)
Penicillium chrysogenum	21.4 (3.2)	31.2 (4.6)	2.0 (5.0)	-	-	-	-	-
Phoma sp.	-	-	-	-	-	-	-	11.1 (1.9)
Trichoderma viride	7.1 (1.0)	50.0 (9.0)	15.0 (3.0)	-	-	-	18.7 (2.7)	5.5 (0.9)
Sterile	-	-	-	-	-	9.5 (1.9)	6.25 (0.9)	5.5 (0.9)

Table : 1.12. Temporal variation in the population of fungal species per gram dry soil x 10^2 in terrace land field soils at 20-30 cm depth for the period of 10 September, 1986 to 20 November, 1986. Values in parentheses are percentage relative dominance.

Fungal species	September 10	September 20	September 30	October 10	October 20	October 30	November 10	November 20
Absidia corymbifera	-	16.5 (2.2)	20.0 (3.2)	-	-	-	-	-
Aspergillus flavus	-	-	-	22.0 (4.2)	-	-	14.0 (2.0)	15.0 (1.9)
Aspergillus niger	-	-	-	-	20.0 (2.0)	25.0 (2.9)	-	-
Fusarium oxysporum	28.5 (4.3)	16.5 (2.2)	-	-	-	-	-	-
Monilia sp.	-	-	6.5 (1.0)	-	10.0 (1.9)	16.5 (1.3)	21.5 (3.0)	23.0 (2.9)
Mortierella minutissima	-	-	20.0 (3.2)	20.0 (4.0)	-	-	-	-
Mucor hiemalis	-	-	13.0 (2.0)	-	-	-	-	-
Mucor mucedo	14.0 (2.1)	25.0 (3.3)	20.0 (3.2)	11.0 (2.1)	20.0 (2.0)	16.5 (1.9)	-	-
Mucor plumbeus	-	-	-	-	-	-	14.0 (2.0)	15.0 (1.9)
Mucor racemosus	-	-	-	11.0 (2.1)	-	-	-	-
Penicillium brevicompactum	-	16.5 (2.2)	20.0 (3.2)	11.0 (2.1)	20.0 (2.0)	25.0 (2.9)	-	-
Penicillium chrysogenum	28.5 (4.3)	-	-	-	-	-	14.0 (2.0)	23.0 (2.9)
Penicillium fellutanum	-	-	-	-	-	-	21.5 (3.0)	-
Trichoderma harzianum	-	8.5 (1.1)	-	-	-	-	-	-
Trichoderma viride	28.5 (4.3)	17.0 (2.2)	-	-	-	-	-	-
Verticillium sp.	-	-	-	-	30.0 (3.0)	16.5 (1.9)	14.0 (2.0)	24.0 (3.0)
Sterile	-	-	-	25.0 (4.7)	-	-	-	-

Table : 1.13. Temporal variation in the population of fungal species per gram dry soil x 10^2 in valley land field soils at 0-10cm depth for the period of 10 September,1985 to 20 November, 1985. Values in parentheses are percentage relative abundance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus niger	-	-	-	-	8.6 (2.4)	-	-	-
Fusarium oxysporum	19.0 (4.5)	22.0 (6.5)	17.0 (5.4)	-	-	-	-	-
Fusarium poae	-	-	-	-	30.4 (8.5)	22.2 (4.0)	-	-
Fusarium solani	-	-	-	-	-	-	15.3 (2.0)	-
Mucor circenelloides	-	-	-	-	-	-	-	26.3 (5.4)
Mucor hiemalis	-	-	-	-	39.1 (10.9)	-	-	-
Mucor plumbeus	-	15.5 (4.5)	13.7 (4.3)	29.00 (10.0)	-	-	23.0 (3.1)	-
Mucor racemosus	33.3 (7.8)	18.5 (5.4)	24.1 (7.6)	35.4 (12.2)	-	22.2 (4.0)	30.7 (4.1)	-
Penicillium brevicompactum	-	-	-	-	8.6 (2.4)	38.8 (7.0)	23.0 (3.1)	15.7 (3.2)
Penicillium chrysogenum	42.8 (10.1)	33.3 (9.7)	20.7 (0.5)	-	-	-	-	-
Rhizopus oryzae	-	-	10.3 (3.2)	-	-	-	-	-
Trichoderma viride	4.7 (1.1)	-	13.7 (4.3)	22.5 (7.8)	-	-	-	-
Sterile white	-	11.1 (3.2)	-	12.9 (4.4)	13.0 (3.6)	11.1 (2.0)	7.6 (1.0)	31.5 (6.5)
Sterile yellow	-	-	-	-	-	5.5 (1.0)	-	26.3 (5.4)

Table 1.14. Temporal variation in the population of fungal species per gram dry soil x 10^2 in valley land field soils at 0-10 cm depth for the period of 10 September,1986 to 20 November 1986. Values in parentheses are percentage relative abundance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Absidia glauca	10.0 (2.2)	13.5 (3.1)	-	-	-	-	-	13.5 (2.9)
Emmonsiella capsulata	25.5 (5.5)	-	-	-	-	-	-	-
Fusarium oxysporum	10.0 (2.2)	23.0 (5.2)	-			-	-	-
Mortierella minutissima	-	-	20.0 (6.5)	21.0 (7.7)			-	-
Mucor hiemalis	15.0 (3.3)	-	13.0 (4.3)	21.0 (7.7)	-	-	-	-
Mucor plumbeus	15.0 (3.3)	-	-	-	16.5 (5.3)	15.0 (3.9)	24.0 (6.2)	18.0 (3.9)
Mucor racemosus	15.0 (3.3)	27.0 (6.3)	20.0 (6.5)	27.0 (10.0)	30.0 (10.1)	11.0 (2.9)	20.0 (5.2)	13.5 (2.9)
Penicillium brevicompactum	-	-	10.0 (3.3)	- (7.8)	23.5 (7.8)	18.5 (4.9)	16.0 (4.1)	13.5 (2.9)
Penicillium chrysogenum	-	18.0 (4.2)	17.0 (5.4)	-	13.0 (4.4)	22.0 (5.9)	-	-
Trichoderma viride	-	-	20.0 (6.5)	18.0 (6.6)	-	-	28.0 (7.3)	23.0 (4.9)
Sterile	10.0 (2.2)	18.0 (4.2)	-	13.0 (4.5)	17.0 (5.6)	7.5 (1.9)	12.0 (3.1)	18.5 (4.0)

Table : 1.15. Temporal variation in the population of fungal species per gram dry soil x 10^2 in valley land field soil at 10-20cm depth for the period of 10 September, 1985 to 20 November, 1985. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus niger	-	-	-	-	36.8 (8.7)	-	-	-
Fusarium poae	23.5 (4.4)	17.3 (4.9)	15.3 (4.5)	-	-	-	-	-
Fusarium solani	-	-	-	-	21.0 (5.0)	29.4 (5.5)	-	-
Mucor hiemalis	-	-	-	-	15.7 (3.7)	-	-	-
Mucor plumbeus	-	21.7 (6.2)	15.3 (4.5)	25.9 (8.1)	-	-	16.6 (2.1)	-
Mucor racemosus	23.5 (4.4)	17.3 (4.9)	19.2 (4.6)	33.3 (10.4)	-	17.6 (3.3)	33.3 (4.2)	33.3 (7.0)
Penicillium brevicompactum	-	-	-	-	26.3 (6.2)	23.5 (4.4)	24.9 (3.2)	-
Penicillium chrysogenum	41.7 (7.8)	21.7 (6.2)	15.3 (4.5)	-	-	-	-	-
Penicillium fellutanum	-	-	-	-	-	-	-	22.2 (4.6)
Trichoderma viride	11.7 (2.2)	-	34.6 (10.1)	14.8 (4.6)	-	-	-	-
Sterile white	-	21.7 (6.2)	-	14.8 (4.6)	-	29.4 (5.5)	24.9 (3.2)	44.4 (9.3)
Sterile yellow	-	-	-	11.1 (3.4)	-	-	-	-

Table 1.16. Temporal variation in the population of fungal species per gram dry soil x 10^2 in valley land field soil at 10-20 cm depth for the period of 10 September, 1986 to 20 November, 1986. Values in parentheses are percentage relative dominance.

Fungal species	September 10	September 20	September 30	October 10	October 20	October 30	November 10	November 20
Alternaria alternata	-	-	-	7.5 (2.1)	-	-	-	-
Aspergillus flavus	-	14.0 (3.1)	8.0 (2.1)	11.0 (3.2)	-	-	-	-
Aspergillus niger	-	5.0 (1.0)	-	-	-	13.0 (3.0)	-	-
Fusarium oxysporum	-	19.0 (4.3)	-	-	-	-	-	18.5 (3.0)
Mortierella minutissima	-	16.5	16.5 (4.3)	18.5 (5.4)	16.5 (5.4)	21.5 (5.0)	11.0 (2.2)	12.5 (2.0)
Mucor hiemalis	15.5 (3.6)	-	-	-	-	17.5 (4.0)	11.0 (2.2)	25.0 (4.0)
Mucor mucedo	10.5 (2.4)	-	-	-	-	-	-	-
Mucor racemosus	-	28.5 (6.3)	8.5 (2.2)	33.5 (9.8)	25.0 (6.6)	-	-	-
Penicillium brevicompactum	-	-	-	-	-	21.5 (5.0)	22.0 (4.4)	12.5 (2.0)
Penicillium chrysogenum	15.5 (3.6)	14.0 (3.1)	8.5 (2.2)	14.5 (4.3)	25.0 (6.6)	17.5 (4.0)	22.0 (4.4)	18.5 (3.0)
Penicillium fellutanum	26.5 (6.1)	19.0 (4.3)	8.5 (2.2)	-	-	-	-	-
Phoma sp.	-	-	12.5 (3.2)	15.0 (4.5)	16.5 (4.4)	-	-	-
Trichoderma viride	16.0 (3.8)	-	25.0 (6.5)	-	-	-	22.0 (4.4)	13.0 (2.3)
Sterile	16.5 (3.8)	-	12.5 (3.2)	-	17.0 (4.6)	9.0 (2.2)	12.0 (2.3)	-

Table : 1.17. Temporal variation in the population of fungal species per gram dry soil x 10^2 in valley land field soils at 20-30 cm depth for the period of 10 September, 1985 to 20 November, 1985. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus flavus	-	-	10.5 (2.5)	-	-	-	-	-
Aspergillus niger	-	-	-	-	-	-	-	-
Fusarium poae	23.5 (3.5)	19.9 (4.0)	5.2 (1.2)	-	47.3 (11.4)	-	-	-
Fusarium solani	-	-	5.2 (1.2)	-	-	-	-	-
Monilia sp.	-	-	5.2 (1.2)	-	-	-	-	-
Mucor circenelloides	-	-	-	-	-	-	-	29.4 (6.1)
Mucor hiemalis	-	-	-	-	26.3 (6.3)	-	-	-
Mucor plumbeus	-	19.9 (4.0)	15.7 (3.7)	18.1 (4.9)	-	-	27.2 (3.4)	-
Mucor racemosus	23.0 (3.5)	26.6 (5.3)	26.3 (6.2)	22.7 (6.0)	-	21.4 (3.5)	27.2 (3.4)	-
Penicillium chrysogenum	38.4 (5.8)	19.9 (4.0)	15.7 (3.7)	18.1 (4.8)	26.3 (6.3)	28.5 (4.6)	27.2 (3.4)	-
Trichoderma viride	15.3 (2.3)	-	10.5 (2.5)	22.7 (6.0)	-	-	18.1 (2.2)	-
Sterile	-	13.3 (2.6)	5.2 (1.2)	9.0 (5.4)	-	49.9 (8.1)	9.0 (1.1)	47.0 (9.8)

Table : 1.18. Temporal variation in the population of fungal species per gram dry soil x 10^2 in valley land field soils at 20-30 cm depth for the period of 10 September, 1986 to 20 November, 1986. Values in parentheses are percentage relative dominance.

Fungal species	September			October			November	
	10	20	30	10	20	30	10	20
Aspergillus alutaceus	7.5 (1.2)	-	-	-	-	-	-	-
Aspergillus flavus	-	5.5 (1.0)	10.0 (2.2)	5.0 (1.0)	17.5 (3.2)	12.5 (2.1)	-	-
Aspergillus niger	-	-	-	5.0 (1.0)	-	-	-	-
Fusarium oxysporum	15.5 (2.5)	16.5 (3.2)	-	-	-	-	-	-
Mortierella minutissima	-	-	-	-	17.5 (3.2)	12.5 (2.1)	-	-
Mucor hiemalis	15.5 (2.5)	-	-	-	-	-	18.5 (3.3)	12.5 (2.0)
Mucor mucedo	15.5 (2.5)	-	-	-	-	-	-	6.0 (1.0)
Mucor racemosus	-	27.5 (5.3)	20.0 (4.4)	45.0 (9.8)	17.5 (3.2)	18.5 (3.2)	6.0 (1.1)	12.5 (2.0)
Penicillium chrysogenum	-	-	15.0 (3.3)	10.0 (2.1)	17.5 (3.2)	25.0 (3.3)	12.5 (2.2)	-
Penicillium fellutanum	15.5 (2.5)	16.5 (3.2)	20.0 (4.4)	-	-	-	-	-
Penicillium funiculata	-	5.5 (1.0)	-	-	-	-	-	-
Phoma sp.	-	-	10.0 (2.2)	-	-	-	-	-
Trichoderma harzianum	15.5 (2.5)	-	-	-	-	-	18.5 (3.3)	25.0 (4.1)
Trichoderma viride	15.0 (2.3)	16.5 (3.2)	15.0 (3.2)	15.0 (3.2)	17.5 (3.2)	12.5 (2.1)	25.0 (4.4)	12.5 (2.0)
Sterile	-	11.0 (2.1)	10.0 (2.2)	20.0 (4.3)	12.5 (2.5)	19.0 (3.3)	18.5 (3.3)	6.5 (1.0)

Table 1.19. Simple correlation coefficient (r) values among various soil characteristic parameters of valley land potato field.

	F	B	D	U	Pe	Co_2
T	0.54***	0.47***	N.S.	N.S.	0.30*	0.70***
Mc	N.S.	N.S.	N.S.	N.S.	0.28*	0.31*
pH	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C	N.S.	N.S.	0.573**	0.49***	0.52***	N.S.
N	0.79***	0.72***	0.51***	0.34*	0.44*	0.65***
Ph	0.75***	0.74***	0.29*	N.S.	0.62***	0.68***
K	N.S.	N.S.	0.52***	0.34*	N.S.	N.S.
F	x	0.69***	0.33*	0.29*	0.57***	0.77***
B	x	x	0.34*	0.37**	0.46***	0.58***
D	x	x	x	0.66***	0.36*	N.S..
U	x	x	x	x	0.35*	N.S.
Pe	x	x	x	x	x	N.S.

*, **, *** Significant at 0.05, 0.01 and 0.001 P respectively.

T = Temperature, Mc = moisture content, C = organic carboh, N = nitrogen, Ph = phosphorus, K = potassium, F = fungal population, B = bacterial population, D = dehydrogenase, U = Urease, Pe = Phosphatase, Co_2 = carbon dioxide, N.S. = not significant.

Table 1.20. Simple correlation co-efficient (r) values among various soil characteristics parameters of Terrace land soil.

	F	B	D	U	Pe	Co_2
T	0.35*	N.S.	N.S.	N.S.	0.66***	0.55***
Mc	N.S.	N.S.	N.S.	N.S.	0.43**	0.29*
pH	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C	0.43**	N.S.	0.53***	N.S.	0.52***	0.44**
N	0.83***	N.S.	0.30**	0.40**	0.48***	0.80***
Ph	0.78***	N.S.	0.62***	0.66***	0.52***	0.72***
K	0.44**	N.S.	0.59***	0.47***	0.35*	0.28*
F	X	N.S.	0.40**	0.52**	0.28*	0.81***
B	X	X	N.S.	N.S.	0.29*	N.S.
D	X	X	X	0.56***	0.58***	0.36*
U	X	X	X	X	N.S.	0.34*
Pe	X	X	X	X	X	0.38**

*, **, *** Significant at 0.05, 0.01 and 0.001 P respectively

T = Temperature, Mc = moisture content, C = organic carbon,

N = nitrogen, Ph = phosphorus, K = potassium, F = fungal population,

B = Bacterial population, D = dehydrogenase, U = Urease,

Pe= prosphatase, Co_2 = carbon dioxide, N.S. = not significant.

Table 1.21. Simple correlation co-efficient (r) values among various characteristic parameters of slope land potato field.

	F	B	D	U	Pe	Co_2
T	N.S.	0.75**	N.S.	N.S.	0.28*	0.49***
Mc	0.49***	N.S.	N.S.	N.S.	0.59***	0.45***
pH	0.30*	N.S.	N.S.	N.S.	0.33*	N.S.
C	0.28*	N.S.	N.S.	N.S.	0.31*	N.S.
N	0.55***	0.85***	N.S.	0.57***	0.51***	0.63***
Ph	0.56***	0.82***	N.S.	0.78***	0.59***	0.58***
K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
F	X	N.S.	0.32*	0.41**	0.71***	0.86***
B	X	X	N.S.	0.64***	0.63***	0.72***
D	X	X	X	N.S.	0.28*	N.S.
U	X	X	X	X	0.42**	0.36**
Pe	X	X	X	X	X	0.77***

*, **, *** Significant at 0.05, 0.01 and 0.001 P respectively

T = Temperature, Mc = moisture content, C = organic carbon, N = nitrogen, Ph = phosphorus, K = potassium, F = fungal population, B = bacterial population, D = dehydrogenase, U = Urease, Pe = phosphatase, Co_2 = carbon dioxide, N.S. = not significant.

Table : 1.22. Comparison of soil fungi using model of Sorenson for similarity index at different depths and in different field soils.

Valley land	Terrace land	Slope land
$Depth_1$ x $Depth_2$ = 68%	$Depth_1$ x $Depth_2$ = 77%	$Depth_1$ x $Depth_2$ =84%
$Depth_1$ x $Depth_3$ = 64%	$Depth_1$ x $Depth_3$ = 78%	$Depth_1$ x $Depth_3$ =91%
$Depth_2$ x $Depth_3$ = 78%	$Depth_2$ x $Depth_3$ = 78%	$Depth_2$ x $Depth_3$ =68%

$Depth_1$	$Depth_2$	$Depth_3$
VL x TL = 68%	VL x TL = 55%	VL x TL =75%
TL x SL = 70%	TL x SL = 70%	TL x SL =71%
VL x SL = 66%	VL x SL = 65%	VL x SL =61%

VL x TL = 93%	Potato field vs. Rice field[1] = 61%
TL x SL = 71%	Potato field vs. Maize field[2] =56%
VL x SL = 67%	

$Depth_1$ = 0-10 cm, $Depth_2$ = 10-20cm, $Depth_3$ = 20-30cm
VL = valley land, TL = terrace land, SL = slope land.
[1]Baruah(1983), [2]Dkhar(1983), Sorenson(1948).

and in hill slope land soil it ranged from 36.3 to 91 mg CO_2/g dry soil per 24 h. The peak of CO_2 evolution was noted in the month of October in all the three agricultural systems. In 1985, on 20th November, the CO_2 evolution suddenly increased while the same was not observed in the year 1986. Surface soil (0-10 cm) showed higher CO_2 evolution as compared to the deeper layers of the soils. In general, the trend of temporal variation was similar in all the three field soils. In valley land soil the CO_2 evolution was significantly correlated with soil temperature, moisture content, nitrogen, phosphorus, fungal population and bacterial population. In terrace land soil it correlated with soil temperature, moisture content, organic carbon, nitrogen, phosphorus, potassium, fungal population, dehydrogenase activity, urease activity and phosphatase activity. In hill slope land soil it correlated with soil temperature, moisture content, nitrogen, phosphorus, fungal population, bacterial population, urease activity and phosphatase activity.

DISCUSSION

The three types of potato fields differ markedly with respect to soil moisture status (Fig.1.2). The slope land soil generally contains less moisture mainly because of heavy run off losses allowing little percolation of water; next comes the terrace land where some moisture is retained due to the terracing and bands; the valley land

contains maximum moisture due to constant seepage from the adjoining hillocks and less evapotranspiration losses. Thus, moisture is one of the most important single factor that is responsible for the differences in soil characteristics of the three systems. As a result of run off losses and nutrient input from the adjoining hillocks, the valley land fields, generally, contain higher level of organic C,N,P,K, Ca and Mg. Another important feature of the valley land field is that it receives minimum amount of solar radiations, as part of it is intercepted by the adjoining hillocks and therefore, the soil temperature of valley land fields is generally lower by 2-3°C. Fig.1.1 shows that maximum fungal and bacterial population was recorded in surface layer soil in all the three agricultural systems. The fungal and bacterial population of soil decreased with increase in depth. The decrease in microbial population along depth can be attributed to the less amount of nutrients, low oxygen concentration and increase in concentration of CO_2 in deeper soils. The drop in fungal population in lower depth could also be attributed to the high moisture content of the deeper soils resulting into reduced aeration of soil (Dastane et al. 1965). Waid (1960) found that there is great reduction in the active growth of fungi when the moisture content is sufficiently high which reduces aeration. Griffin (1963) is of the opinion that actual volume of water, taken as a factor in itself, has no marked effect on fun-

gal ecology and the growth of fungi is dependent upon moisture content, presumably, acting through an aeration effect. Surface soil is usually provided with high organic matter content which in presence of adequate moisture supply is acted upon by a team of microorganisms to decompose the complex organic residue into simpler forms, hence the microorganisms are higher on upper layer of the soil (Dwivedi, 1966; Eicker, 1970; Mishra and Kanaujia, 1972; Acea and Carballas, 1986). Generally, total microbial population was highest in the month of October at the middle age of plants and lowest in November. In October, high population may be due to favourable factors (N,P,K) and also due to possible increase in the root exudation (Rovira, 1956). The root exudates contain sugars and amino acids which may be used by the microbes as a food or energy source. Lowest population in the month of November might be due to low temperature and low moisture content of the soils (Fig.1.2). In general, highest population was in valley land soil followed by terrace land and hill slope land soil. Bacterial population was maximum in terrace land soil followed by valley land and hill slope soil. Maximum concentration of nitrogen, organic carbon, phosphorus and potassium was in valley land followed by terrace land and hill slope land soils. The maximum fungal population in valley land might be due to high concentration of these elements. Higher bacterial population in terrace land might be due to bet-

ter aeration. Hill slope land soil was poor in nutrients and had less moisture content probably that may be reason why it harboured less fungal and bacterial population. According to Upadhyay and Rai (1979) higher fertility and aeration of soil favoured a broad spectrum of fungal genera and species. Certain fungi are characteristics of a particular type of soil. Species of Mucor, Penicillium and Trichoderma seem to be tolerant to a wider range of environmental conditions as they were recorded from all the three different agricultural soils. Dwivedi (1966) reported Mucor, Penicillium and Trichoderma as the most dominant fungi from grassland soil. Gujrati (1966) and Moubasher and Dohlib (1970) found that Aspergillus, Penicillium, Fusarium and Curvularia were the dominant fungi in cultivated soil. Mishra and Kanaujia (1973) isolated more diverse microflora from cultivated soil as compared to grassland and forest soil and they found that Mucor hiemalis, Aspergillus flavus, A. niger, Penicillium chrysogenum and Cladosporium herbarum were most dominant fungi. Penicillium, Fusarium and Trichoderma were also dominant fungi in maize field soils of this region (Dkhar, 1983). While Pythium, Mucor, Geotrichum, Penicillium and Trichoderma were dominant fungi in rice field soils of Shillong (Baruah, 1983). The species of Mucor were prevalent in the soil of all the three fields; this result is similar to the work of Herman and Kucera (1979). Similarly, index of the fungal communities of different fields

at different depths is given in table 1.22. In valley land fungal species composition of depth 1 (0-10 cm) was similar to depth 2 (10-20 cm) and depth 2 was similar to depth 3 (20-30 cm) while depth 1 was less similar to depth 3. In terrace land there was no marked difference in fungal species composition of the three depth soils. In hill slope land soil depth 1 was more similar to depth 3 as compared to depth 2. When the fungal community of depth 1 of the three agricultural system was compared using Sorenson's Index of Similarity (Sorenson, 1948) it was found that at the depth 1 similarity index among three fields varied between 66 and 70, while at depth 2 it varied between 50 and 70, and in depth 3 it varied from 61 to 75. When the three fields were compared using data of all the three depths, it was noted that species composition of the valley land was more similar to terrace land differed markedly from hill slope land soils. Fungal species composition of potato fields was more similar to the rice field soils (61%) of the same locality (Baruah 1983) as compared to the maize field soils of the same locality (Dkhar, 1983). Taking similarity index of the fungal community as an index of homogeneity of habitat (Clark and Christensen, 1981), it may be suggested that soil upto a depth of 30 cm was almost homogenous. However, the same does not hold good when we look at the population of fungi and bacteria (Fig.1.8,1.9) and other soil characteristics (C,N,P,K). It appears that

during ploughing or digging the soil is mixed thus the fungal species are distributed almost uniformly upto the depth studied. Also, it may be inferred that most species were capable of colonising the soil upto 30 cm depth.

Dehydrogenase has been used as a general indicator of microbial activity (Stevenson, 1959; Skujin, 1967, 1976; Casida, 1977; Ladd, 1978). Dehydrogenase activity in soil reflects the metabolic rate rather than the microbial numbers (Casida et al. 1964). Generally, dehydrogenase followed a pattern valley land > terrace land > slope land which was in accordance with the more or less similar pattern in the organic carbon and bacteria and fungi population. This suggests that possibly these factors individually or in combination regulate the dehydrogenase activity. Correlation coefficient values between dehydrogenase and these factors were significant in certain cases (In valley land with organic C,N,P, fungal population, bacterial population urease and phosphatase activity; in terrace land with organic C,N,P,K, fungal population, urease activity, phosphatase activity and CO_2 evolution; In hill slope land with fungal population and phosphatase activity) while in others it was not significant. The depth wise variation in the dehydrogenase activity was also, probably, governed by the same set of factors, as the activity followed the pattern 0-10 cm depth > 10-20 cm depth > 20-30 cm depth which was similar in the cases of organic carbon, bacteria and fungal

population. Thus it is inferred that the dehydrogenase activity is a organic carbon and microbial population dependent parameter (Kuprevich and Shenerbakova, 1971). In soil, dehydrogenase activity has been reported to decrease with depth, thereby being related to the concentration of organic matter (Ross, 1973). In the present study the dehydrogenase activity is correlated positively with fungal population in all the three agricultural systems while bacteria is correlated with dehydrogenase only in the valley land soil (Table 1.19). It suggests that probably fungi are more important contributor to the dehydrogenase activity in these soils. Bacteria receive prominence in high moisture soils (valley land) where the fungi probably becomes less important as reduction in aeration due to high moisture content may result into a drop in respiratory activity of the fungi which are predominantly aerobic. On the other hand bacteria being capable of facultative anaerobic and anaerobic respiration, can thrive even in reduced aeration. It is inferred that relationship may be modified by other physico-chemical characters of the soil (Table 1.19,1.20, 1.21). Possibly this is the reason why a number of contradictory reports are available on the relationship of dehydrogenase with microbial numbers (Frankenberger and Dick, 1983; Ross, 1971).

Urease is an agriculturally important enzyme which

might limit the nitrogen availability to plants from fertilizers or natural sources. The data revealed that valley land and terrace land soil had higher urease activity whereas it was less in the case of slope land soil. In planted soil continued addition of enzymes could be expected from plant roots (Skujin, 1967; Hall and Davie, 1971) and from associated microorganisms (Paulson and Kurtz, 1969; Speir, 1976; Ross, 1977; Speir and Ross, 1976, 1978). It is likely that supplementation from these sources accounted for the increase in urease activity during the middle age of the plants i.e. in the month of October. Speir (1977) and Baruah and Mishra (1984) also found higher urease activity during the periods of plant growth. Nitrogen and fungal population correlated with the urease activity in all the three agricultural systems while organic carbon, potassium, phosphorus, bacterial population and soil respiration correlated in one or two fields only. Studies on the relationship between urease activity and other soil properties have indicated that the urease activity tend to increase with organic carbon content. Gould et al. (1973) observed a significant positive correlation between urease activity and organic carbon in profile samples of an Alberta soil. Beri et al. (1978) found that soil urease activity is largely controlled by the organic carbon status of soils. Zantua et al. (1977) and Tobatabai (1977) also showed that urease activity was significantly correlated with organic carbon. Das

et al (1981) could establsh a positive correlation between urease activity organic C, N and P. Pancholy and Rice (1972) however reported that urease activity in surface soils was not significantly correlated with organic carbon and concluded that the level of urease in the soils was determined by the type of vegetation. Frankenberger and Dick (1983) found that urease activity highly correlated with various soil properties viz., organic C and total N. The relationship between urease activity and soil properties supports McLaren's (1975) proposal that urease can exist as an extracellular enzyme in a "three dimensional network or organo-mineral complexes". In the present study, urease showed a positive correlation with microbial population CO_2 evolution (Table 1.19,1.20,1.21); while Alexander (1977) noted that urease activity compared poorly with respiration rate. Other factors affecting the urease activity in soils are temperature (Pettit et al. 1976; Vontolsky and Klunker, 1967), pH (Delaune and Patrick, 1970; Kistaikowski and Shaw, 1953) and soil moisture (Sankhayan and Shukla, 1976). However, in the present study temperature, pH and soil moisture did not show statistically significant correlation with the urease activity.

Roots and microorganisms are major sources of phosphatase in soil (Glolebiewska, 1956; Esterman and McLaren, 1961; Greaves and Webley, 1969). Dick et al. (1983) men-

tioned the degradation of the enzyme by the action free protease produced by the soil microflora which may inhibit the phosphatase activity. Thus, microorganisms are involved in the production of phosphatases as well as in the distribution of it and the net activity is a function of the two contrary processes. Phosphatase activity in all the three agricultural systems decreased with increasing depth. The interaction with depth in soil profile may be explained by the differential distribution of root in soil which is a major source of phosphatase (Esterman and McLaren, 1961; Greaves and Webley, 1969). The concentration of microbial population was much higher in 0-10 cm horizon and microbial population and activities decreased with depth in soil profile(Parkinson et al. 1968; Acea and Carballas, 1985) which might be responsible for the similar variation in phosphatase activity. Maximum activity in all the three fields was recorded in the month of October. It might be due to the high fungal and bacterial population recorded at the same period. In general, phosphatase was highest in valley land soil followed by terrace land and hill slope land soil. The higher mineral contents in valley land soil probably stimulated the fungal and bacterial population which in turn may be responsible for the higher phosphatase activity. Phosphatase activity in all the three agricultural systems did not correlate with different soil characteristics in similar

fashion. In valley land soil it significantly correlated with soil temperature, moisture content, organic carbon, nitrogen, phosphorus, fungal population, bacterial population, dehydrogenase activity and urease activity. In terrace land it correlated with soil temperature organic carbon, nitrogen, phosphorus, potassium, fungal population, dehydrogenase activity and CO_2 evolution. In hill slope land soil it correlated with soil temperature, moisture content, soil pH, organic carbon, nitrogen, phosphorus, fungal population, bacterial population, dehydrogenase activity, urease activity and CO_2 evolution. In comparison, to dehydrogenase and urease activity, the phosphatase activity was found more correlated with the physico-chemical characteristics of soil, microbial number and its activity (Table 1.19,1.20,1.21). Khan (1970) reported that addition of organic matter stimulated phosphatase activity and it is reported that phosphatase correlates significantly with organic carbon content of soil (Speir, 1977; Nohrstedt, 1985). The correlation of phosphatase activity with organic carbon, nitrogen, phosphorus and pH was reported by Schlesinger (1977). The positive relationship with organic matter content is probably associated with the fact that phosphatase, like other enzymes become bound in humo-protein complexes (Ladd and Butler, 1975; McLaren, 1975) which possibly protects the enzymes from decomposition. Organic matter is also a source or nutrients for microorganisms and as the

organic matter content in soil increases so does the potential nutrient may be that mineralizable nitrogen and total nitrogen content of soil are often inter-correlated and increasing nitrogen supply increase microbial synthesis of phosphatase (Speir and McGill, 1979). Ramirez-Martirez and McLaren (1966) could not get any relationship of phosphatase with the respiration rate. However, in the present study the soil respiration was found to be positively related with the phosphatase activity in two agricultural systems.

Respiration rate is the most widely used index of soil microbial activity (Chaney et al. 1978). It is often preferred over microbial numbers. Respiration activity is influenced by microbial count, organic carbon and inorganic nutrient contents (Stroo and Jencks, 1982; Jorgensen and Wells, 1973). Maximum respiration activity was recorded in upper soil and as depth increased the respiration activity decreased which was similar to the microbial population and urease, dehydrogenase and phosphatase activities. It appears that CO_2 evolution was also governed by the same or similar set of physico-chemical and biological factors. This was contrary to the observation of Ross (1975) who noted that each biochemical activity has its own characteristic distribution in soil. Minimum CO_2 evolution was found from the hill slope land soil as compared to valley land and terrace

land soil, which was again similar to the microbial population and other activity estimate parameters. The data showed that CO_2 evolution from soil is more related to the fungal population than bacterial population (Table 1.19, 1.20,1.21). Some other workers have also reported similar observation of positive relation between fungal biomass and soil respiration (Stotzky, 1960; Tesavora and Gloson, 1976; Baruah and Mishra, 1981). Respiration was related to the other soil biochemical activities (dehydrogenase, urease, phosphatase) which may be because of common origin of the enzymes concerned or similar response to environmental and soil factors. Frankenberger and Dick (1983) found strong correlation between CO_2 evolution and enzyme, phosphatase, amidase, glucosidase and dehydrogenase. Ross et al. (1982) reported that all enzyme-activities (urease, phosphatase, xylanase, invertase and amylase) were correlated with CO_2 evolution. The organic-C was found to be the strongest predictor of CO_2 evolution from soil by Ross et al. (1982) and Stroo and Jencks (1982). However, in the present study the total nitrogen content of soil was more important factor determining the soil respiration rate than the organic carbon content (Table 1.19,1.20,1.21).

A perusal of results shows that the microbial population and activity followed a general trend : valley land > terrace land > slope land and in depth-wise distribution the pattern was 0-10 cm > 10-20 cm > 20-30 cm

Suggesting that organic C, inorganic nutrients and soil moisture were the most important factors regulating the microbial population as well as their activities measured in terms of dehydrogenase, urease, phosphatase activities and soil respiration.

CHAPTER-II

INFLUENCE OF FUNGICIDES AND HERBICIDES ON PHYLLOSPHERE MICROFLORA OF POTATO

INTRODUCTION

The occurrence and role of epiphytes in the phyllosphere of living plants have been the subject of several reviews (Sinha, 1965; Last and Deighton, 1965; Leben, 1965). The microflora of leaf surface has received ample attention and a number of generalization pertaining to the community structure of leaf surface microorganisms, their role as decomposer and in biological control of plant pathogens have emerged (Blakeman and Fokkema, 1981; Mishra and Dickinson, 1981,84; Preece and Dickinson, 1971; Dickinson and Preece, 1976; Baker and Cook, 1974; Mishra and Tiwari, 1976). Leaf surface microflora of potato has been investigated by Holloman (1967), Sinha (1971) and Kumar and Gupta (1976). The effects of fungicides on leaf surface microflora has also been studied by Bainbridge and Dickinson (1972). Studies on the effect of herbicides on plant diseases reported that depending on the chemical composition and time of application, the herbicides may be stimulatory or inhibitory to the pathogens (Altman and Campbell, 1977; Hodges, 1981,82). Application of fungicides affects the quantity and type of leaf exudates (Mulinge and Griffiths, 1974; Warren, 1974; Dickinson and Wallace, 1976). In addition, fungicides disturb the natural equilibrium of microbial community by partial destruction of microflora (Hislop and Cox, 1969; Dickinson, 1973; Jhooty and Munshi, 1976; Kuthubutheen and

Pugh, 1978, Mishra and Tiwari, 1979).

The climate and soil of high altitude region of Meghalaya are very favourable for the cultivation of potato and large area of the region is under this crop. Late blight and early blight diseases take heavy toll of the crop productivity. Farmers have started using fungicides during recent years. A general survey has revealed that in most cases single spray of fungicides is applied to the crops and fungicide treated plants also get infected by the pathogen resulting in death of the plants before maturity of the crop. However, in such cases the infection is delayed to some extent and therefore, yield is higher than non-fungicides treated crops.

Our knowledge on the effect of fungicides application on phyllosphere microflora of potato is based on the studies conducted in Europe and elsewhere (Bainbridge and Dickinson, 1972) which may not hold good in cool, humid climate of higher altitudes of Meghalaya (India). No attempt has so far been made to study the effect of herbicide on the leaf surface microflora in general and potato in particular. In this context it was was thought desirable to study the effect of fungicides and herbicides on the leaf surface microflora of potato.

REVIEW OF LITERATURE

The terms phylloplane and phyllosphere have been used imprecisely with different meaning or as synonyms to designate the leaf as a particular habitat (Last, 1955; Ruinen, 1956). The living leaf may be colonized by parasites and saprophytes. Examination of living leaves for the colonizers of early stage of microflora succession has been carried out by Kendrick and Burges (1962) and Hogg and Hudson (1966). Hislop and Cox (1969) found that fungicides reduced the total number of fungi, bacteria and yeast on leaf surface of apple, however, when spraying was stopped the number and type of microorganisms returned to near normal within a few months. Wilkinson and Lucas (1969) reported that herbicide reduced the fungal population on leaf surfaces. They found that paraquat and MCPA inhibited the activity of Trichoderma viride, Rhizopus stolonifer and Penicillium notatum. Bainbridge and Dickinson (1972) reported that saprophytic fungi were more susceptible to fungicide captafol than to maneb+fantin acetate, however, bacterial numbers were apparently unaltered by the spray treatment. Norse (1972) found that fungicides inhibited the fungal population on tobacco leaves and most dominant fungi which accounted for 50-90% of the population were Alternaria sp., A. longipes, Cladosporium oxysporum, Epicoccum purpurascens and Phoma eupyrena. Warren (1974) evaluated the effect

of fungicides on phyllosphere fungi. He found that all fungicides reduced the microbial population, among which benomyl was most effective. Dickinson and Wallace (1976) examined the effect of late application of fungicides on winter wheat flag leaves. Repeated spray of tridemorph had only minor effect on the phylloplane population but benomyl and more particularly zineb inhibited the development of many yeast and fungi. Jhooty and Munshi (1976) found that fungicides resulted into decline in the microbial population from leaf surface. Kumar and Gupta (1976) isolated 60 microorganisms : 52 species of fungi, 20 actenomycetes and 6 bacteria from leaf surface of potato. They reported that older leaves were more densely populated as compared to younger ones. Dickinson and Donnel (1977) studied the growth behaviour of Cladosporium cladosporioides, Alternaria alternata and Sporobolomyces roseus on Phaseolus vulgaris leaves. They found best germination and growth under condition of very high humidity. Mcbride and Hayes (1977) observed bacteria, yeast and flamentous fungi inhabiting the phylloplane of European larch. On young leaves filamentous fungi were present only as spores, but hyphal development started abruptly and increased rapidly on old leaves. Cladosporium herbarum, Fusarium oxysporum, Acremonium sp., Epicoccum purpurascens, Penicillium sp. and Botrys cinera were frequently isolated from the leaf surface. Mishra and Tiwari (1979) studied the effect of two

fungicides captan and ziram and two antibiotics streptomycin and penicillin on microbial population of phyllosphere of wheat and barley. Bacterial population was less effected by fungicides while fungal population dropped by several degrees. Decrease in bacterial population was more pronounced in cases of antibiotics. Cladosporium spp. and Alternaria spp. were dominant on both wheat and barley in all the treated sets. Fitzell (1981) found that benomyl significantly reduced the population of Colletotrichum glocosporioides but did not eradicate the fungus from leaf surface. Mishra and Dickinson (1981,1984) studied the phylloplane and litter fungi of Ilex aquifolium. They reported that green leaves remain physiologically active for several years but there was no evidence for a progressive build up of phylloplane mycoflora. There were marked seasonal fluctuation in population on green leaves and the older leaves supported larger and more varied assemblage than newly formed leaves. Sharma and Tiwari (1981) recorded maximum species of fungi on diseased leaves whereas maximum yeast and bacteria were found on healthy leaves of Solanum khasianum, Cladosporium cladosporioides, Sporobolomyces roseus and Aureobasidium pullulans were the dominant fungi. Garg and Sharma (1983) studied phylloplane fungi of triticale and guar on adaxial and abaxial surface. Total fungal population was invariably higher on adaxial surfaces and

the dominant fungi was Alternaria alternata. Sharma et al. (1984) reported that micro-climatic factors viz., temperature and relative humidity affect the phyllosphere microflora. The population of microbes decreased with a simultaneous fall in temperature and an increase in relative humidity but later on a reverse trend was observed. Cabral (1985) opined that leaf surface fungal population is directly correlated with humidity and inversely with temperature. The microorganisms colonising the interior of the leaf exhibit more dependence on age and/or physiological condition of the leaf. Thomas and Shattock (1986) reported Cladosporium, Drechslera, Phoma epicoccum, Alternaria and Leptosphaeria as dominant fungi on phyllosphere of Lolium perenne.

MATERIALS AND METHODS

Disease free tubers of potato (variety - K.Jyoti) were procured from the Central Potato Research Station (CPRS), Shillong. The crop was sown in the last week of March, 30 M^2 plot was taken for each treatment and the control. The plots were randomized.The fungicides and herbicides recommended for potato and commonly used by growers of this region were used. The technical detail about fungicides and herbicides is given in Table 2.1.

Table 2.1. Fungicides and herbicides, their chemical names, recommended doses and manufacturers.

Commercial name (common name)	Chemical name	Recommended dose/hectare	Manufacturer
1. Dithane M.45 (Mancozeb)	Zinc ethylene bisdithiocarbamate	20 Kg	Indofil Chemicals
2. Blitox-50	Copper oxychloride 50%	7.4 KG	Rallis Agrochemical Research Station, Bangalore.
3. Benlate (Benomyl)	Mythyl 1-Butyl chlorabenzyl) -2-benzimidazole carbamate	0.37KG	E.I.DU PONT NE MOURS & Co.INC.,USA.
4. Benthiocarb (Saturn)	S-(4-chlorabenzyl)-N, N diethylthiol carbamate	3 lit	Pesticides India, Udaipur. Bangalore.
5. 2, 4-D (Weedon)	2,4-Dichlorophenoxy acetic acid	1.2lit	Agromore Limited,
6. Fluchloralin (Basalin)	N-Propyl-N(2' Chloroethyl) -2,6 dinitro-n-trifluoromethyl aniline	1.7lit	B.A.S.F. India limited, Bombay

Initial sampling for microbiological analysis was done 20 days after emergence of the plants and on the same day manufacturers' recommended doses of the fungicides and herbicides were sprayed. Subsequent samples were collected at 15 days interval. For each treatment five plants were collected from the field and five leaves of same vigour and age from each plant were used. To determine population of viable fungi and bacteria, leaf pieces were cut by a sharp sterilized cork borer of 5 mm diameter. 50 pieces were shaken in 250 ml conical flask containing 100 ml sterilized distilled water and serial dilutions were prepared. For enumeration of fungal propagules, 0.5 ml of appropriate dilution was inoculated on sterilized petriplates containing 20 ml of rose bengal agar medium (Martin, 1950). For bacterial population nutrient agar medium (Johnson and Curl, 1972) was used. Petriplates for fungi were incubated at 25°C for seven days and for bacteria at 30°C for 24 hours. The microbial population was calculated on the basis of per square cm. area of the leaf.

RESULTS

Fungicide :

It is evident from the fig.2.1 and 2.2 that foliar application of various fungicides affected the microflora of leaf surface at varying degrees. Mancozeb resulted into

instantaneous decrease in fungal population, benomyl did not affect the population initially and an increase in fungal population was noted during initial 15 days; a drop in fungal population was, however, recorded after 30 days. In case of copper oxychloride the population of fungi did not drop at any point of study. However, the rate of increment was slower than control and in this case least population was recorded at the end of experiment. Table 2.2 lists fungi isolated from leaf surfaces of fungicide treated and control plants. A comparison of the fungal flora of leaf surfaces of fungicides treated plants with that of control ones revealed that no marked change in the species composition was noticed. Mucor racemosus was isolated only from the phyllosphere of control plants while Acremoniella was found restricted to the fungicide sprayed leaves only. Penicillium chrysogenum and two sterile forms were common to all the treatments as well as control.

Herbicide :

An initial drop in fungal population was observed in most herbicide treated leaves, however, recovery was noted 15 days after the spray and thereafter the population increased with time (Fig.2.3 and 2.4). Herbicides treated leaves harboured lower population as compared to the control ones. The three herbicides marginally differed in their net effect on the population. In the case of benthiocarb the population did not decrease initially but the

Fig. 2.1. Bacterial population on phyllosphere of potato sprayed with fungicides.

Fig. 2·1

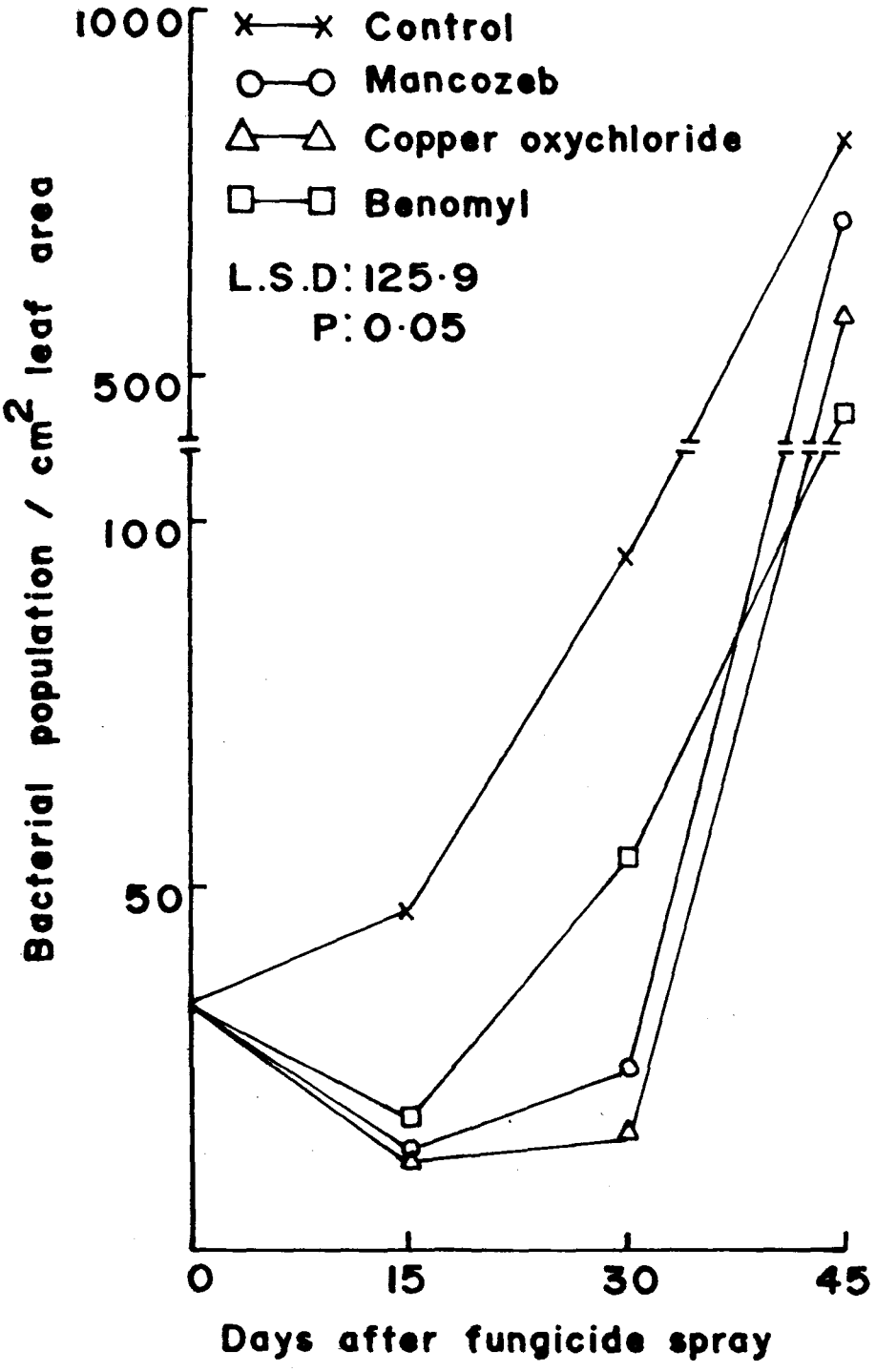

1000
500
100
50
Control
Mancozeb
Copper oxychloride
Benomyl
L.S.D: 125·9
P: 0·05
Bacterial population / cm² leaf area
0
15
30
45
Days after fungicide spray

Fig. 2.2. Fungal population onpphyllosphere of potato sprayed with fungicides.

Fig. 2·2

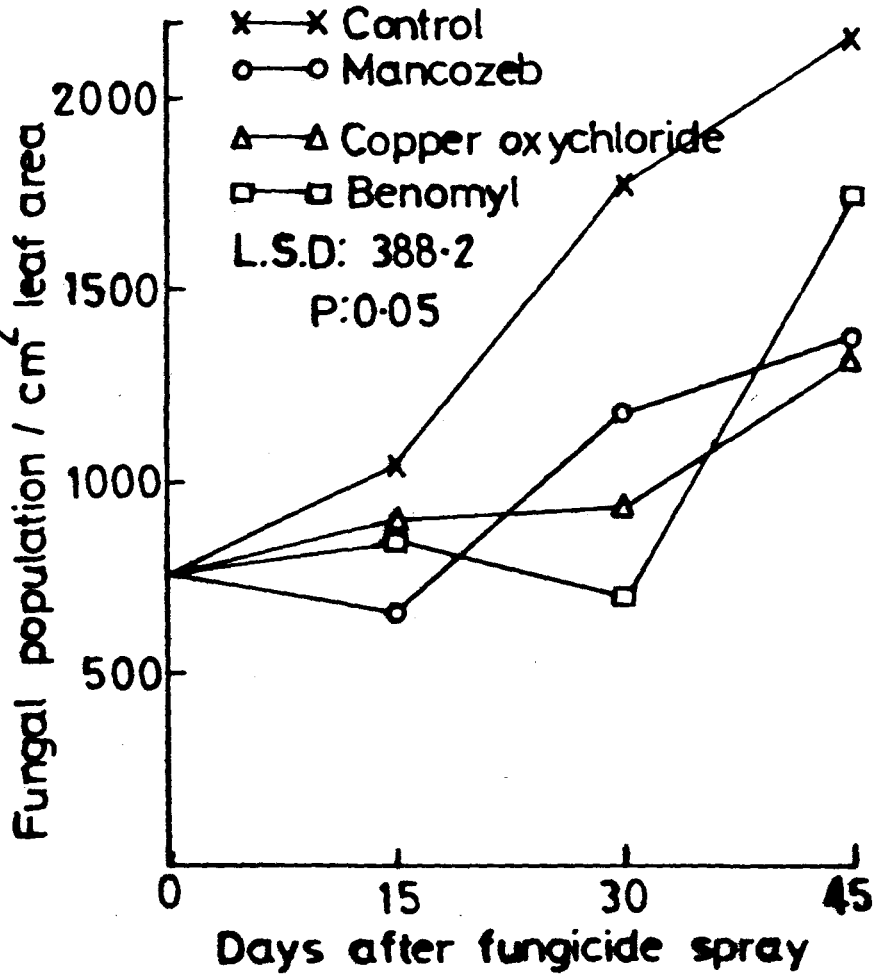

Control
Mancozeb
Copper oxychloride
Benomyl
L.S.D: 388·2
P:0·05
Fungal population / cm² leaf area
2000
1500
1000
500
0
15
30
45
Days after fungicide spray

Fig. 2.3. Bacterial population on phyllosphere of potato sprayed with herbicides.

Fig. 2·3

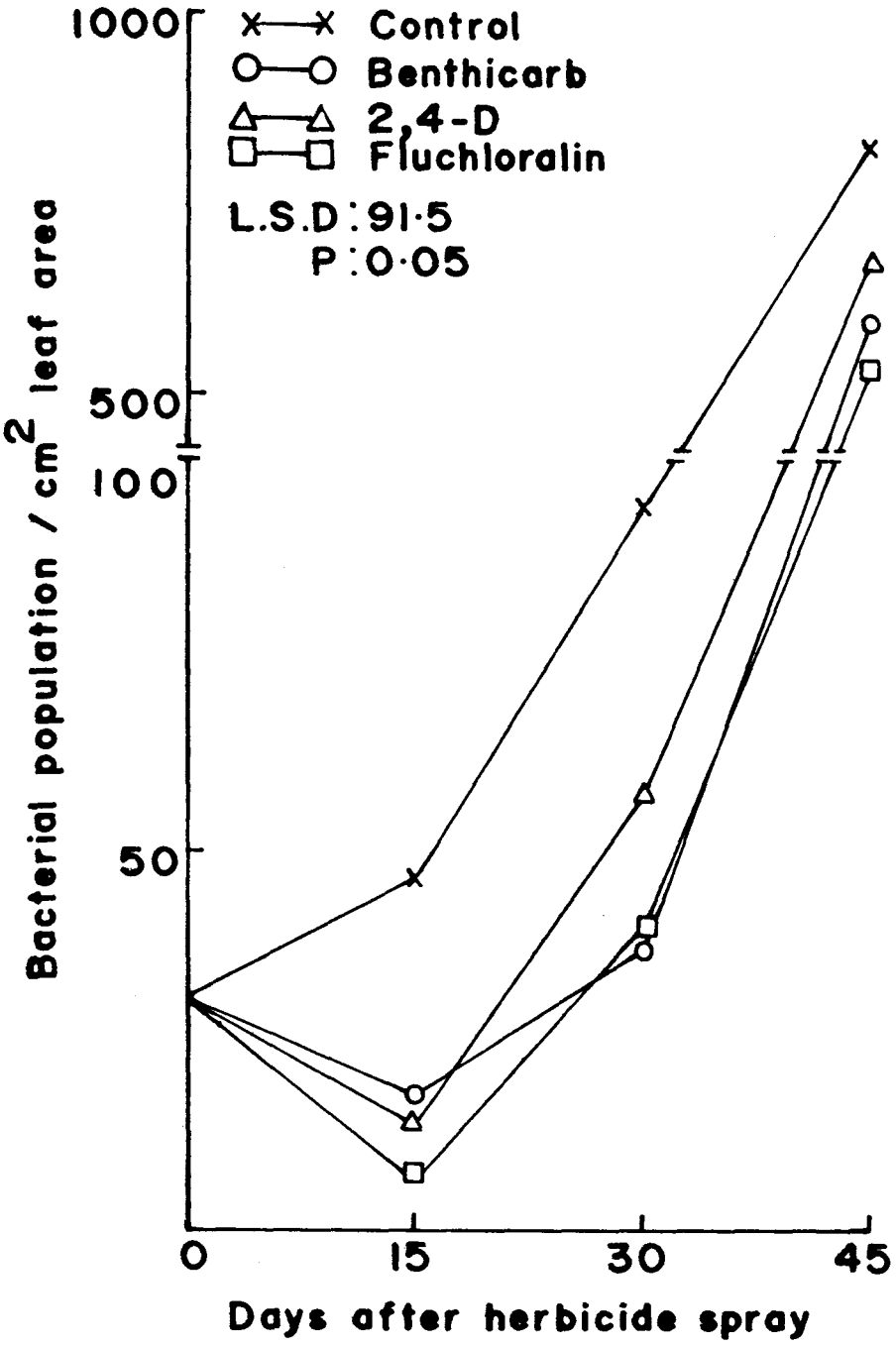

1000
500
100
50
Control
Benthicarb
2,4-D
Fluchloralin
L.S.D : 91·5
P : 0·05
Bacterial population / cm² leaf area
0
15
30
45
Days after herbicide spray

Fig. 2.4. Fungal population on phyllosphere of potato sprayed with herbicides.

Fig. 2·4

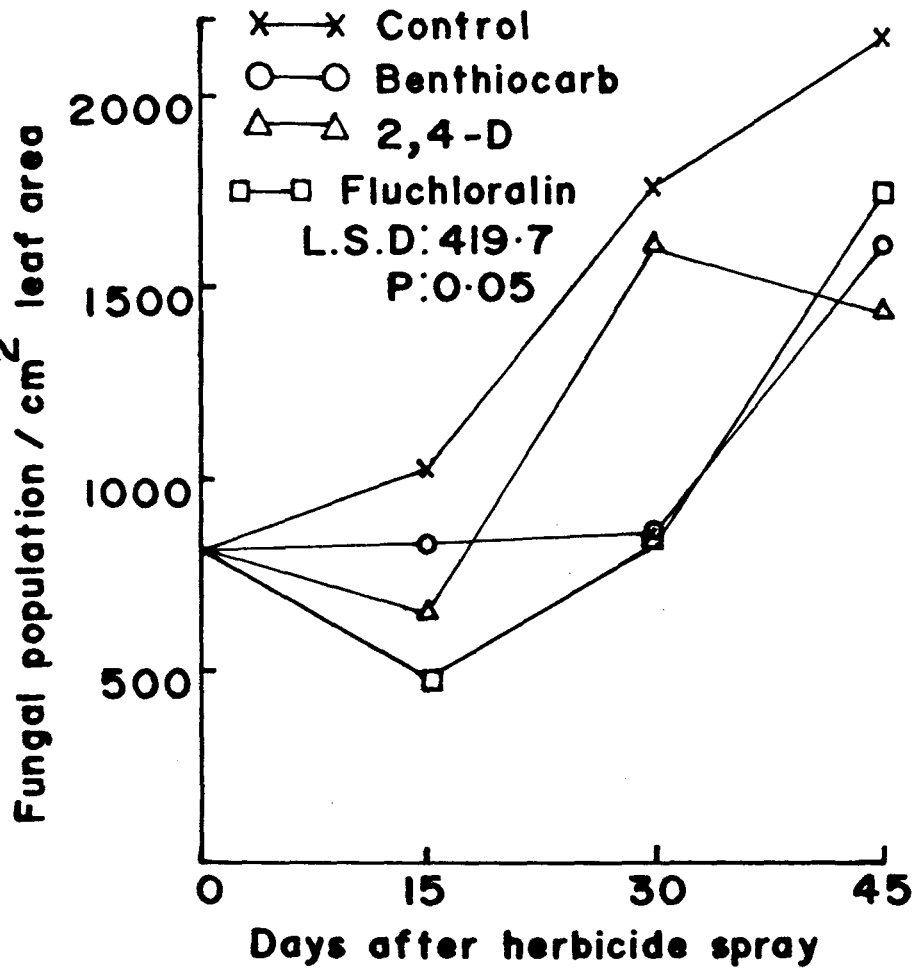

Control
Benthiocarb
2,4-D
Fluchloralin
L.S.D: 419·7
P: 0·05
2000
1500
1000
500
Fungal population / cm² leaf area
0
15
30
45
Days after herbicide spray

Table 2.2. Percentage abundance and number of propagules of fungi at 0,15,30 and 45 days after treatment with fungicides. Upper values are percentage abundance and values in brackets are number of propagules per unit area of leaf.

Name of fungi	Control				Benomyl			Copper oxychloride			Mancozeb		
	0	15	30	45	15	30	45	15	30	45	15	30	45
Acremoniella sp.	-	10	24		38 (305)	29 (204)	-	-	44 (407)	-	-	36 (407)	-
Alternaria alternata	-	10 (102)	24 (408)	14 (306)	-	-	12 (204)	-	-	-	16 (101)	9 (10)	-
Arthrobotrys arthrobotryoides	-	-	-	28 (494)	-	-	29 (509)	-	-	31 (407)	-	-	-
Cladosporium cladosporioides	34 (255)	20 (204)	15 (262)	23 (494)	-	-	-	13 (102)	-	-	-	9 (101)	23 (305)
Fusarium oxysporum	-	10 (102)	-	-	-	-	-	13 (102)	-	-	33 (204)	-	-
Mucor hiemalis	13	10	-	-	-	-	-	-	-	-	33 (204)	-	-
M. racemosus	10 (76)	10 (102)	-	-	-	-	-	-	-	-	-	-	-
Penicillium brevicompactum	-	10 (102)	5 (97)	-	-	-	-	25 (204)	-	23 (305)	-	-	30 (408)
P. chrysogenum	-	20 (204)	10 (175)	14 (306)	13 (101)	14 (101)	18 (305)	-	-	-	-	-	-
Rhizopus oryzae	10 (76)	-	-	-	13 (101)	-	-	-	-	-	-	-	-
Trichoderma sp.	-	-	-	-	-	-	-	13 (102)	-	-	-	-	-
Sterile green	22 (165)	10 (102)	41 (713)	18 (387)	19 (152)	29 (204)	38 (305)	22 (203)	-	-	16 (101)	45 (509)	46 (611)
Sterile white	11 (80)	-	5 (87)	8 (172)	19 (152)	29 (204)	41 (713)	-	33 (306)	46 (611)	-	-	-

*Percentage abundance = $\frac{\text{No. of colonies of the fungi} \times 100}{\text{Total no. of colonies of all fungi}}$

Table 2.3. Percentage abundance* and number of propagules of fungi at 0, 15, 30 and 45 days after treatment with herbicides. Upper values are percentage abundance and values in brackets are number of propagules per unit area of leaf.

Name of fungi	Control				Benthiocarb			2,4-D			Fluchloralin		
	0	15	35	45	15	30	45	15	30	45	15	30	45
Alternaria alternata	-	10 (102)	24 (408)	14 (306)	-	-	-	-	-	7 (102)	-	-	6 (102)
Arthrobotrys arthrobotryoides	-	-	-	23 (494)	-	-	31 (1529)	-	6 (100)	-	-	-	24 (408)
Cladosporium cladosporioides	34 (255)	20 (204)	15 (262)	23 (494)	-	-	-	23 (204)	-	35 (500)	-	25 (204)	-
Fusarium oxysporum	-	10 (102)	-	-	-	-	-	-	-	-	-	-	-
Mucor hiemalis	13 (98)	10 (102)	-	-	-	-	-	-	-	-	60 (306)	13 (102)	
Mucor racemosus	10 (76)	10 (102)	-	-	50 (408)	-	-	-	-	-	-	-	-
Oidiodendron echinulatum	-	-	-	-	-	13 (102)	-	-	13 (207)	-	-	13 (102)	-
Penicillium brevicompactum	-	10 (102)	5 (97)	-	-	-	-	-	-	-	-	-	-
Penicillium chrysogenum	-	20 (204)	10 (175)	14 (306)	-	13 (102)	-	33 (204)	-	29 (408)	-	-	24 (408)
Rhizopus oryzae	10 (76)	-	-	-	-	-	-	-	-	-	-	-	-
Rhizopus stolonifer	7 (54)	-	-	-	-	-	-	-	-	-	-	-	-
Sterile green	22 (165)	10 (102)	41 (713)	18 (387)	25 (204)	25 (204)	31 (1528)	-	43 (712)	28 (406)	40 (204)	30 (245)	12 (175)
Sterile white	4 (30)	-	8 (87)	28 (172)	29 (204)	38 (408)	38 (1630)	34 (207)	38 (611)	1 (14.5)	-	19 (155)	34 (589)

*Percentage abundance = $\frac{\text{No. of colonies of the fungi} \times 100}{\text{Total No. of colonies of all fungi}}$

increase was averted and population remained almost at the same level upto a period of 30 days after the spray. It appears the effect of benthiocarb was persistent for a longer period.

Table 2.3 lists the fungal species isolated from leaf surface of herbicide treated and control plants. Penicillium brevicompactum and Fusarium oxysporum were isolated only from untreated plants and Oidiodendron echinulatum was restricted to the herbicides treated plant. Arthrobotrys orthrobotryoides, Cladosporium cladosporioides, Mucor hiemalis, Mucor racemosus, Penicillium chrysogenum and sterile forms were common to all the treated as well as untreated plants.

In the case of bacteria also the population decreased initially which was followed by a rapid increase in all the herbicide treated plants while in case of untreated ones the population increased steadily. Throughout the study period treated leaves harboured less population as compared to the control (Fig.2.3 and 2.4).

DISCUSSION

Some times degradation products of certain fungicides are more toxic than the fungicides themselves and in such cases a lag period is noticed between the application and the actual drop in the fungal population. Benomyl

belongs to this category of fungicides. Its degradation product, Methyl benzimidazole-2-Carbamate is highly fungicidal and this may be the reason why in this case the drop in the fungal population was observed after 30 days. It seems other two fungicides are effective just after their application.

Throughout the study period the fungal as well as bacterial population on fungicide and herbicide treated leaves remained lower than the control, however, the effect decreased slowly and recovery was observed during later periods. Activities of microorganisms on leaf surfaces are modified by application of extraneous chemicals (Hislop,1976; Dickinson, 1973). These chemicals are generally detrimental for the growth of most microorganisms which result into a decrease in the microbial population of leaf surfaces (Hislop and Cox, 1969; Mishra and Tiwari, 1979; Dickinson and Wallace, 1976). After spray these chemicals are slowly lost from the leaf surfaces due to biodegradation, evaporation and removal through rain waterand dew. Thus, their influence on microflora decreases with time. It has also been recognised that older leaves exude increased amount of carbohydrates and amino acids which may be responsible for the continued increase in leaf surface microbial population of treated as well as control plants. Kerling (1964) and Cabral (1985) also noted increase in microbial population with the age of the leaf. Gradual increase in microflora may also be due to deposition of the air spora and/or multiplication of

microbes in the phyllosphere of old leaves (Dickinson et al. 1975).

The application of biocides alters the microenvironments of leaf surfaces to a great extent as they modify the quality and quantity of leaf exudates, kill a large number of microbes and adversely affect the activity of many others (Hislop and Cox, 1969; Mishra and Tiwari, 1979). Thus, the habitat of leaf surface microorganisms becomes favourable for few while detrimental to others. This is evident from the change in species composition of fungal flora (Tables 2.2,2.3).

In general the biocides did not affect significantly the species composition of phyllosphere and the species isolated were similar to that of Bainbridge and Dickinson (1972), Hollonan (1967) and Sinha (1971). Two sterile forms were resistant to fungicides as well as herbicides and they were consistantly isolated in higher numbers. Probably these fungi develop certain resting structures on the leaf surfaces which are not affected by the biocides. The appearance of O. echinulatum on 30 day and its disappearance again at 45 day was an interesting observation (Table 23). May be, this fungus found the habitat more conducive when the population of most other fungi diminished due to the effect of herbicides and again when the recolonization started it disappeared. It shows its resistance to the herbicides and that it is probably a weak competitor on leaf

surface.

It was observed that both control as well as fungicide treated crop was attacked by late blight. In case of fungicide treated plants although the infection was delayed, the rate of spread of disease was faster than the control and it was observed that all the plants died before maturity. It appears that after the spray antagonistic saprotrophs as well as propagules of the pathogen were killed. So later when fresh propagules of the pathogens arrived or the ones which could survive, found the habitat more conducive for their growth due to part or full removal of their antagonists. This resulted into fast multiplication of the pathogen resulting into premature death of the plants. The growers thus derive only marginal benefit from single spray of fungicides. Year after year single spray of fungicides may induce the pathogen to develop resistant races. The growers should therefore, be discouraged for single spray of fungicides.

Population and species composition of leaf surface microbial communities are governed by the physico-chemical characteristics of the leaf surfaces (Dickinson et al.1975; Cabral, 1985). Under normal conditions microbial population on leaf surfaces are held in a dynamic balance by interaction between the host plant and saprotrophic microflora. Application of extraneous chemical modifies the leaf surface microenvironment. Initial drop in the microbial population

may be ascribed to this disturbance. It appears the effect of herbicides persists only for a short period and it diminishes slowly after 15 days and after about 45 days the microbial population of leaf surface of herbicide treated plants becomes almost similar to that of the control ones. Steep reduction in the population of saprotrophs from the leaf surfaces for a period of fifteen days may make the plant more susceptible to the attack of pathogens due to removal of the saprophytic antagonistics. Thus, herbicides spray may stimulate disease incidence, however, no study on this aspect is available.

CHAPTER - III

INFLUENCE OF FUNGICIDES AND HERBICIDES ON RHIZOSPHERE MICROFLORA OF POTATO

INTRODUCTION

Fungicides and herbicides are used extensively in modern agriculture for the control of fungal pathogens and weeds. These chemicals are applied directly to the soil or they enter the soil through run-off from treated aerial system or from drifting spray.These chemicals alter the number and activity of microorganisms and thus affect the biochemical processes and fertility of soil. The volume of soil in immediate vicinity of the roots, where chemical exudates of roots can be detected by microorganisms called rhizosphere, is the most important site of microbial activitity. The sprayed chemicals affect the rhizosphere activity through direct contact of the chemicals reaching the soil, or through alteration of plant excretions. Most studies on effect of fungicides (Wainwright, 1978; Kuthubutheen, 1979; Torstenson and Wessen, 1984) and herbicides (Chen et al. 1981; Lewis et al. 1978) concern with soils and a good number of thesestudies are conducted in laboratory conditions. Very few studies are available on the effect of fungicides (Sunar and Chohan, 1971; Gupta, 1974; Srivastava and Dayal, 1981; Bagyaraj and Rangaswami, 1982) and herbicides (Smirnoba, 1983; Catska and Vrany, 1976; Olson et al. 1984; Sandmann and Loos, 1984) on the rhizosphere microorganisms. Further, although a huge quantity of fungicides and herbicides are applied in potato production, no information is available on the effect of these chemicals on the

rhizosphere microflora of potato. Keeping this in view the present study was undertaken to investigate the effect of foliar application of these chemicals on the rhizosphere microflora of potato.

REVIEW OF LITERATURE

Effect of herbicides on various groups of micro-organisms was first studied by Smith et al. (1945). Inhibitory as well as stimulatory effects of herbicides on the microbial population were reported by Warren et al. (1951). Naito and Kohima (1957) found that Gleosporium sp. produced antibiotic substances when grown on media containing either 2-chlorophenoxy acetic acid or 2-methyl phenoxy acetic acid. Richardson (1957,1959) observed that some herbicides stimulate including PCP, isoprophyl N-Phenyl carbonate and 2-chloro-N-N dially acetamide have been found to inhibit the growth of Sclerotium rolfsii, S. batatiçola and Rhizoctonia sp. (Bain, 1961). Kaufman (1964) demonstrated the inhibitory effect of S-triazine on Fusarium spp. and Rhizoctonia solani in soil. He further observed that S-triazine and Phenyl urea herbicides stimulated some genera of fungi in soil. Corden and Young (1965) found that the application of fungicide metasol resulted in the rapid reduction in the fungal population. According to Hartley and West (1969) herbicides had little effect on soil microorganisms which he attributed to the quick changes brought about either in

enzyme system of microorganisms or their ability to mutate into a resistant strain. Srivastava et al. (1970) reported that foliar application of fungicides and antibiotics decreased the fungal population of rhizosphere of wheat. Balasubramanian et al. (1970) examined that insecticides and fungicides drastically reduced the microbial population and enzyme activities in the rhizosphere of Eleusine coracana. Vanschreven et al. (1970) noticed that 10 and 100times recommended concentration of dichloroprop and micoprop significantly reduced CO_2 output from soil during the first week. Clark and Wright (1970) suggested that the degradation of herbicides is predominantly carried out by the microbes in the soil and little or no degradation occurs in sterilized soil. Inhibition of CO_2 evolution at higher concentration of the herbicides was reported by Simon (1971) and Messersmith et al.(1971). Mahmoud et al. (1972) found adverse effect of fungicides and insecticides on the bacterial population of rhizosphere of cotton plants. Choudhury et al. (1972) reported that the application of DPA at higher doses inhibits the growth of fungi for some time. Peeples (1974) observed that fungal and bacterial population in benomyl treated plants was reduced to less than half of the control plot soil. According to Wainwright and Pugh (1975) fungicides captan, dichloran, milceland and thiasimol reduced the fungal numbers, however, after 15 days it returned to the level of control. They found Trichoderma koningii and Penicillium nigricans as dominant fungi in treated soil. Sahrawat (1976)

reported that most of the herbicides fungicides and insecticides applied at recommended doses have little, if any, effect on the availability of plant nutrients. Helling (1976) examined that dinitroaniline herbicides degrade more rapidly in anaecrobic than aerobic soils. Davies and Marsh (1977) reported that dalapan pyrazone and trifluralin at 100 ppm had no adverse effect on carbon dioxide evolution but metabuzin and glyphosate at 100 ppm reduced the CO_2 evolution from the soil. Lewis et al. (1978) tested 25 herbicides and their combination on microbial activity in two soil types in laboratory condition. They found that herbicides did not affect soil respiration and dehydrogenase activity. The United States Environmental Protection Agency (EPA, 1978) has introduced the effect of herbicides on enzyme activities as a guideline to assess their effect on the microflora and data on the enzyme activities must be supplied as part of the registration package for the herbicides. Kader et al. (1978) examined that fungicides reduced the rhizosphere and soil fungal flora of cotton. After 40 days their toxicity was almost aleviated in the soil but persisted in the rhizosphere. Popaiah and Rai (1979) studied the effect of four common herbicides viz., larso, nitrofen, propinol and simazine on microorganisms in red sandy soil. They observed that propinol and nitrofen decreased the bacterial population. Kuthubutheen and Pugh (1979) found that fungicides reduced fungal population upto 50% in treated soil as compared to the con-

trol. They found Cladosporium cladosporioides, Mortierella minutissima, Trichocladium asperum, Trichoderma hamatum and Zygorlynetus moulleri were generally tolerant to fungicides. Studies on soil treated with simazine incubated under aerobic or anaerobic conditions indicated that the herbicide retarded nitrification and denitrification upto 12 months (Weeraratna, 1979). Verstralte et al.(1979) studied the effect of different herbicide viz., metamitron, chloridazone, ethofumerate and phenmedipham on soil microbial biomass, respiration, nitrification, ATP concentration and p-nitrophynyl phosphatase activity. They found that all the herbicides affected adversely the soil microbiota and microbial activities also decreased. Quilt et al. (1979,1980) reported that baraban and carbyne decreased the fungal population and increased the bacterial population in treated soils. Taleta and Stolminova (1980) studied the effect of various herbicides combination on the soil biological and bio-chemical processes of rhizosphere. They found that herbicides combination had no harmful effect on soil biological processes in the rhizosphere zone. Roslycky (1980,1081) reported that fungicides vortex and linuron exerted little initial effect on bacteria and actinomycetes population whereas vortex caused drastic reduction in the fungal population. Lethbridge et al. (1981) noted that 2,4-D application increased gluconase activity initially which was followed by decline. They observed that urease activity

remained unaffected at low doses but high doses were inhibitory. Chen et al. (1981) reported that butachlore at all doses inhibited the rate of ammonification and stimulated the rate of nitrification, while population of fungi, bacteria and actinomycetes were increased. Greaves et al. (1981) evaluated the effect of herbicide dalapone on the soil microflora, dehydrogenase activity and soil respiration. According to them at normal concentrations dalapon had little effect on soil microflora or soil fertility but at very high concentrations marked effect was noticed on the microflora and their activities. Tu (1981) determined the effect of 32 herbicides and fungicides on microorganisms and enzyme activities. He found that none of pesticides inhibited enzyme activities while decrease in bacterial numbers occurred. Bakalivanov and Kastov (1981) observed that 2,4-D, MCPA, CDAA, alachlor, propachlor, diphenyl amide, trifularin, dalapon, bromacil and linacil inhibited the soil fungal, bacterial and actinomycetes population. Smith (1982) reviewed the literature on the effect of herbicide on soil. According to him, the chemical and bio-chemical processes of soil degrade the herbicides and the degradation is dependent upon chemical structure of the organic molecule. Roslycky (1982) examined that the low concentration of glyphosate had little effect on microorganisms while high concentration stimulated actinomycetes bacterial and fungal population. Bollen et al. (1983) found that benomyl fungicide reduced the fungal population of rhizosphere region of rye. They reported that

Alternaria spp. and Fusarium culmorum were dominant and tolerant fungi. Doneche et al. (1983) reported that fungicides inhibited the fungal and bacterial population in soil. They also found degradation of mancozeb in soil and suggested that possibly it may be due to chemical and biochemical factors. Olson (1984) reported that trifluralin had no effect on fungal, bacterial and actinomycetes population either in general soil or in rhizosphere. Abyad and Amitra (1985) reported that effect of herbicides on microflora depends upon the type and concentrations of herbicide and nature of the soil. He examined the alteration in species composition by disappearance or appearance of certain species under a specific concentration. According to Radka et al. (1985) alteration of microorganisms population by application of herbicides depends upon chemical nature of herbicides, rate of application and the moisture content of soil. Baruah and Mishra (1986) concluded that herbicides 2,4-D, butachlor and oxyfluorfen stimulated the dehydrogenase activity and CO_2 evolution whereas urease activity remained unchanged. Yentume and Joynson (1986) found that insecticides, fungicides and herbicides significantly lowered the microbial population in soil. Jain et al. (1987) found that foliar application of antibiotics and fungicides inhibited the microbial population and changed the species composition of rhizosphere microflora of Ocimum basilicum. Mekwatanakasn and Sivasithamparam (1987) evaluated the

effect of herbicides glyphosate, diguate, paraquate and trifluralin on the saprophytic survivality and pathogenicity of Gaemannomyces granus. They found that herbicides inhibited the infection and population of the pathogen.

MATERIALS AND METHODS

Disease free tubers were procured from the C.P.R.S. Shillong. The crop was sown in the last week of March,1986. Five 30 M^2 plots were taken for each treatment and the control. The plots were randomized. The fungicides and herbicides recommended for potato and commonly used by the growers of this region were used. The technical details about fungicides and herbicides are given in Table 2.1. Initial sampling for microbiological analysis was done 20 days after emergence of the plants and on the same day manufacturers recommended doses of the fungicides and herbicides were sprayed.The samples were collected at 15, 30, 45 and 60 days after application of the fungicides and herbicides.

For the study of rhizosphere microflora(fungi and bacteria), the complete root system was taken out carefully with a sterilized spatula in a sterilized polythene bag. The root system was tapped gently to remove the extra attached soil. The roots were transferred to a 500 ml conical flask containing 100 ml of sterilized distilled water

and serial dilutions were preapred. For the enumeration of fungal propagules 0.5 ml of appropriate dilution was inoculated on sterilized petriplates containing 20 ml of rose bengal agar medium (Martin, 1950). For bacterial population nutrient agar medium (Johnson, and Curl, 1972) was used. The rhizosphere suspension left out after inoculation was evaporated separately at 105°C in hot air oven for 24 hrs, cooled to room temperature and finally weighed to determine the dry weight of the soil. Rhizosphere microbial population was calculated on the basis of per gram dry weight of soil.

Corresponding non-rhizosphere soil samples, were also collected at each sampling time from the depth in the soil corresponding to the root zone. From 10 g of the soil the suspension of 1:100, 1:1000 and 1:10000 dilutions were prepared in sterilized distilled water. The 1:1000 suspension was used for the assessment of the fungal population and 1:10000 suspension was used for the assessment of bacterial population. Rose bengal agar was used for fungi and nutrient agar medium was used for bacteria. Fungi and bacteria per gram dry soil was calculated by multiplying the average colony number per plate by dilution factor taking the moisture content into consideration. Petriplates for fungi were incubated at 25°C for seven days and for bacteria at 30°C for 24 hours. Three replicates were maintained for each sample.

RESULTS

The effect of foliar application of fungicides, benomyl, copper oxychloride and mancozeb on fungal and bacterial population of rhizosphere and non-rhizosphere soils is depicted in Figs. 3.1 and 3.3. Except rhizosphere bacterial population in the case of benomyl treated plants, fungicides spray resulted into a drop in the microbial population. Throughout the study, rhizosphere and non-rhizosphere soils of fungicides treated plants harboured less population than the control. Fig.3.2,3.4 shows that in most cases after the initial drop in population a recovery was observed. The recovery was speedy and maximum in the case of non-rhizosphere bacteria (75%-85%). Recovery was slow and minimum in the case of rhizospheric fungi (35%-40%). R/S ratio for fungi varied between 9 and 43 while in the case of bacteria it ranged between 11 and 88 (Table 3.1). Table 3.3 to 3.8 lists fungal species isolated from rhizosphere and non-rhizosphere soils of treated and control plants. Acremonium rutilum, Aspergillus flavus, Mucor circenelloides and Necteria ventricosa were isolated only from the fungicides treated plants. Acremonium rutilum and Necteria ventricosa were isolated only from rhizospheric soils while Arthrobotrys conoides, A. oligospora, Oidiodendron echinulatum were isolated from non-rhizospheric soils only. Cladosporium cladosporioides, Fusarium oxysporum, F. poae, F. solani, Monilia sp., Mortierella

minutissima, Mucor hiemalis, M. plumbeus, M. racemosus, Oidiodendron echinulatum, Penicillium brevicompactum, P. chrysogenum, Rhizopus oryzae, Trichoderma harzianum and T. viride showed sporadic appearance and did not show any treatment or habitat (rhizosphere, non-rhizosphere) preference.

Herbicides :

The effect of foliar application of herbicides, benthiocarb, 2,4-D and fluchloralin on fungal and bacterial population of rhizosphere and non-rhizosphere soils are given in fig.3.5 and 3.7. Herbicides affected the fungal and bacterial population of both rhizospheric and non-rhizospheric soils. The soils from treated plants showed an initial drop in fungal population followed by an increase upto 45 days after which population declined in case of control as well as treated plots. The benthiocarb treated plots harboured less fungal population than the other treatment and control. Bacterial population was also inhibited but later on it recovered and followed a trend of variation similar to that of the control, although values remained lower than the control. Fig.3.6 and 3.8 shows the fungal and bacterial population in rhizosphere and non-rhizosphere soil of treated plots in terms of percentage of control. The maximum recovery was in the case of non-rhizospheric fungi (37%-114%), while slow and minimum in case of non-rhizospheric bacteria (11%-82%). R/S values

Fig. 3.1. Fungal population in rhizosphere and non-rhizosphere soils of potato sprayed with fungicides.

FIG-3·1.

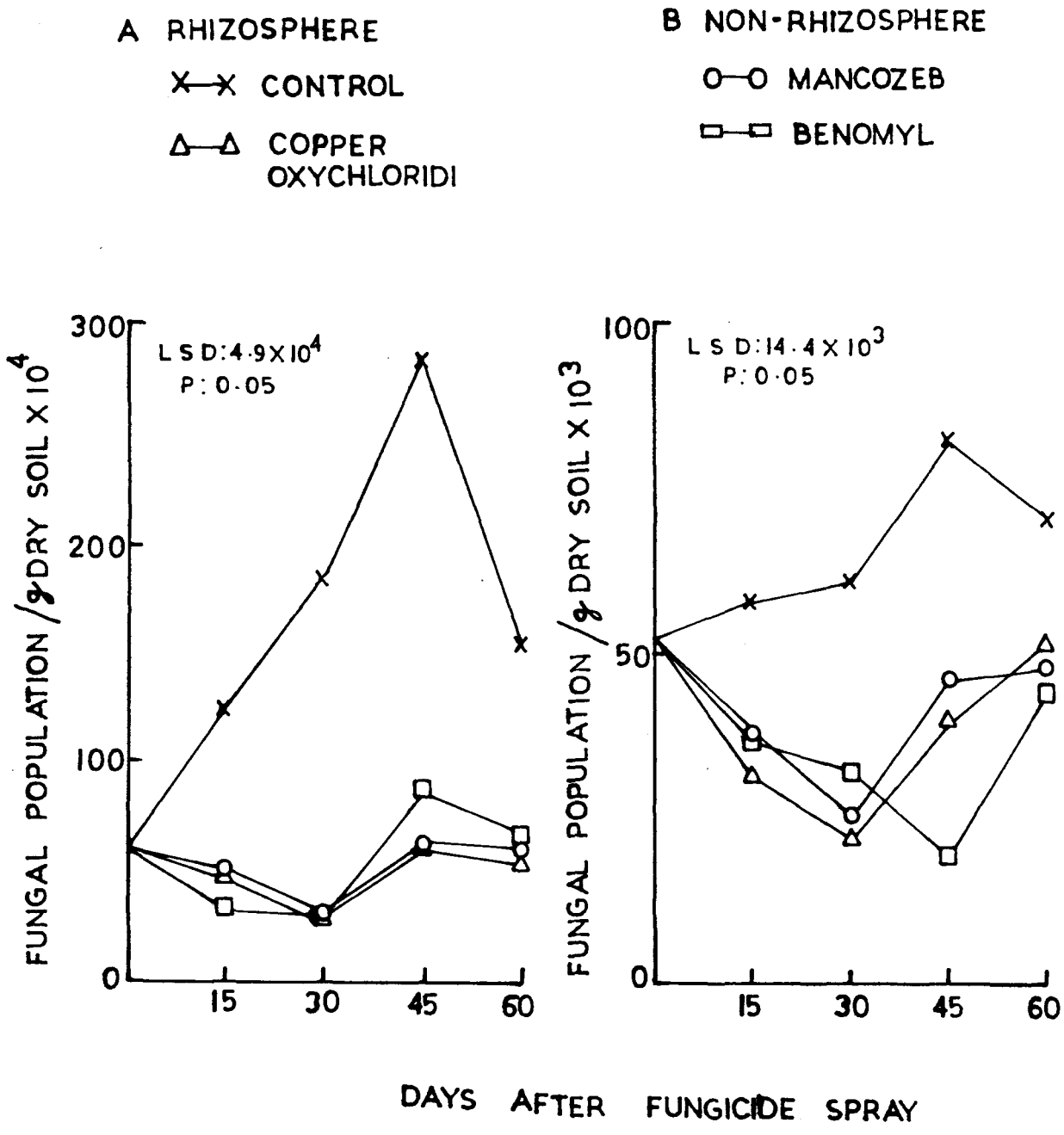

A RHIZOSPHERE
X—X CONTROL
Δ—Δ COPPER OXYCHLORIDI
B NON-RHIZOSPHERE
O—O MANCOZEB
□—□ BENOMYL
L S D:4·9X10⁴
P: 0·05
FUNGAL POPULATION /g DRY SOIL X 10⁴
300
200
100
0
15
30
45
60
L S D:14·4X10³
P: 0·05
FUNGAL POPULATION /g DRY SOIL X 10³
100
50
0
15
30
45
60
DAYS AFTER FUNGICIDE SPRAY

Fig. 3.2. Effect of fungicides on fungal population of rhizosphere and non-rhizosphere soils expressed as percentage of the control.

FIG-3.2.

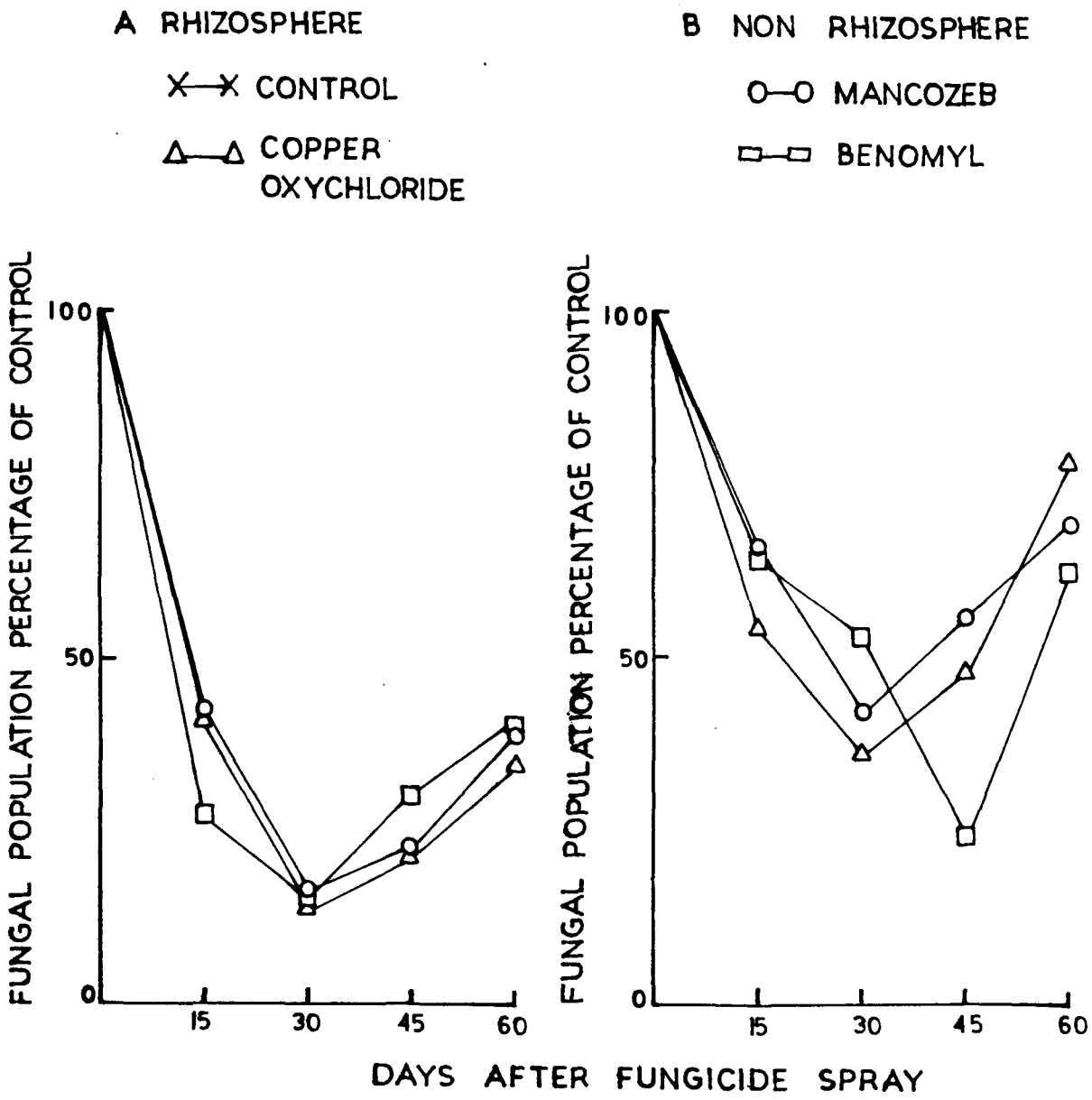

A RHIZOSPHERE
X—X CONTROL
Δ—Δ COPPER OXYCHLORIDE
B NON RHIZOSPHERE
O—O MANCOZEB
□—□ BENOMYL
FUNGAL POPULATION PERCENTAGE OF CONTROL
100
50
0
15
30
45
60
DAYS AFTER FUNGICIDE SPRAY

Fig. 3.3. Bacterial population in rhizosphere and non-rhizosphere soils of potato sprayed with fungicides.

FIG-3·3

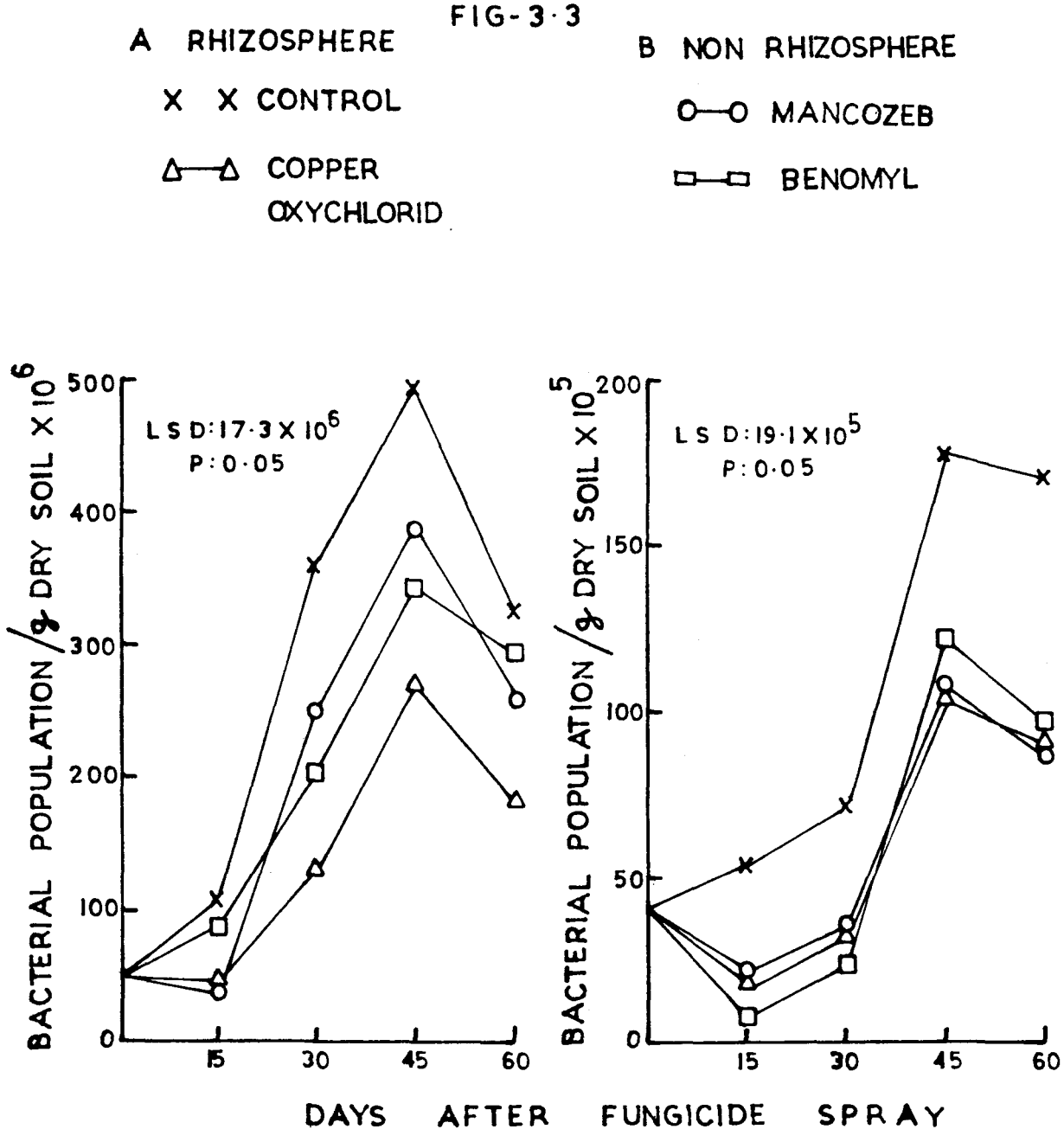

A RHIZOSPHERE
X X CONTROL
Δ—Δ COPPER OXYCHLORID
B NON RHIZOSPHERE
O—O MANCOZEB
□—□ BENOMYL
BACTERIAL POPULATION /g DRY SOIL X 10^6
LSD:17·3 X 10^6
P:0·05
BACTERIAL POPULATION /g DRY SOIL X 10^5
LSD:19·1 X 10^5
P:0·05
0
100
200
300
400
500
50
100
150
200
15
30
45
60
DAYS AFTER FUNGICIDE SPRAY

Fig. 3.4. Effect of fungicides on bacterial population of rhizosphere and non-rhizosphere soils expressed as percentage of the control.

FIG - 3.4.

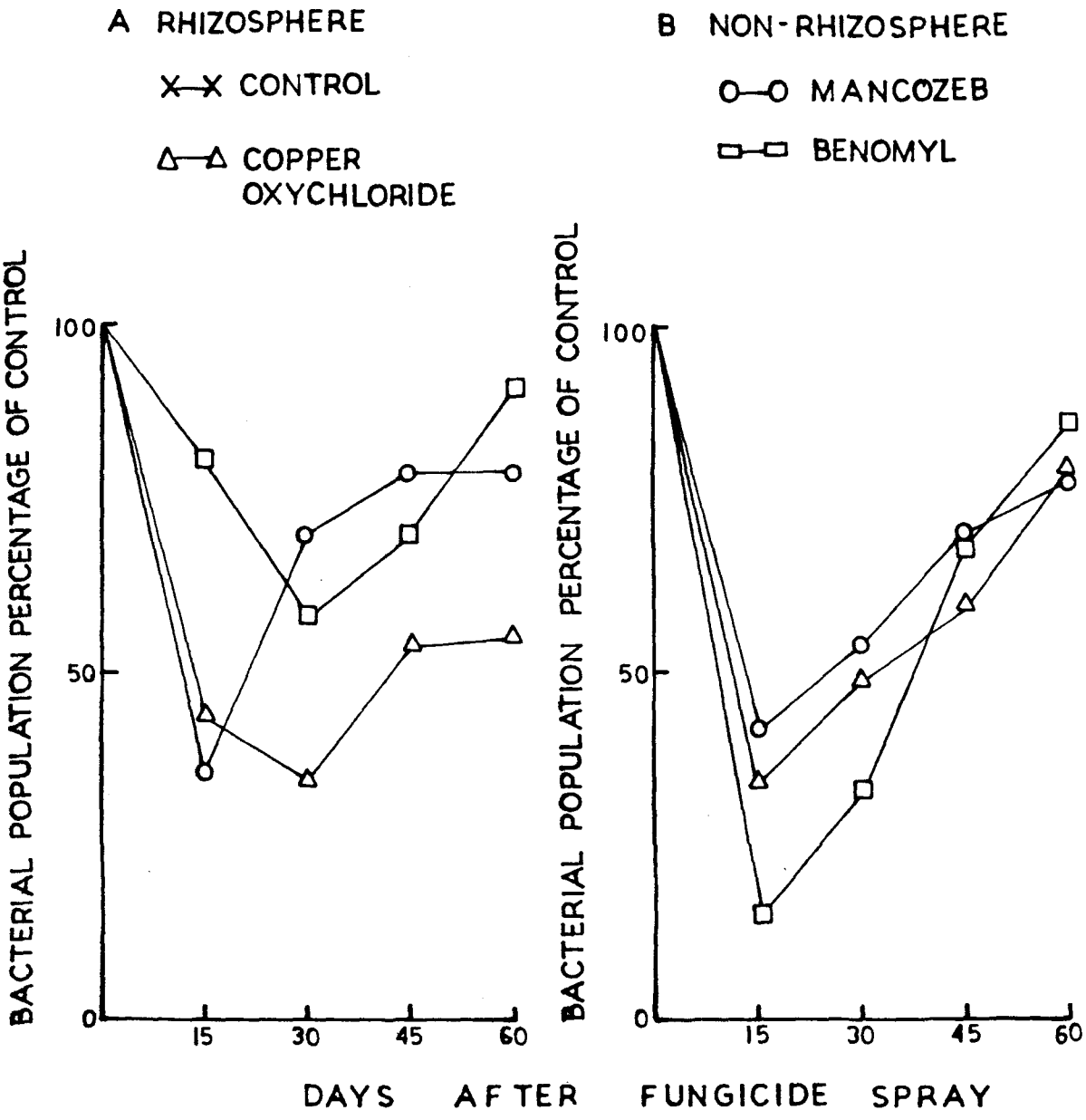

A RHIZOSPHERE
X—X CONTROL
Δ—Δ COPPER OXYCHLORIDE
B NON-RHIZOSPHERE
O—O MANCOZEB
□—□ BENOMYL
BACTERIAL POPULATION PERCENTAGE OF CONTROL
100
50
0
15
30
45
60
DAYS AFTER FUNGICIDE SPRAY

Fig. 3.5. Fungal population in rhizosphere and non-rhizosphere soils of potato sprayed with herbicides.

FIG - 3.5.

A RHIZOSPHERE

X—X CONTROL

Δ—Δ 2,4- D

B NON RHIZOSPHERE

O—O BENTHIOCARB

□—□ FLUCHLORALIN

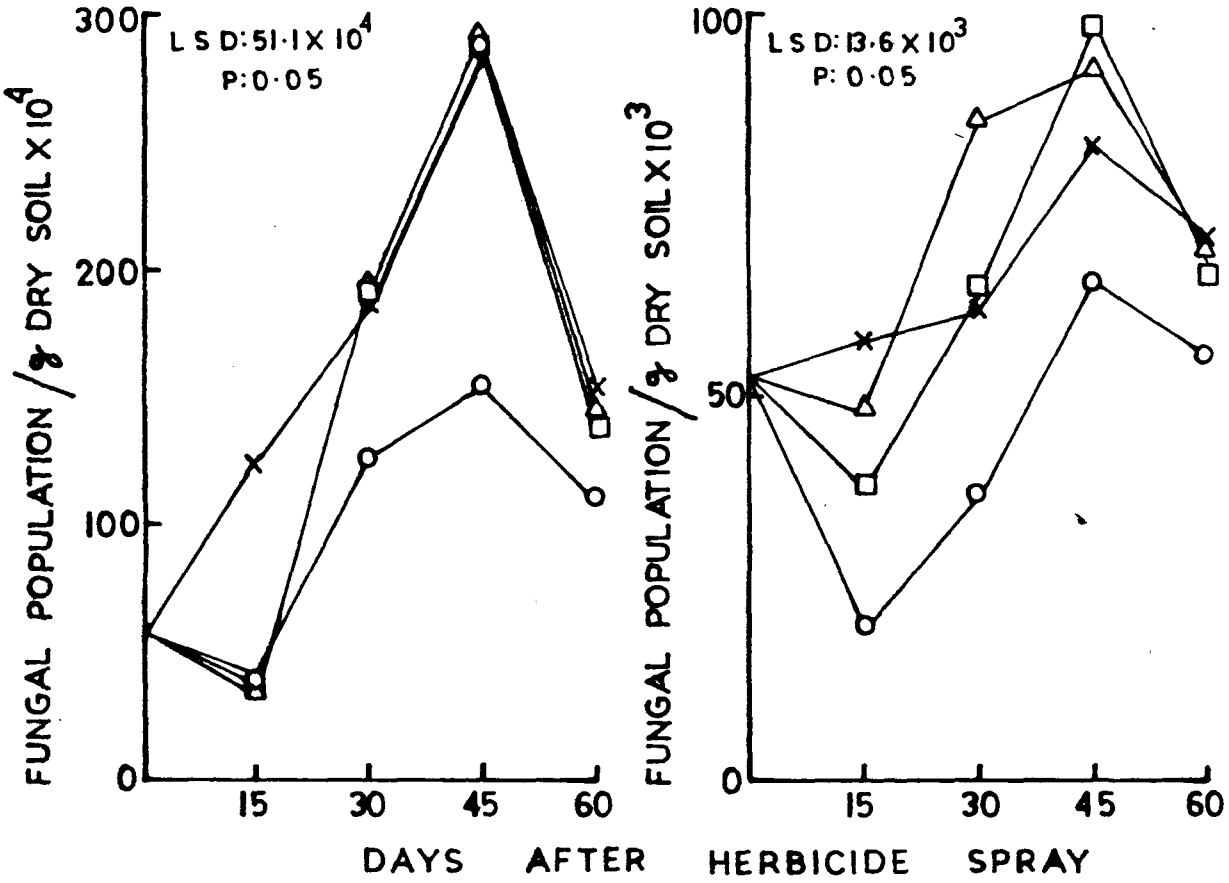


Fig. 3.6. Effect of herbicides on fungal population of rhizosphere and non-rhizosphere soils expressed as percentage of the control.

FIG-3.6.

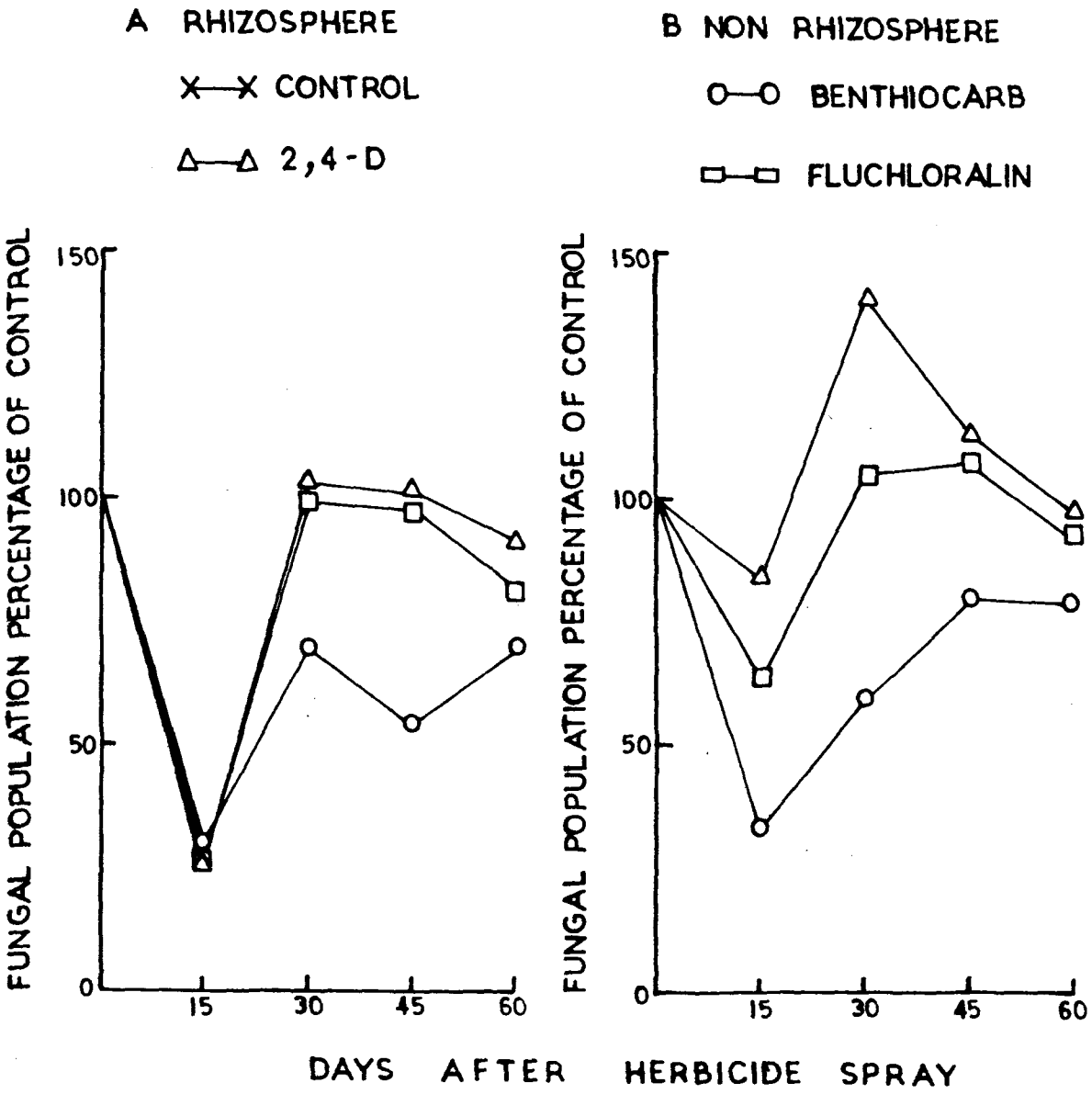

A RHIZOSPHERE
X—X CONTROL
Δ—Δ 2,4-D
B NON RHIZOSPHERE
O—O BENTHIOCARB
□—□ FLUCHLORALIN
FUNGAL POPULATION PERCENTAGE OF CONTROL
150
100
50
0
15
30
45
60
DAYS AFTER HERBICIDE SPRAY

Fig. 3.7. Bacterial population in rhizosphere and non-rhizosphere soils of potato sprayed with berbicides.

FIG-3.7.

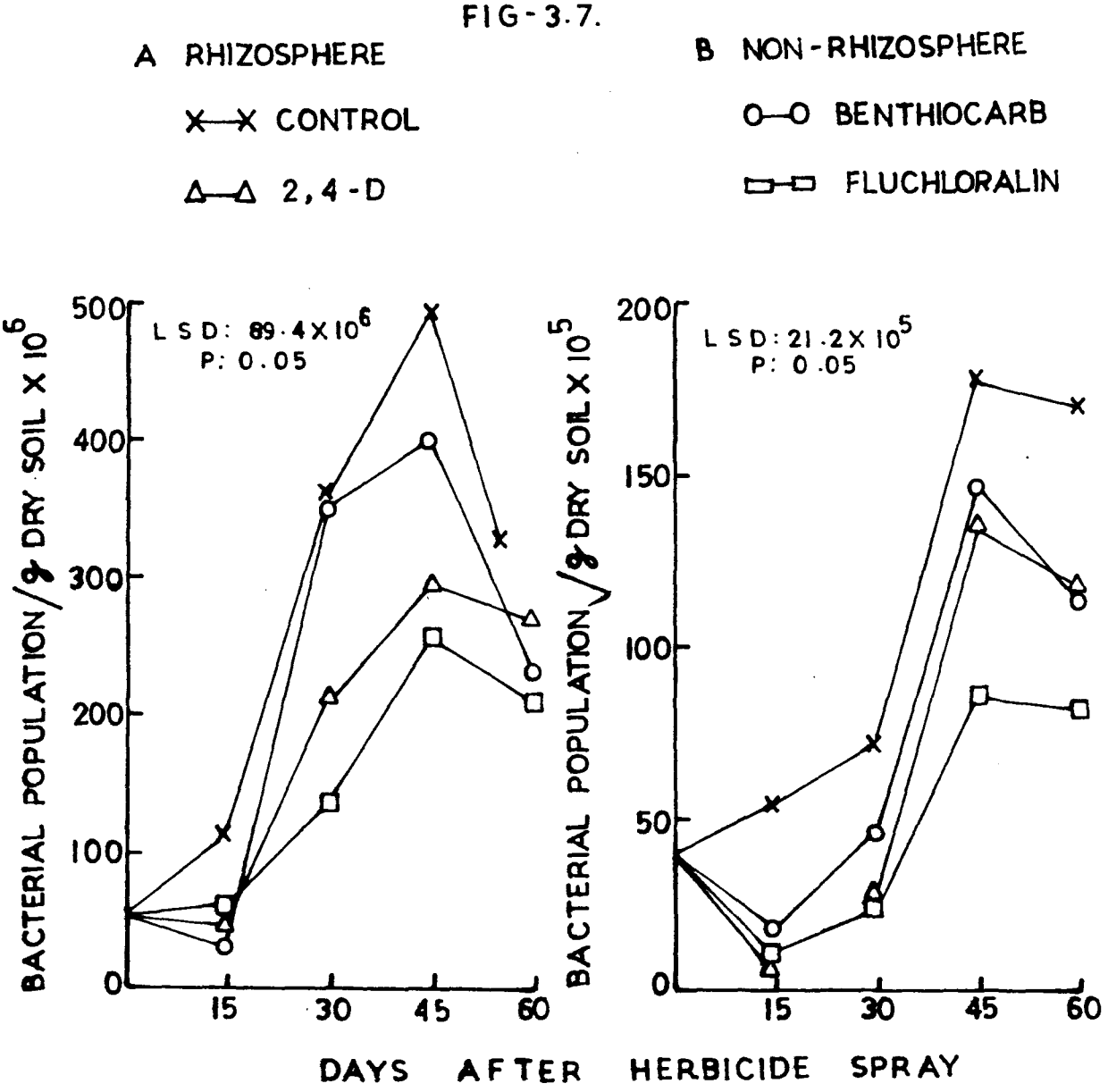

A RHIZOSPHERE
X—X CONTROL
Δ—Δ 2,4-D
B NON-RHIZOSPHERE
O—O BENTHIOCARB
□—□ FLUCHLORALIN
LSD: 89.4X10^6
P: 0.05
LSD: 21.2X10^5
P: 0.05
BACTERIAL POPULATION/g DRY SOIL X 10^6
BACTERIAL POPULATION/g DRY SOIL X 10^5
500
400
300
200
100
0
200
150
100
50
0
15
30
45
60
DAYS AFTER HERBICIDE SPRAY

Fig. 3.8. Effect of herbicides on bacterial population of rhizosphere and non-rhizosphere soils expressed as percentage of the control.

FIG-3.8.

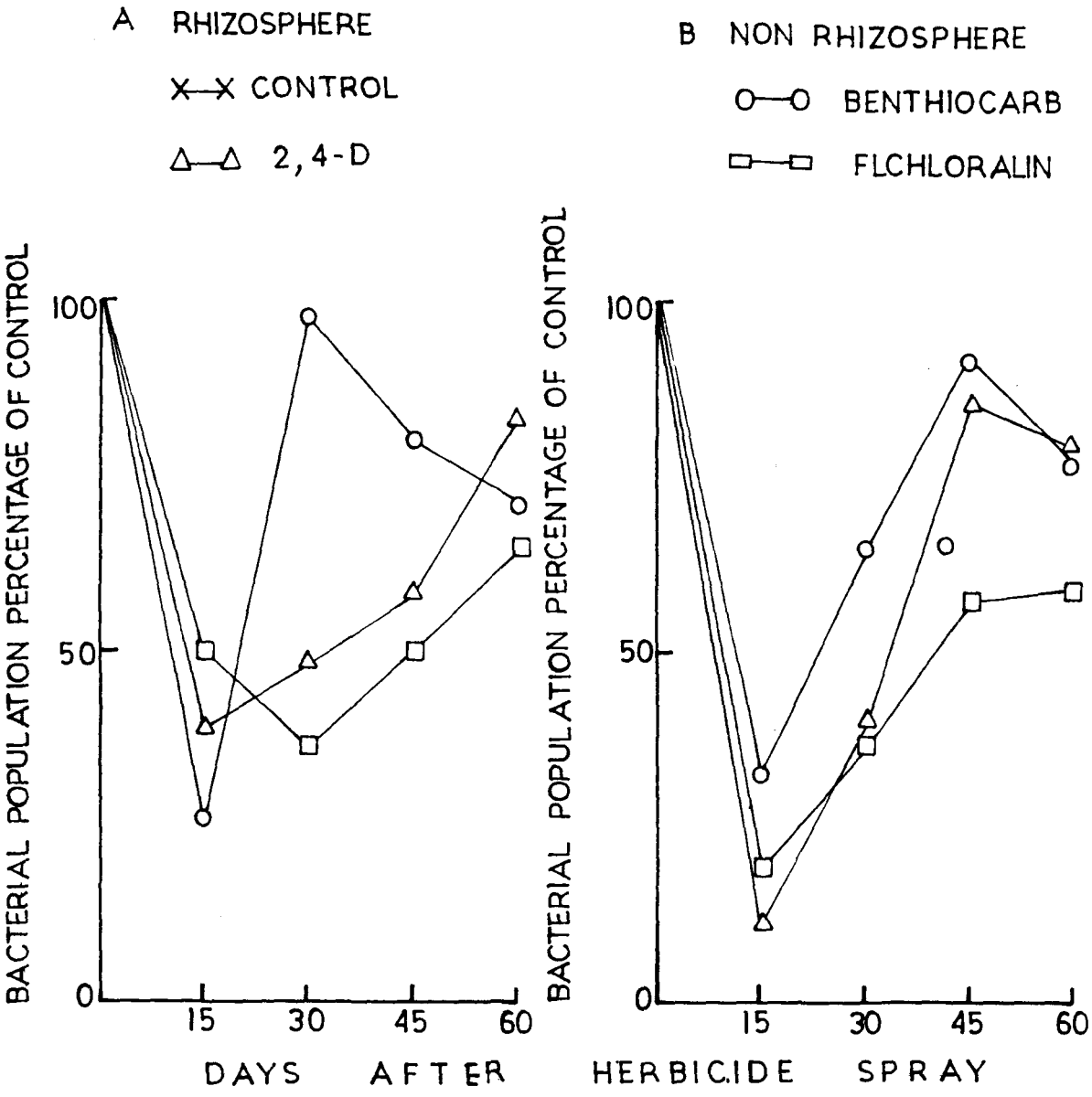

A RHIZOSPHERE
X—X CONTROL
Δ—Δ 2,4-D
B NON RHIZOSPHERE
O—O BENTHIOCARB
□—□ FLCHLORALIN
BACTERIAL POPULATION PERCENTAGE OF CONTROL
100
50
0
15
30
45
60
DAYS AFTER HERBICIDE SPRAY

Table 3.1. Influence of fungicides on Rhizosphere effect *(R/S) of Fungal and bacterial population. Upper values are R/S of fungi and lower values are R/S of bacteria.

Sampling period	Control	Benomyl	Copper oxychloride	Manoozeb
15	21.40 20.20	9.00 11.50	15.90 25.70	13.50 18.30
30	29.80 50.00	8.80 87.70	12.20 36.40	11.50 69.40
45	34.30 27.90	43.20 28.40	15.70 25.60	14.00 35.90
60	22.00 19.20	14.20 30.50	10.40 19.90	12.50 29.30

$$*R/S = \frac{\text{Microbial population in rhizosphere region}}{\text{Microbial population in soil}}$$

Table 3.2. Influence of herbicides on rhizosphere effect (R/S) of fungal and bacterial population. Upper values are R/S of fungi and lower values are R/S of bacteria.

Sampling period	Control	Benthiocarb	2,4-D	Fluchloralin
15	21.40	19.00	5.60	9.10
	20.20	15.70	76.6	52.10
30	29.8	34.30	21.40	28.60
	50.50	75.00	72.20	50.50
45	34.30	23.20	31.10	28.80
	27.90	26.60	21.5	29.10
60	22.00	19.40	20.70	20.40
	19.20	20.40	23.7	25.70

Table : 3.3. Percentage abundance and number of propagules of fungi (per gram dry soil) at 0 days after treatment with fungicides in Rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benomyl		Copperoxychloride		Mancozeb	
	R	N	R	N	R	N	R	N
Cladosporium cladosporioides	26.3 (14.7)	21.0 (1.17)	26.3 (14.7)	21.0 (1.17)	26.3 (14.7)	21.0 (1.17)	26.3 (14.7)	21.0 (1.17)
Fusarium oxysporum	- (0.5	11.7 (0.5)	- (0	11.7 (0.5)	-	11.7 (0.5)	-	11.7 (0.5)
Monilia sp.	-	5.0 (0.2)	- (	5.0 (0.2)	-	5.0 (0.2)	-	5.0 (0.2)
Mucor circenelloides	23.5 (11.7)	-	23.5 (11.7)	-	23.5 (11.7)	-	23.5 (11.7)	-
Mucor hiemalis	26.0 (14.7)	5.2 (0.2)	26.0 (14.7)	5.2 (0.2)	26.0 (14.7)	5.2 (0.2)	26.0 (14.7)	5.2 (0.2)
Penicillium chrysogenum	10.5 (5.8)	15.7 (0.8)	10.5 (5.8)	15.7 (0.8)	10.5 (5.8)	15.7 (0.8)	10.5 (5.8)	15.7 (0.8)
Rhizopus coroci	-	11.1 (0.5)	-	11.1 (0.5)	-	11.1 (0.5)	-	11.1 (0.5)
Rhizopus orizae	15.7 (8.81)	26.3 (1.4)	15.7 (8.81)	26.3 (1.4)	15.7 (8.81)	26.3 (1.4)	15.7 (8.81)	26.3 (1.4)
Trichoderma harzianum	-	15.7 (0.8)	-	15.7 (0.8)	-	15.7 (0.8)	-	15.7 (0.8)
Sterile	21.1 (11.7)	16.6 (0.9)	21.1 (11.7)	16.6 (0.9)	21.1 (11.7)	16.6 (0.9)	21.1 (11.7)	16.6 (0.9)

Table 3.4 Percentage abundance and number of propagules of fungi (per gram dry soil) at 15 days after treatment with fungicides in Rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benomyl		Copper oxychloride		Mancozeb	
	R	N	R	N	R	N	R	N
Aspergillus flavus	-	-	-	-	-	-	25 (1.2)	15.40 (5.8)
Cladosporium cladosporioides	33.00 (4.10)	20.00 (11.7)	10.00 (0.33)	-	-	-	-	-
Fusarium solani	12.80 (1.5)	15.00 (8.8)	20.00 (0.65)	-	46.6 (2.22)	18.2 (5.8)	6.25 (0.32)	-
Monilia sp.	-	-	-	30.7 (11.8)	-	-	-	46.20 (17.6)
Mucor hiemalis	15 (1.9)	-	30 (0.86)	-	-	9.0 (2.9)	18.75 (0.96)	-
Mucor plumbeus	20.5 (2.53)	15. (8.7)	-	-	19.9 (0.99)	18.2 (5.8)	12.5 (0.64)	-
Mucor racemosus	-	-	30 (0.86)	-	-	18.2 (5.8)	-	-
Oidiodendron echinulatum	-	25 (14.6)	-	-	-	-	-	-
Penicillium chrysogenum	17.9 (2.2)	-	-	23.0 (8.8)	-	27.3 (8.7)	18.75 (0.96)	-
Rhizopus oryzae	-	-	-	23.0 (8.8)	-	-	-	-
Trichoderma harzianum	-	20 (11.7)	10 (0.32)	23 (8.8)	-	27.3 (8.7)	-	23.00 (8.8)
White sterile	-	5.0 (2.9)	-	-	33.0 (1.62)	-	-	-

Table 3.5 Percentage abundance and number of propagules of fungi (per gram dry soil) at 30 days after treatment with fungicides in Rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benomyl		Copper oxychloride		Mancozeb	
	R	N	R	N	R	N	R	N
Cladosporium cladosperioides	-	13 (8.2)	-	17.00 (5.5)	33.30 (0.94)	-	40 (1.2)	22.00 (5.7)
Monilia sp.	-	8.6 (4.9)	-	-	-	-	-	12.00 (2.8)
Mucor hiemalis	31.5 (5.8)	26 (16.4)	62.5 (1.5)	-	55.5 (1.57)	-	40 (1.2)	-
Mucor plumbeus	33.30 (6.12)	-	-	-	-	25 (5.5)	-	22.00 (5.7)
Mucor racemosus	20.8 (5.4)	-	37.5 (0.91)	-	11.00 (0.31)	12.5 (2.7)	20 (0.63)	-
Penicillium brevicompactum	-	-	-	49.00 (16.7)	-	37.5 (8.3)	-	-
Penicillium chrysogenum	22.8 (4.5)	39 (24.7)	-	-	-	-	-	22.00 (5.7)
Sterile	-	13 (8.2)	-	33.00 (11.1)	-	25 (5.5)	-	22.00 (5.7)

Table 3.6. Percentage abundance and number of propagules of fungi (per gram dry soil) at 45 days after treatment with fungicides in Rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benomyl		Copper oxychloride		Mancozeb	
	R	N	R	N	R	N	R	N
Cladosporium cladosporioides	24.60 (7.0)	10.7 (0.8)	-	14.2 (0.29)	-	-	-	-
Fusarium poae	-	-	-	-	-	-	33.3 (2.2)	-
Fusarium solani	-	21.4 (1.7)	-	42.8 (0.8)	-	15.3 (0.59)	-	-
Monilia sp.	-	-	-	-	-	15.3 (0.59)	-	12.20 (0.58)
Mucor hiemalis	29.8 (8.5)	7.1 (0.2)	44 (3.7)	-	38.3 (2.4)	15.3 (0.59)	38.8 (2.56)	12.20 (0.58)
Mucor plumbeus	-	-	-	14.2 (0.2)	- (0.2)	-	-	-
Mucor racemosus	-	-	56 (4.7)	-	-	-	-	-
Penicillium chrysogenum	27.2 (7.7)	14.2 (1.1)	-	-	38.8 (2.4)	30.7 (1.1)	-	31.2 (1.4)
Penicillium brevicompactum	-	-	-	28.5 (0.59)	-	-	27.7 (1.8)	-
Sterile	18.0 (5.1)	46.4 (3.8)	-	-	22.2 (1.3)	23 (0.8)	-	43.7 (2.0)

Table 3.7. Percentage abundance and number of propagules of fungi (per gram dry soil) at 60 days after treatment with fungicides in Rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benomyl		Copper oxychloride		Mancozeb	
	R	N	R	N	R	N	R	N
Arthrobotrys conoides	-	8.4 (0.62)	3.84 (0.13)	4.7 (0.3)	-	-	-	-
Arthrobotrys oligospora	-	8.61 (0.62)	-	4.7 (0.3)	-	-	19.3 (1.2)	-
Cladosporium cladosporioides	16.2 (2.4)	4.3 (0.2)	19.2 (1.3)	14.2 (0.92)	18.5 (2.0)	-	35.4 (2.2)	-
Fusarium oxysporum	-	-	30.7 (2.0)	-	-	-	-	-
Fusarium poae	18.9 (2.8)	-	-	-	-	10.5 (0.6)	-	-
Fusarium solani	8.10 (6.10)	13.6 (0.95)	-	-	-	10.5 (0.6)	-	11.7 (0.62)
Monilia sp.	5.4 (1.6)	13.8 (0.6)	-	14.2 (0.9)	-	10.7 (0.6)	-	11.6 (0.6)
Mortierella minutissima	-	8.61 (0.62)	-	9.5 (0.6)	11.00 (0.75)	15.7 (0.9)	-	-
Mucor hiemalis	8.10 (1.2)	13.8 (0.5)	7.6 (0.52)	9.5 (0.6)	7.4 (0.5)	10.5 (0.6)	-	-
Mucor plumbeus	2.70 (0.40)	-	-	9.5 (0.6)	-	-	6.45 (0.41)	17.6 (0.9)
Necteria ventricosa	-	-	-	-	22.2 (1.5)	-	-	-
Oidiodendron echinulatum	-	-	-	-	22.2 (1.5)	-	6.45 (1.5)	-
Penicillium brevicompactum	14.00 (2.2)	-	-	14.2 (0.92)	11.00 (0.75)	15.7 (0.9)	-	23.5 (1.2)
Penicillium chrysogenum	-	8.6 (0.6)	19.2 (1.3)	-	7.4 (0.5)	-	-	-
Penicillium frequentus	6.75 (1.2)	-	7.6 (0.52)	-	11.00 (0.75)	10.5 (0.6)	3.2 (0.2)	23.5 (1.2)
Trichoderma harzianum	-	8.61 (0.6)	-	9.5 (0.6)	-	-	6.45 (0.41)	-
Trichoderma viride	10.8 (1.6)	8.6 (0.6)	-	-	-	-	-	-
Sterile white	8.10 (1.2)	8.61 (0.6)	11.5 (0.70)	9.5 (0.6)	-	10.5 (0.6)	22.5 (1.4)	11.7 (1.6)

Table 3.8. Effect of fungicides on the fungal population (per gram dry soil) of rhizospheric (R) x 10^4 and non-rhizospheric (N) x 10^3 soils of potato. Values are means of four determinations.

Isolates	Control		Benomyl		Copper oxychloride		Mencozeb	
	R	N	R	N	R	N	R	N
Acremonium rutilum	-	-	0.3	-	-	-	-	-
Aspergillus flavus	-	-	-	-	-	-	3.2	1.4
Arthrobotrys conoides	-	1.5	-	0.7	-	-	-	-
Arthrobotrys oligospora	-	1.5	-	0.7	-	-	-	-
Cladosporium cladosporioides	34.0	3.1	4.0	2.8	7.3	-	7.1	1.4
Fusarium oxysporum	3.9	6.6	6.8	2.2	5.6	2.9	12.0	4.4
Fusarium poae	7.1	-	-	2.3	-	1.5	-	-
Fusarium solani	3.0	2.3	-	2.3	-	1.5	-	1.5
Monilia sp.	2.0	2.9	-	5.2	-	3.8	-	3.0
Mortierella minutissima	-	1.5	-	1.5	1.8	2.3	-	-
Mucor circinelloides	-	1.5	-	-	0.7	-	-	-
Mucor hiemalis	43.6	2.3	16.5	1.5	11.2	3.6	1.30	3.8
Mucor plumbeus	22.6	6.8	-	2.2	2.4	2.8	2.6	1.4
Mucor racemosus	15.3	0.7	16.3	-	0.7	0.6	3.2	-
Necteria ventricosa	-	-	-	-	3.7	-	-	-
Oidiodendron echinulatum	-	-	-	-	-	-	-	3.1
Penicillium brevicompactum	24.8	4.5	-	2.3	3.7	2.3	0.8	-
Penicillium chrysogenum	19.4	6.1	3.2	4.1	-	7.2	7.6	9.6
Rhizopus oryzae	-	-	-	2.2	-	-	-	-
Trichoderma harzianum	-	1.5	1.3	2.2	-	3.7	-	2.2
Trichoderma viride	2.5	2.9	0.3	0.7	1.8	-	1.0	-
Sterile white	4.0	2.0	-	-	1.2	-	-	-
Sterile orange	-	12.8	1.9	4.3	13.5	5.2	7.9	8.1

Table : 3.9. Percentage abundance and number of propagules of fungi (per gram dry soil) at 0 days after treatment with herbicides in Rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benthiocarb		2,4-D		Fluchloralin	
	R	N	R	N	R	N	R	N
Cladosporium cladosporioides	26.3 (14.7)	21.0 (1.17)	26.3 (14.7)	21.0 (1.17)	26.3 (14.7)	21.0 (1.17)	26.3 (14.7)	21.0 (1.17)
Fusarium oxysporum	-	11.7 (0.5)	-	11.7 (0.5)	-	11.7 (0.5)	-	11.7 (0.5)
Monilia sp.	-	5.0 (0.2)	-	5.0 (0.2)	-	5.0 (0.2)	-	5.0 (0.2)
Mucor circenelloides	23.5 (11.7)	-	23.5 (11.7)	-	23.5 (11.7)	-	23.5 (11.7)	-
Mucor hiemalis	26.0 (14.7)	5.2 (0.2)	26.0 (14.7)	5.2 (0.2)	26.0 (14.7)	5.2 (0.2)	26.0 (14.7)	5.2 (0.2)
Penicillium chrysogenum	10.5 (5.8)	15.7 (0.8)	10.5 (5.8)	15.7 (0.8)	10.5 (5.8)	15.7 (0.8)	10.5 (5.8)	15.7 (0.8)
Rhizopus coroci	-	11.1 (0.5)	-	11.1 (0.5)	-	11.1 (0.5)	-	11.1 (0.5)
Rhizopus orizae	15.7 (8.81)	26.3 (1.4)	15.7 (8.81)	26.3 (1.4)	15.7 (8.81)	26.3 (1.4)	15.7 (8.81)	26.3 (1.4)
Trichoderma harzianum	-	15.7 (0.8)	-	15.7 (0.8)	-	15.7 (0.8)	-	15.7 (0.8)
Sterile	21.1 (11.7)	16.6 (0.9)	21.1 (11.7)	16.6 (0.9)	21.1 (11.7)	16.6 (0.9)	21.1 (11.7)	16.6 (0.9)

Table 3.10. Percentage abundance and number of propagules of fungi (per gram dry soil) at 15 days after treatment with herbicides in rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benthiocarb		2, 4-D		Fluchloralin	
	R	N	R	N	R	N	R	N
Cladosporium cladosporioides	33.3 (4.1)	20 (1.7)	-	14.2 (0.2)	36.30 (11.7)	-	33.3 (11.4)	15.3 (0.5)
Fusarium moniliforme	12.8 (1.5)	15 (0.8)	15.3 (5.8)	-	-	-	-	15.3 (0.5)
Mucor hiemalis	15.3 (1.9)	15 (0.8)	38.4 (14.7)	-	27.2 (8.8)	-	22.2 (7.6)	-
Mucor plumbeus	20.5 (2.5)	-	23 (8.8)	-	-	-	-	15.3 (0.5)
Oidiodendron echinulatum	-	25 (1.4)	-	-	-	-	-	-
Penicillium chrysogenum	17.9 (2.2)	-	-	-	27.2 (8.8)	30 (0.8)	-	-
Periconia macrospinosa	-	-	-	-	-	-	-	23.0 (0.8)
Trichoderma viride	-	20 (1.1)	23 (8.8)	42.8 (0.8)	15.1 (5.8)	40 (1.1)	22.2 (7.6)	15.3 (0.5)
Sterile	-	5 (0.2)	-	42.8 (0.8)	-	30 (0.8)	22.2 (7.6)	15.3 (0.5)

Table 3.11. Percentage abundance and number of propagules of fungi (per gram dry soil) at 30 days after treatment with herbicides in Rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benthiocarb		2, 4-D		Fluchloralin	
	R	N	R	N	R	N	R	N
Cladosporium cladosporioides	-	13.0 (0.8)	42.8 (12.0)	23.0 (0.8)	33.3 (12.5)	23.0 (0.8)	33.3 (11.5)	23.0 (0.8)
Monilia sp.	-	8.6 (0.5)	-	-	-	-	-	-
Mucor hiemalis	31.5 (5.8)	-	42.8 (12.0)	-	41.6 (15.6)	-	44.4 (15.3)	23.0 (0.8)
Mucor plumbeus	33.3 (6.1)	26.0 (1.6)	14.2 (4.0)	-	-	-	22.2 (7.6)	-
Mucor racemosus	20.8 (5.4)	-	-	-	24.9 (9.3)	-	-	-
Penicillium chrysogenum	22.8 (5.8)	39.1 (2.4)	-	30.7 (1.1)	-	23.0 (0.8)	-	23.0 (0.8)
Sterile	-	13.0 (0.8)	-	46.1 (1.6)	-	53.8 (1.9)	-	7.6 (0.2)

Table 3.12. Percentage abundance and number of propagules of fungi (per gram dry soil) at 45 days after treatment with herbicides in Rhizosphere (R) x 10^4 and Non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benthiocarb		2, 4-D		Fluchleralin	
	R	N	R	N	R	N	R	N
Cladosporium cladosporioides	24.6 (7.0)	10.7 (0.8)	7.6 (3.9)	25 (1.1)	52.9 (31.3)	28.5 (1.1)	24.9 (11.7)	15.3 (0.5)
Fusarium oxysporum	-	21.4 (1.7)	-	-	-	-	-	-
Mucor hiemalis	29.8 (8.5)	7.1 (0.7)	30.7 (15.6)	-	47.0 (27.8)	-	16.6 (7.8)	23.0 (0.8)
Mucor racemosus	-	-	23.0 (11.7)	-	-	-	16.6 (7.8)	-
Penicillium chrysogenum	27.2 (7.7)	14.2 (1.1)	23.0 (11.7)	27.5 (1.7)	-	28.5 (1.1)	24.9 (11.7)	30.7 (1.1)
Sterile	18.1 (5.5)	46.4 (3.8)	15.3 (7.8)	37.5 (1.7)	-	42.8 (1.7)	16.6 (7.8)	30.7 (1.1)

Table 3.13. Percentage abundance and number of propagules of fungi (per gram dry soil) at 60 days after treatment with herbicides in Rhizosphere (R) x 10^4 and non-rhizosphere (N) x 10^3 soils of potato. Upper values are abundance and in brackets are number of propagules.

Isolates	Control		Benthiocarb		2, 4-D		Fluchloralin	
	R	N	R	N	R	N	R	N
Arthrobotrys conoides	-	0.6 (0.6)	-	-	-	-	-	-
Arthrobotrys oligospora	-	8.6 (0.6)	-	-	-	-	-	-
Arthrobotrys arthrobotryoides	-	-	-	-	-	9.0 (0.6)	-	-
Cladosporium eladosporioides	16.2 (2.4)	4.3 (0.2)	16.1 (15.1)	-	-	13.6 (0.9)	18.9 (22.0)	1.8 (1.2)
Fusarium moniliforme	-	-	25.8 (24.2)	-	21.7 (24.2)	-	15.5 (27.9)	-
Fusarium oxysporum	-	-	25.8 (24.2)	-	-	21.4 (27.9)	-	-
Fusarium poae	18.9 (2.8)	-	-	-	-	-	-	-
Fusarium solani	8.1 (1.2)	13.0 (0.9)	-	-	-	-	-	-
Gonytrichum machrocladum	-	-	-	-	-	-	24.1 (28.0)	-
Humicola fuscoatra	-	-	-	15.7 (0.8)	-	-	-	-
Monilia sp.	5.4 (0.8)	13.0 (0.9)	-	-	-	-	-	-
Mortierilla minutissima	-	8.6 (0.6)	-	-	-	13.6 (0.9)	-	-
Mucor hiemalis	8.1 (1.2)	13.0 (0.9)	12.9 (12.1)	20.0 (1.1)	14.2 (18.6)	-	6.8 (8.0)	10 (0.9)
Mucor plumbeus	2.7 (0.4)	-	3.2 (3.0)	-	-	9.0 (0.6)	-	-
Mecteria ventricosa	-	-	-	-	-	13.6 (0.9)	-	-
Oidiodendron echinulatum	-	-	12.9 (12.1)	-	-	-	-	-
Penicillium brevicompactum	14.0 (2.2)	-	-	15.7 (0.8)	-	-	-	-
Penicillium chrysogenum	-	8.2 (0.6)	-	-	35.7 (16.5)	22.7 (1.5)	-	8.2 (0.6)
Penicillium frequentus	-	-	19.3 (18.1)	-	-	-	15.5 (18.0)	-
Trichoderma harzianum	-	-	9.6 (9.0)	-	-	9.0 (0.6)	6.0 (8.0)	-
Trichoderma viride	6.7 (1.0)	8.6 (0.6)	-	15.7 (0.8)	28.5 (37.2)	-	-	6.0 (1.2)
Sterile white	10.8 (1.6)	8.6 (0.6)	-	10.5 (0.5)	-	-	12.0 (14.0)	6.0 (1.5)
Sterile orange	8.1 (1.2)	8.6 (0.6)	10.5 (0.5)	-	9.0 (0.6)	-	8.1 (1.2)	-

Table 3.14. Effect of herbicides on the fungal population (per gram dry soil) of rhizospheric (R)x10^4 and non-rhizospheric (N)x10^3 soils of potato. Values are mean of four determinations.

Isolates	Control		Benthiocarb		2, 4-D		Fluchloralin	
	R	N	R	N	R	N	R	N
Arthrobotrys conoides	-	1.5	-	-	-	-	-	-
Arthrobotrys oligospora	-	1.5	-	-	-	-	-	-
Arthrobotyrs arthrobotryoides	-	-	-	1.5	-	1.5	-	-
Cladosporium cladosporioides	34.0	3.1	18.0	15.6	43.8	27.2	44.1	28.0
Fusarium oxysporum	3.9	6.6	8.0	5.5	7.0	4.0	4.5	1.5
Fusarium poae	7.1	-	-	-	-	-	-	-
Fusarium solani	3.0	2.3	-	-	-	-	4.5	1.5
Fusarium moniliforme	-	-	7.5	-	-	-	-	-
Gonytrichum machrocladum	-	-	-	-	-	-	5.0	-
Humicola fuscoatra	-	-	-	2.2	-	-	-	-
Monilia sp.	2.0	2.9	-	-	-	-	-	-
Mortierella minutissima	-	1.5	-	-	-	2.2	-	-
Mucor hiemalis	43.6	2.3	13.5	4.0	18.0	-	10.0	6.5
Mucor plumbeus	22.6	6.8	5.0	-	2.0	1.5	1.9	1.5
Mucor racemosus	15.3	3.0	3.0	3.0	2.3	-	1.9	-
Nectria ventricosa	-	-	-	-	-	2.2	-	-
Oidiodendron echinulatum	-	-	3.0	-	-	-	-	-
Penicillium brevicompactum	24.8	4.5		2.2	-	4.2	-	5.0
Penicillium chrysogenum	19.4	6.1	3.0	7.0	13.8	6.9	3.0	1.5
Penicillium frequentans	-	-	0.6	-	-	-	4.5	-
Periconia macrospinosa	-	-	-	-	-	-	-	2.2
Trichoderma harzianum	-	1.5	2.2	2.2	-	4.3	3.9	4.5
Trichoderma viride	2.5	2.9	2.2	2.2	10.7	-	-	-
Sterile white	4.0	2.0	2.0	5.5	8.0	8.1	5.0	5.9
Sterile orange	-	12.8	-	5.8	-	4.8	2.2	5.9

are given in table 3.2. R/S ratio for fungi varied between 9 and 34. In case of bacteria it ranged between 19 and 76.

Fungi isolated from the rhizosphere and non-rhizosphere soil of herbicide treated and control plot are given in Table 3.9 to 3.14. Arthrobotrys orthrobotryoides, Fusarium moniliforme, Gonytrichum machrocladium, Humicola fuscoatra, Necteria ventricosa and Periconia macrospinosa were isolated only from herbicides treated plants. Fusarium poae, F. moniliforme, Gonytrichum Macrocladium, Oidiodendron echinulatum and Penicillium frequentans were isolated only from rhizospheric soils, while Arthrobotrys conoides, A. oligospora, A. orthrobotryoides, Humicola fuscoatra, Mortierella minutissima and Necteria ventricosa were restricted to non-rhizospheric soils only. Cladosporium cladosporioides, Fusarium oxysporum, F. solani, Mucor hiemalis, M. plumbeus, M. racemosus, Penicillium brevicompactum, P. chrysogenum, Trichoderma harzianum, T. viride and sterile forms were common to rhizosphere as well as non-rhizosphere soils irrespective of the treatments.

DISCUSSION

Fungicides treated plants harboured less population in comparison to control throughout study period. Similar results have been reported by several other workers (Srivastava et al. 1970; Kuthubutheen, 1979; Abdelfattah et al. 1982; Doneche et al. 1983). Fast and rapid recovery of

bacteria may be attributed to their tolerance to the action of fungicides (Peeples, 1974; Chaube, 1985) and the capacity of quick growth rate (Wainwright and Pugh, 1975). The section of population susceptible to fungicides might have been eliminated, however, the resistant forms would have multiplied faster to occupy the niche vacated by the death of susceptible bacteria. Possibly this could be one of the reason for fast recovery in total bacterial population. It could be inferred that the adverse effect of fungicides was severe and prolonged in the case of rhizospheric fungi (Fig. 3.1).It is established that foliar spray of chemicals affect the chemical composition and quantity of root exudates (Vrany et al. 1962; Balasubramanian and Rangaswami, 1967). In many plants, the chemicals sprayed on the plant surfaces are absorbed and are translocated through the plant body and are excreted through the root (Linder and Mitchell, 1963). The results of present study demonstrate the possibility of exudation of fungicidal substances in the rhizosphere region as is evident from the significant drop in the fungal population in the rhizosphere region of the fungicide treated plants (Fig.3.1). Except the initial drop, the temporal variation in bacterial population was almost similar in treated as well as in control soils. In the case of fungi, however, fungicidal effect being more pronounced, the general pattern of variation did not follow similar pattern. Continued increase in the microbial

population of untreated soils could be attributed to the more favourable temperature and moisture conditions during later part of the study (Fig.1). This is in general conformity with the earlier studies of Mishra and Srivastava (1969) and Srivastava and Mishra (1971). The higher microbial population in rhizosphere could be attributed to rhizosphere effect. R/S values recorded in the present study were generally in the same range as reported by Zukovskaya (1941) and Rangaswami and Vasantharajan (1961).Generally R/S values of fungi was lower in fungicide treated plants indicating that fungi of rhizosphere region were more severely influenced as compared to the soil fungi which further strenghens our influence on possibility of excretion of fungicides through the roots. R/S of bacteria was also affected by the fungicide treatments. Except at the first sampling the R/S of bacteria was higher in benomyl and mancozeb treatments, while in copper oxychloride treated plots it was lower than the control. This indicates a possibility that probably benomyl and mancozeb affected less adversely the rhizosphere bacteria as compared to the non-rhizosphere bacteria while the reverse was true in the case of copper oxychloride.

Species composition of fungi isolated from rhizosphere and non-rhizosphere soil during the study was similar to that of Sudha (1979) and Chandra et al. (1982). Srivastava and Dayal (1981) also reported change in the structure of fungal community following fungicidal application. It was

found that the population of dominant rhizosphere fungi like C. cladosporioides, F. poae, M. hiemalis, M. plumbeus, M. racemosus, P. brevicompactum and P. chrysogenum was drastically reduced in the fungicide treated sets. On the other hand, fungi with lower population were least affected. This also suggests that the fungicides treatment adversely altered the rhizosphere environment for the fungal community.

Results of the study provides indirect evidences on the possibility of exudation of fungicidal substances from the roots of fungicide treated potato plants. The fungal and bacterial population of rhizosphere of fungicide treated plants is drastically reduced and significantly altered in species composition.

Chen et al. (1981) suggested that in herbicide treatment the usual pattern is a decrease in total numbers in the initial stage, followed by a return to normal or even an increase in numbers. Initial drop in microbial population may be attributed to the toxicity of herbicides, recovery was probably due to dilution, leaching and physicochemical or biological break down of herbicides in the soils. Stimulation of fungal population in 2,4-D and fluchloralin treated plots suggests the possibility of utilization of these herbicides by fungi (Chen et al. 1981). This may also be partially attributed to the production of dead organic matter due to killing of weeds as a result of

herbicide application. Contrary to our results Olson et al. (1984) reported that trifluoralin had no effect on microbial population in either general soil or in the rhizosphere. Zelles et al. (1985) noted that most herbicides at low doses stimulate the microbial activity, however, at higher doses they are generally inhibitory.

Dominant fungi like C. cladosporioides, F. oxysporum, Mucor spp., Penicillium spp. and Trichoderma spp. were found throughout the study period. suggesting that these fungi are more resistant to herbicides. Cullimore (1971) also reported that Fusarium oxysporum, Trichoderma lignorum, and Penicillium sp. were resistant for herbicides. Penicillium and Trichoderma are also capable of herbicide degradation (Kaufman, 1966).

The results of this study demonstrate that the microbial population of soil and rhizosphere is significantly altered after application of herbicides, however, they recover steadily. As evident from the results, till the time of harvest the microbial population of soils treated with herbicides remained lower than control. It appears that the spray of biocides changes fungal community structure and thus adversely affects various fungi mediated processes of soil and rhizosphere. This may harmfully affect the process of nutrient release and aggravate the soil pathogens due to indiscriminate killing of antagonistic saprotrophs of the root region. The effect of herbicides and

fungicides on the soil microbes depends on the type of formulation dose and number of application, physico-chemical characteristics of the soil and species composition of the soil microbial community. A survey of literature on the subject reveals that the same or similar formulation of pesticides may be inhibitory in one set of condition while they may be stimulatory in other condition (Wainwright, 1978; Kuthubutheen andPugh, 1979; Tu, 1981; Zelles et al. 1981). It is suggested that before recommending any herbicide or fungicide a comprehensive study on the effect of the chemicals on soil microbes be ascertained.

CHAPTER IV

INFLUENCE OF FUNGICIDES AND HERBICIDES ON COLONY GROWTH SPORE GERMINATION AND GERM TUBE ELONGATION OF *Alternaria alternata*

INTRODUCTION

Alternaria alternata (Fr.) Kreissler causes brown leaf spot disease of potato. It generally affects the above ground parts causing serious loss in the yield. Recently the fungus was reported to cause black pit disease of potato tuber also (Droby et al. 1984 a,b). A. alternata has been reported as a leaf pathogen on a number of other hosts, which include crops and trees of immense economic value (Sarbhoy et al. 1975;1980; Appendix 1).

Use of chemicals appear to be the only practical method to control the pathogen at the present moment and thereby to realize the full yield potential of the crop. During past a number of chemicals has been used against the pathogen with varying results (Vyas and Singh, 1986; Altman and Campbell, 1977). A survey of the literature pertaining to the studies on influence of fungicides and herbicides on fungi reveals that very few studies are available on the subject and for the better understanding of the behaviour and growth of fungi in response to these chemicals more studies are needed. Some workers have studied the effect of fungicides on plant pathogens. Russell (1965) studied toxicity of fungicides against Alternaria sp. infecting sugarbeet and Chemawat and Prasad (1969) investigated the efficacy of fungicides against Alternaria blight of Cuminum cyminin. In laboratory studies Mathur and Sarbhoy (1983) found aureofungin to be most effective fungicide against

A. alternata. Duncan (1985) reported that matalaxyl, captafol and dichlofluanid retarted the germ tube production and germination of oospore of Phytophthora fragariae on agar medium.

Affect of herbicides on fungi has also been studied by some workers; Hsia and Christensen (1951) reported both stimulatory and inhibitory effect of 2,4-D on Helminthosporium sativum, which was related to the formulation and concentration of 2,4-D. Wilkinson and Lucas (1969) found that gramaxone inhibited the spore germination and mycelial growth of Rhizopus stolonifer. Katan and Eshel (1973) found increase in the incidence of Fusarium wilt in tomatoes by the application of 2,4-D. Karr et al. (1979) reported that with few exceptions herbicides inhibit the radial growth of Drechslera cynodontes, Pythium aphanidermatum, Rhizoctonia solani and Sclerotinia homoeocarpa on agar medium and also delay the sporulation. Hodges (1981) reported that some herbicides inhibit while others have no effect on conidial germination, germ tube growth, mycelial growth and conidial production of Drechslera sorokiniana.

The work presented here was aimed to determine the influence of fungicides and herbicides on the biology of A. alternata; specific observation include the effect of the fungicides and herbicides on spore germination, germ tube growth and linear extention of colony on agar medium.

REVIEW OF LITERATURE

Richards (1948) found that 2,4-D inhibited the colony growth at high concentration and stimulated at low concentration. Bever and Slife (1948) also reported inhibitory and stimulatory effect of 2,4-D herbicide on culture medium. Hsia and Christensen (1951) added ammonium salt of 2,4-D in PDA medium and found that at higher concentrations the growth of Helminthosporium sativum was inhibited in proportion to the concentration of herbicide in medium, at low concentration however, the colony growth was stimulated. Wilkinson and Lucas (1969) studied the efffect of some commercial herbicides on the growth of fungi. They found that herbicides affect the growth of fungi which include suppression of spore germination inhibition of linear extension of mycelia, production of abnormalities in growth habit and in pattern of spore production. They further observed that linuron and paraquat were more inhibitory than NCPA and simazine. Muling and Griffiths (1974) found that fungicides reduced disease incidence by inhibiting the popopulation of Colletotrichum on coffee. Hodges (1977, 1981, 1982) studied the effect of herbicides on conidial cells. At low concentration the germination of conidia was not affected whereas stimulation in germ tube growth and branching of germ tube occurred. Abdalla and Manci (1979) reported that low concentrations of herbicide stomp were more effective in liquid and solid cultures in suppressing Pythium spp. The

fungi survived at 1000 ppm stomp in solid media. A reduction of 91.44% occurred at 3000 ppm concentration of stomp. The development of oogonia and sporangia was greatly stimulated in 100 ppm stomp incorporated with solid media. Karr et al. (1979) studied the effect of herbicides on the growth of Rhizoctonia solani, Sclerotonia homoeocarpa and Pythium aphanidermatum at different temperatures. At low concentration all the herbicides stimulated the fungal growth and the degree of inhibition increased in proportion to the concentration of herbicides. Wilding and Brobyn (1980) found that fungicides viz., benomyl, ethirimal, tridemorph, captafol, captan, fentin acetate, maneb, mancozeb, thiram and zineb inhibited the germination of conidia of Entomophthora aphides at the recommended doses.Fitzell (1981) reported that regular application of benomyl significantly reduced the population of Colletotrichum glocosporioides on mango leaves. Mathur and Sarbhoy (1983) evaluated nine fungicides for their comparative efficacy against Alternaria alternata using spore germination and poisoned food technique. Aureofungin, fentin acetate and fentin chloride showed inhibitory effect, Tay and Wood (1983) evaluated eight fungicides against Phytophthora palmivora. At 100 ppm cuprous oxide, cyclotoximide and mancozeb were highly toxic at most stages of development of the fungus. Kader et al. (1983) studied the effect of bavistin, catoran and curacron incorporated with agar medium on fungal growth. They found that

the herbicides inhibited the growth of fungi. Duncan (1985) extracted Oospores of Phytophthora sp. from untreated roots of infected plant and placed them on agar incorporating the fungicides. He found that fungicides reduced germ tube production in water but not in buffered agar. Singh and Bhowmik (1985) found that fungicides reduced the germination of spore of Alternaria sp. and A. brassicae. They reported that difolatan was the most effective against the pathogens. Sharma and Verma (1985) reported that PCNB and bavistin reduced the colony growth of Sclerotium sp. on agar medium. The inhibition was dose dependent. Hoshimoto et al. (1986) found that fungicides inhibited the spore germination of several fungi even at low concentration (100 ppm). They also noticed abnormality in branching of germ tube. Casale and Hart (1986) found that metribuzin and diuron inhibited the colony growth of Sclerotinia sclerotiorum on agar medium at 50 ug/ml while simazine and atrazine were less effective. Hickisch and Nguyen (1987) found that herbicides were more inhibitory in liquid medium even when added in very low amount compared to solid medium on growing fungi.

MATERIALS AND METHODS

A. alternata was isolated on Potato Dexbose Agar (P.D.A:) medium from an infected potato plant and pure culture was maintained on PDA (Potato 200.00 g, dextrose 20.0g, agar 20.0g and distilled water 1 litre).

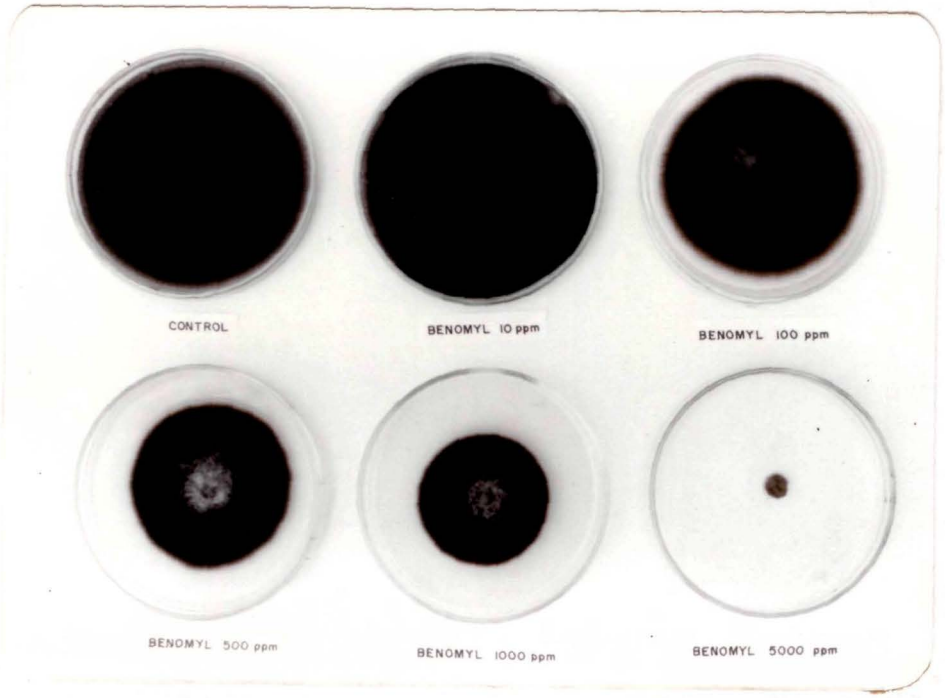
Fungal growth measured as linear extension on agar :

The details about chemical formulation and manufacturers of fungicides and herbicides are given in table 2.1. A series of fungicides and herbicides concentration (0, 10, 100, 500, 1000 and 5000 ppm) was prepared by incorporating them in PDA. 20 ml of each control and treated PDA was dispersed into petriplates (90 mm diameter). 5 replicates were maintained for each concentration and control. About 3 h after the plates were poured, a mycelial disk of 5 mm diameter taken from the perifery of a 5 days old culture of A. alternata, growing on PDA was transferred to the centre of each plate. The plates were incubated at 25°C and fungal growth rate was determined by measuring the diameter of colony at 24 h intervals. Two measurements at right angle to one another were made each time. Measurement were continued until the fungus had calculated upto the perifery of the plate or for a maximum of seven days.

Spore germination and germ tube elongation :

Fungicides and herbicides solutions were prepared in distilled water at the concentrations of 10, 100, 500, 1000 and 5000 ppm. The spores taken from a 5 days old culture were suspended in the above solutions. From each of the suspension a hanging drop was made on a cavity slide. The cavities were sealed with vaseline. Five slides were prepared for each treatment. Slides were incubated at 25°C in dark. Observations were taken at the interval of 24, 48

PLATE.1 COLONY GROWTH



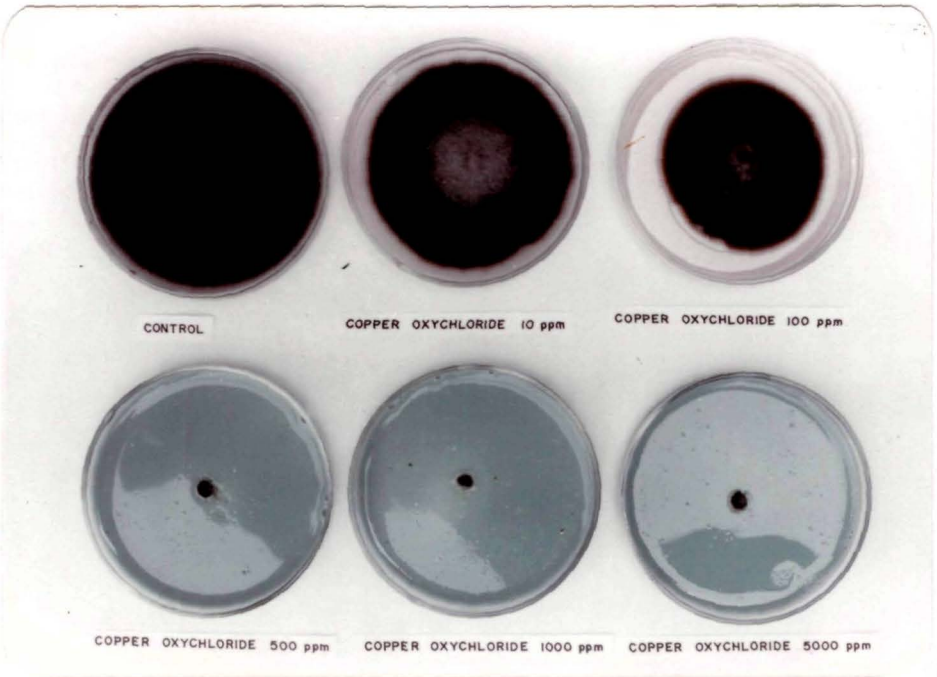
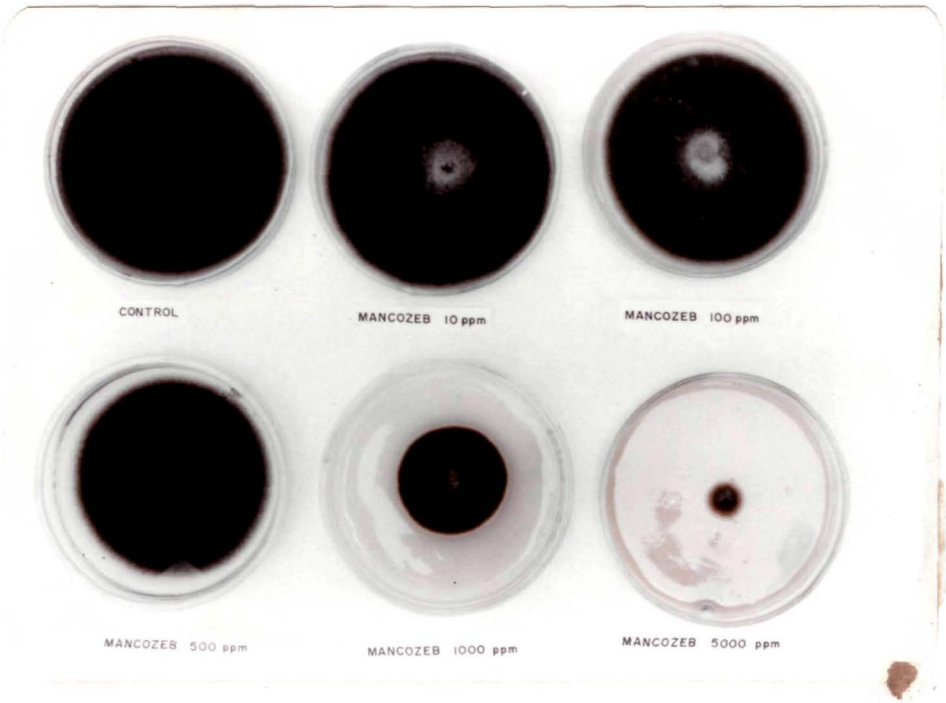


PLATE.2 COLONY GROWTH



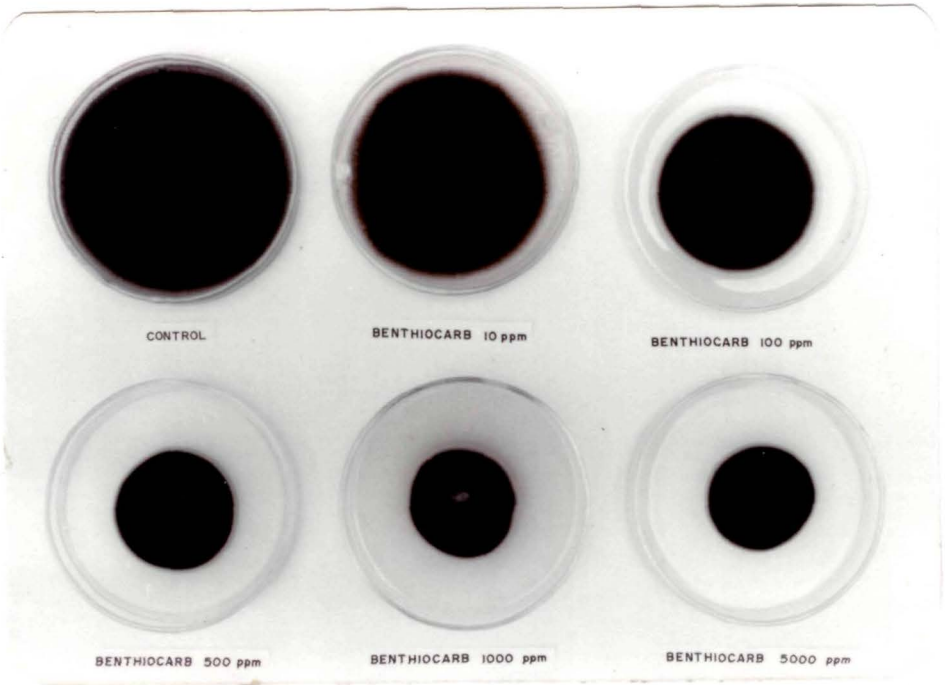
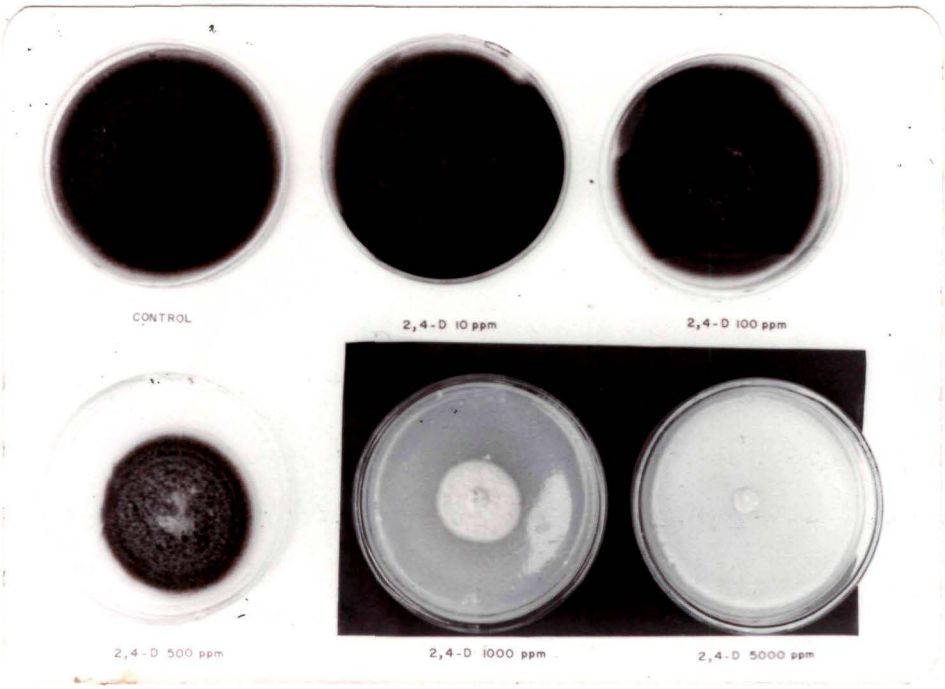
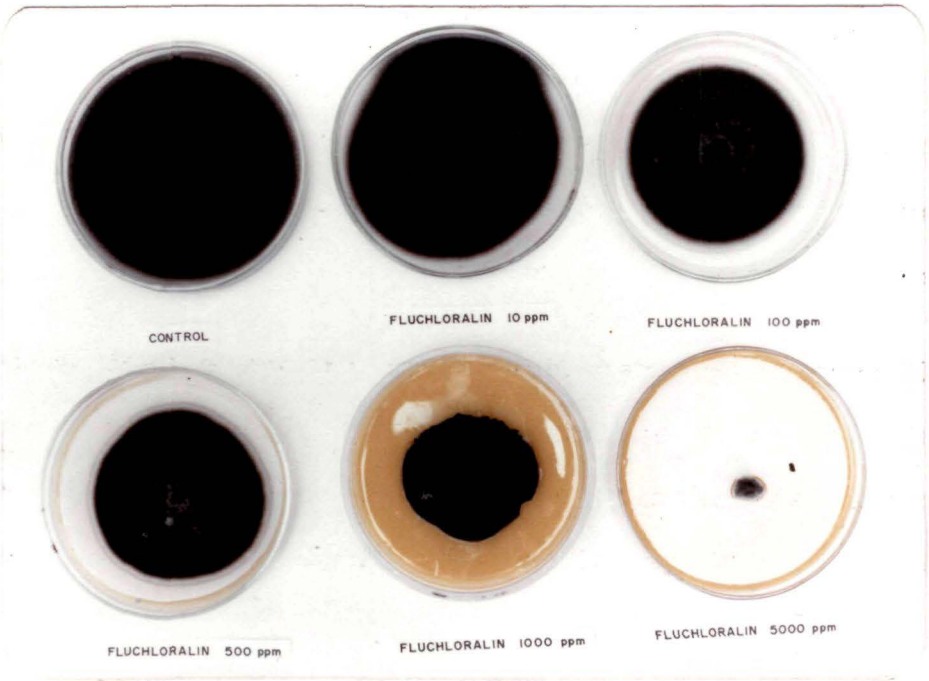


PLATE 3 COLONY GROWTH





and 72 h. Germination and germ tube growth was observed in ten randomly choosen platforms from each of the slides at a microscopic projection of 10 x 10.

RESULTS

Linear extension on agar :

Rate of fungal growth on PDA medium containing fungicides is depicted in Table 4.1, 4.2, 4.3 and figs. 4.1 and 4.3 . All the fungicides inhibited the growth of the fungi and the degree of inhibition increased in proportion to concentration of the fungicides. Towards the end of the experiment on the benomyl and mancozeb containing medium at the concentration of 10 ppm, colony diameter was 75.0 and 81.5 mm, on the other hand at the concentration of 5000 ppm colony growth was totally inhibited in both the treatments. On copper oxychloride incorporated medium colony developed at the concentration of 10 and 100 ppm, while at 500, 1000 and 5000 ppm colony growth did not occur.

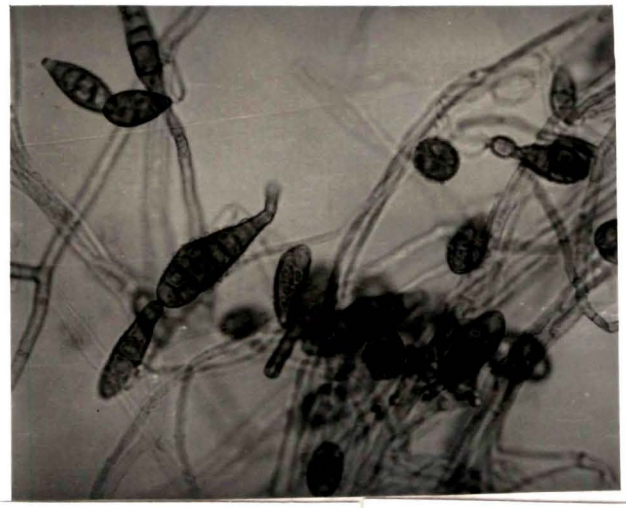
All the herbicides showed inhibitory effect which was dose dependent except in the case of 2,4-D which was found slightly stimulatory at lowest concentration (10 ppm). At 100, 500 and 1000 ppm all the herbicides showed similar

Plate 4 Change in spore structure and size of *A. alternata* after incorporating the fungicides and herbicides in media.

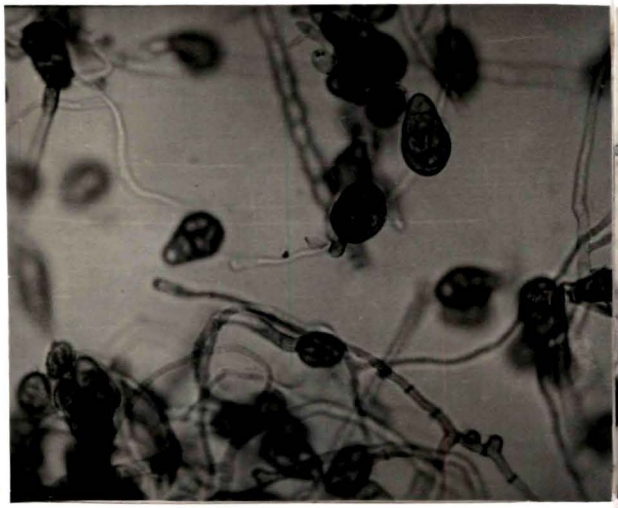
A. Control
B. Benomyl
C. Copper oxychloride
D. Mancozeb
E. Benthiocarb
F. 2,4-D
G. Fluchloralin

PLATE.4

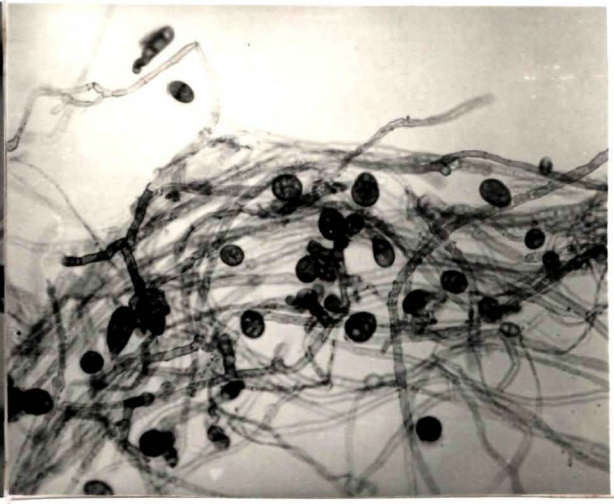
A



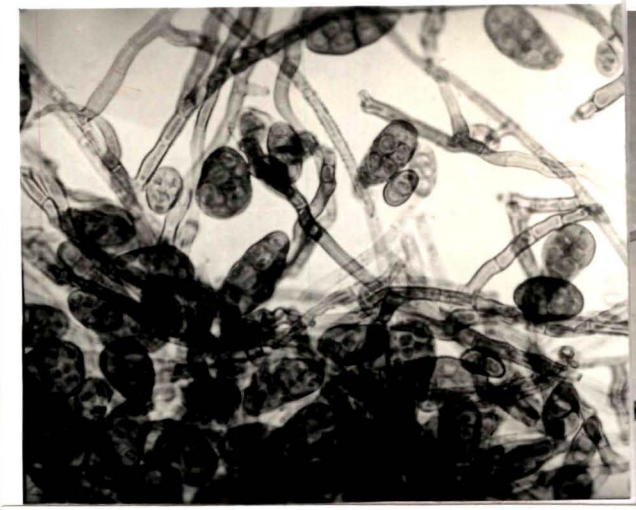
B



E



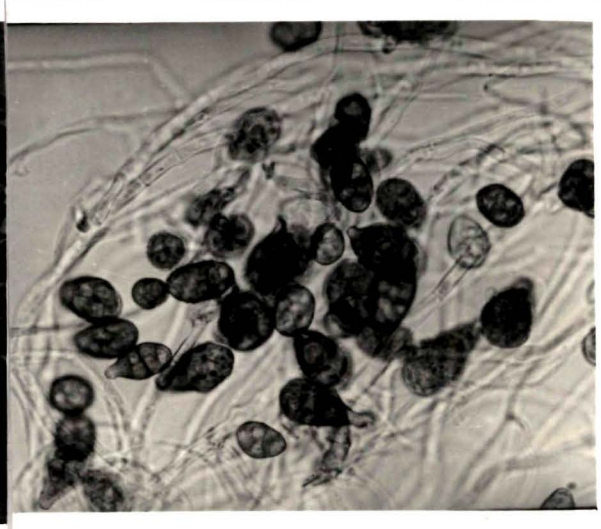
C



F

D

G



effect on the growth of colony which was slower than the control. At the 5000 ppm the growth was totally checked in case of 2,4-D, however, on the fluchloralin and benthiocarb treated plates some growth was recorded.

In addition to affecting the rate of colony growth fungicides and herbicides also promoted abnormalities in colony structure, sporulation and spore structure as shown in plate 4. At lower concentrations there were no abnormalities in the spore structure. Therefore, for observation of spore abnormalities the highest concentration of treatments in which fungal colony grew was selected. Spores of A. alternata growing on untreated PDA had mean length 27.5 µm width 9.5 µm; number of horizontal septa 5.0 and vertical septa were 3.0 and 2.0 respectively. In copper oxychloride treatment mean length, mean width, mean number of horizontal septa and mean number of vertical septa in spores were 26.25 µm, 10.75 µm, 4.0 and 2.0 respectively. While in mancozeb treated culture the corresponding values were 14.15 µm, 10.28 µm, 1.0 and 0.0. The spore wall in copper oxychloride treated culture became dark black and thicker than the control.

At 5000 ppm concentration in 2,4-D treated medium sporulation was prohibited and colour of colony became white. Herbicides also changed the spore structure. In 2,4-D treated cultures mean length of spore decreased by 3.27 µm and mean width increased by 1.80 µm. Number of horizontal

septa also decreased but number of vertical septa was not affected. In case of benthiocarb, spore length decreased considerably while no marked change in width was found. In fluchloralin the mean length of spore was 17.12 µm and mean width 12.65 µm. In benthiocarb and fluchloralin treated cultures the mean number of horizontal septa were 1.0 and no vertical septa were observed.

Germination of spore :

Figs. 4.1 and 4.2 and tables 4.1 and 4.8 shows the effect of fungicides and herbicides on the germination of spore. Under control sets i.e. in the absence of fungicides and herbicides 100% spore germination was recorded after 24 h. All the three fungicides inhibited the spore germination and the percentage inhibition increased with increasing concentration of the fungicides. After 72 h at 5000 ppm 18.30% spore germination was recorded in benomyl while at the same concentration in copper oxychloride and mancozeb treatments germination did not occur. After 72 h at 10, 100, 500 and 1000 ppm concentration of benomyl the germination of spore was 92, 89, 82, and 65 percent respectively. In copper oxychloride treated spores after 72 h at 10, 100, 500 and 1000 ppm concentrations the spore germination was 93.7, 91.2, 85 and 62 per cent respectively. While in case of mancozeb treatment at interval of 72 h the per cent germination in different concentrations (i.e. 10, 100, 500 and 1000 ppm) was 93, 87, 80 and 60 per cent. Periodic observation of

spore germination at the intervals of 24 h showed that a large proportion of spores germinated within 24 h and only a small proportion germinated during next 48 h.

Herbicides also inhibited the spore germination and percentage inhibition increased with increasing concentration of the herbicides in solution. In the case of 2,4-D at the concentration 10, 100, 500 and 1000 ppm the germination at 24 h was 96, 92, 86 and 54 per cent and at 72 h it became 99, 96, 89 and 61 per cent, but at 5000 ppm spores did not germinate. Benthiocarb did not have any marked inhitory effect on spore germination; in the different concentrations i.e. 10, 100, 500, 1000 and 5000 ppm after 24 h 92, 92, 90, 89 and 81 per cent spore germinated and after 72 h it came 100, 100, 100, 97 and 90 per cent. In the solution containing 10, 100, 500 1000 and 5000 ppm concentration of fluchloralin after 72 h the germination was 99, 98, 95, 93 and 78 per cent respectively. In the case of herbicides also most of the germinable spores in treated sets germinated within 24 h and a very small proportion germinated afterwards.

Growth of germ tube :

Mean length of germ tube and their elongation rate are given in Fig.4.1 and 4.2 and table 4.9 and 4.10. Elongation rate of germ tube was generally inhibited by fungicides and herbicides with exception of 2,4-D and benthiocarb which were stimulatory at lower concentrations. All the

concentrations of the three fungicides, were significantly inhibitory to the growth of germ tube. The degree of inhibition increased with increasing concentration of the fungicides. At 10, 100, 500, 1000 and 5000 ppm concentration of benomyl the elongation rate of tube was 11, 8, 3 and 1,5 µm/h and mean length of germ tube after 72 h was 801, 570, 372, 201 and 113 µm respectively. At 10, 100, 500 and 1000 ppm concentration of copper oxychloride at the end of 72 h the mean length of germ tube was 763, 469, 332 and 227 µm and the germ tube elongation rates were 11, 7, 5 and 3 µm/h respectively, while corresponding values in the mancozeb treatments at the same concentrations were 822, 405, 248 and 163 um for the mean length of germ tubes and 11, 6, 3 and 2 µm/h for the germ tube elongation rate. At 5000 ppm concentration of copper oxychloride and mancozeb germ tubes did not appear.

Herbicides had both stimulatory and inhibitory effect on the germ tube growth. Benthiocarb and 2,4-D stimulated the germ tube growth atthe concentration of 10 ppm. However, both the herbicides were inhibitory at higher concentrations. Fluchloralin inhibited germ tube growth at all concentrations. At 5000 ppm concentrations of 2,4-D the spores did not germinate, however, at 10, 100, 500 and 1000 ppm the elongation rate of germ tube was 22, 16, 12 and 7 µm/h respectively. In case of benthiocarb at the concentrations of 10, 100, 500, 1000 and 5000 ppm the rate of germ tube elongation was 30, 26, 21, 15 and 9 µm/h respectively.In fluchloralin treated sets the elongation rate of germ tube in different con-

Fig. 4.1. Effect of fungicides on colony growth, spore germination and germ tube growth of A. alternata expressed an index obtained by dividing the values of treated sets by the corresponding control.

FIG-4·1

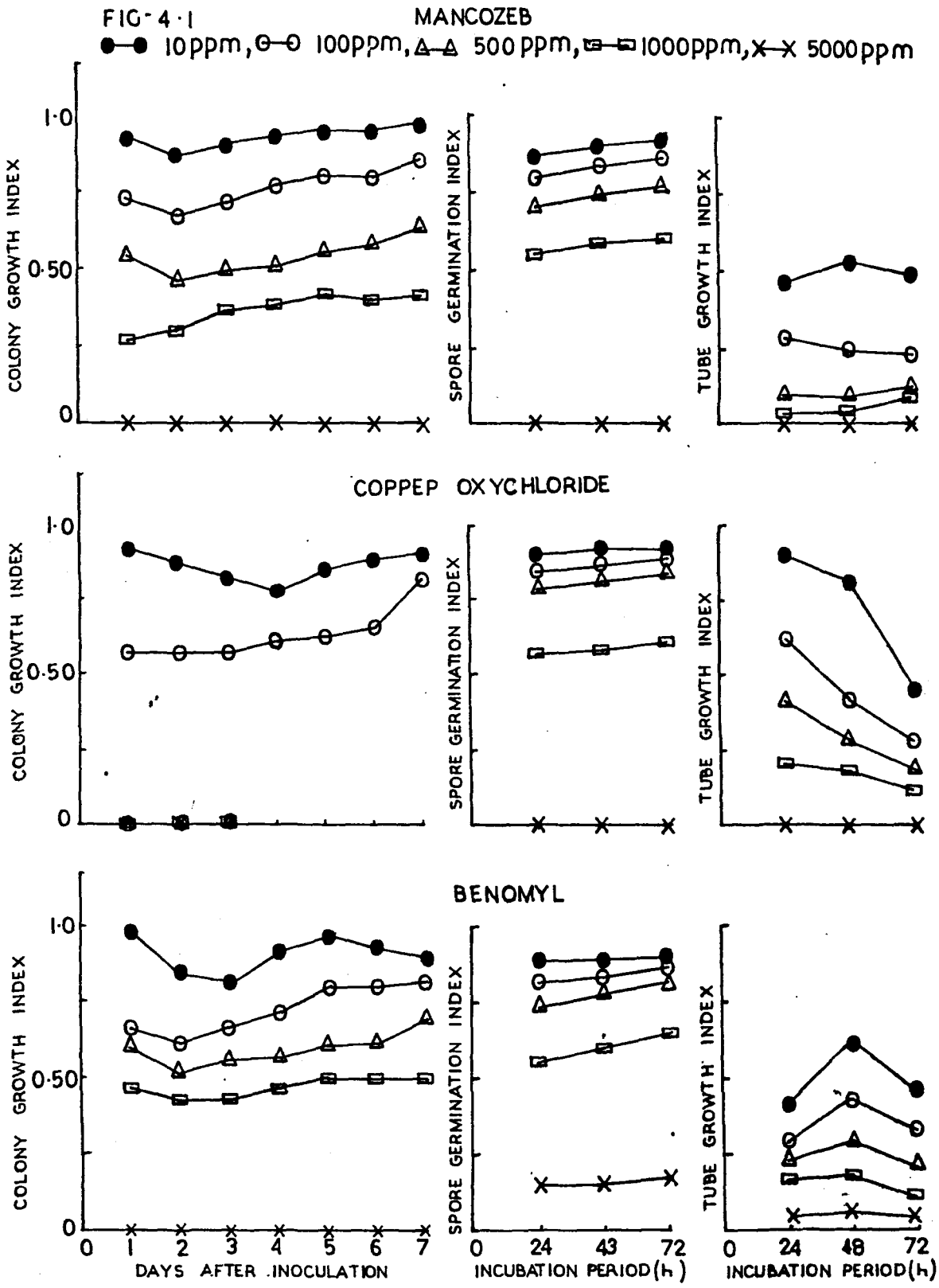

MANCOZEB
10ppm, 100ppm, 500 ppm, 1000ppm, 5000ppm
COLONY GROWTH INDEX
SPORE GERMINATION INDEX
TUBE GROWTH INDEX
1·0
0·50
0
COPPEP OXYCHLORIDE
BENOMYL
0 1 2 3 4 5 6 7
DAYS AFTER INOCULATION
0 24 43 72
INCUBATION PERIOD(h)
0 24 48 72
INCUBATION PERIOD(h)

Fig. 4.2. Effect of herbicides on colony growth spore germination and germ tube growth of A. alternata expressed an index obtained by dividing the values of treated sets by the corresponding control.

FIG 4·2

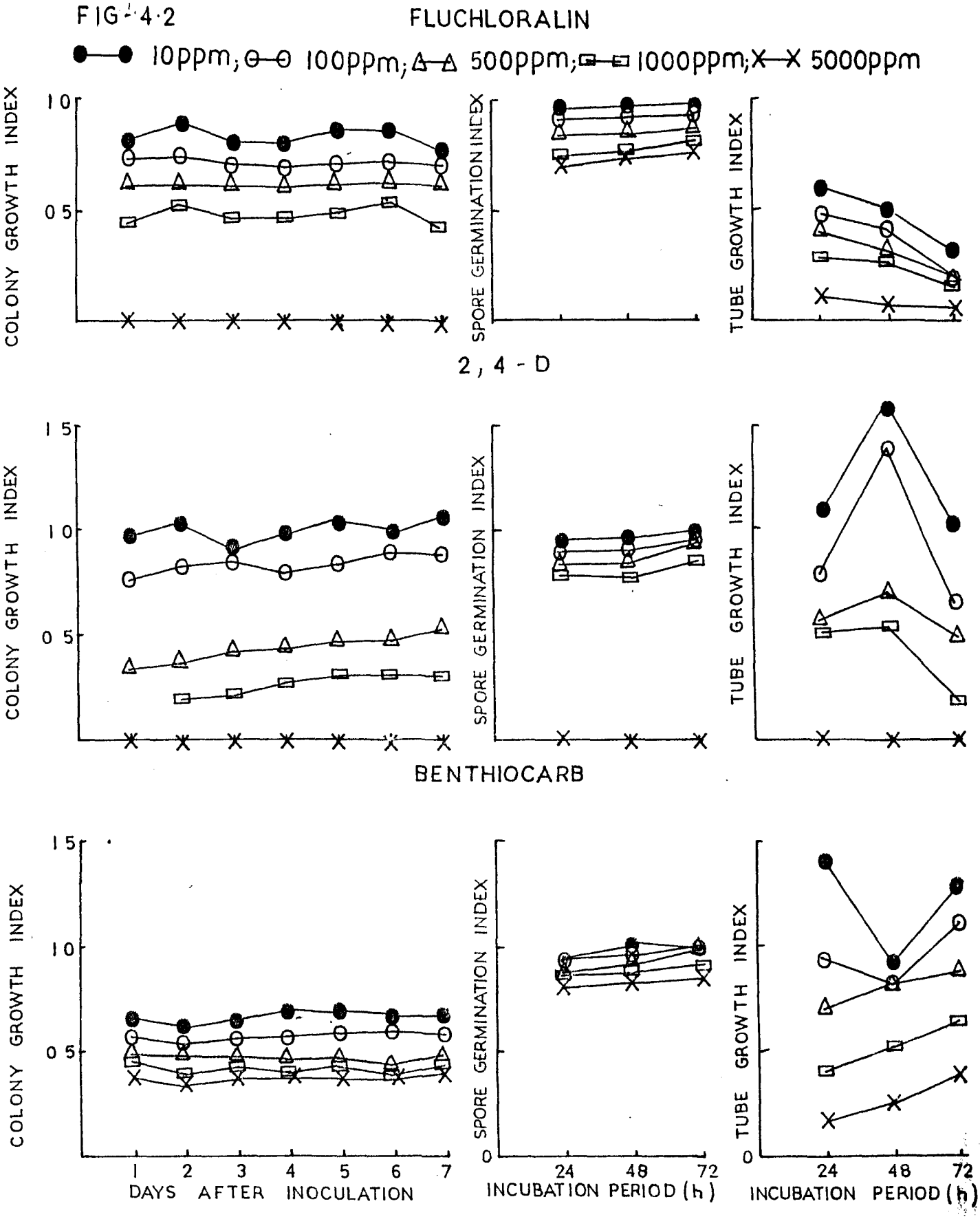

FLUCHLORALIN
10ppm; 100ppm; 500ppm; 1000ppm; 5000ppm
COLONY GROWTH INDEX
SPORE GERMINATION INDEX
TUBE GROWTH INDEX
2, 4 - D
BENTHIOCARB
DAYS AFTER INOCULATION
INCUBATION PERIOD (h)
INCUBATION PERIOD (h)

Fig. 4.3. Effect of different concentration of fungicides on colony growth (after 7 days) spore germination (after 72 h.) and germ tube growth (after 72 h.).

FIG-4·3

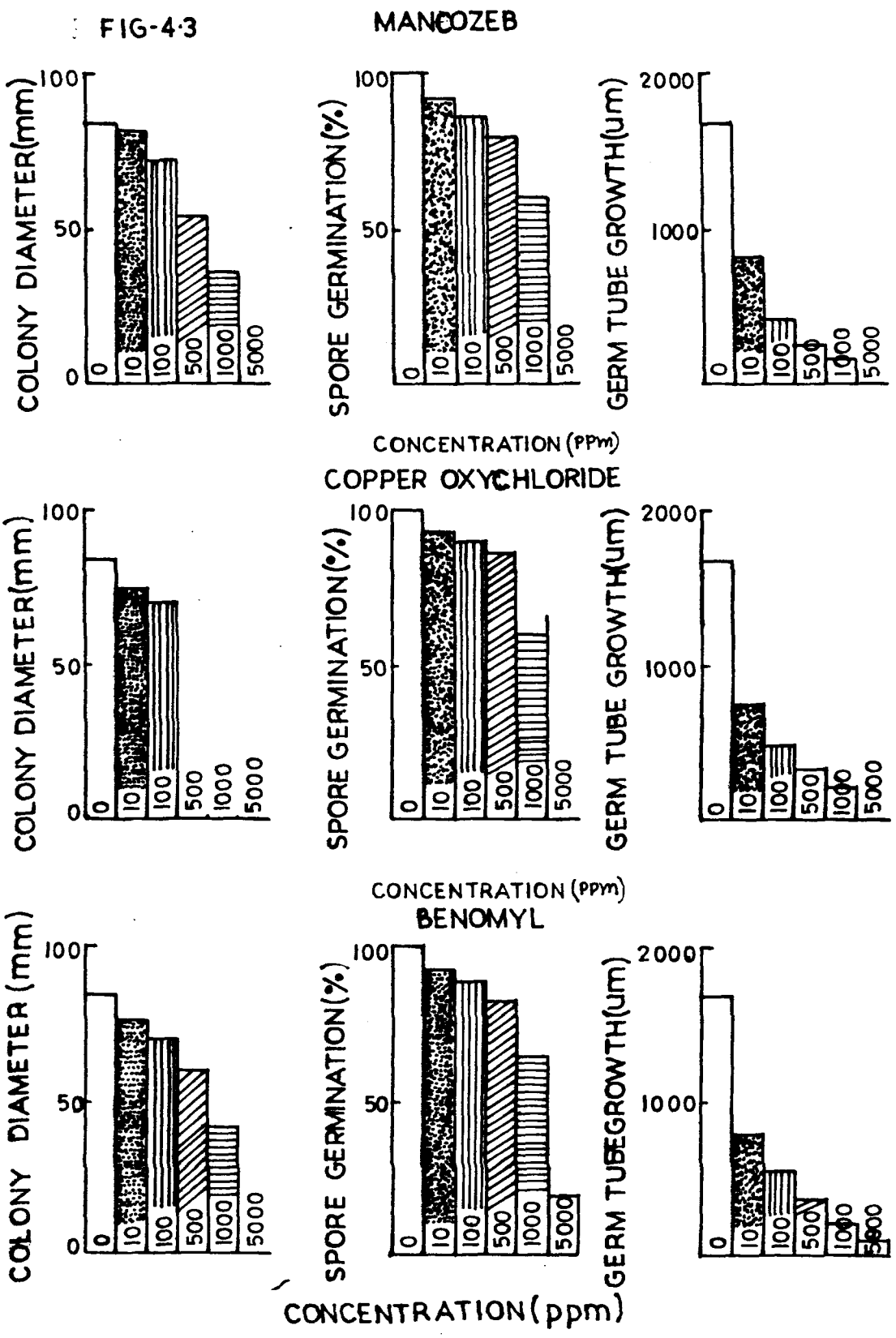
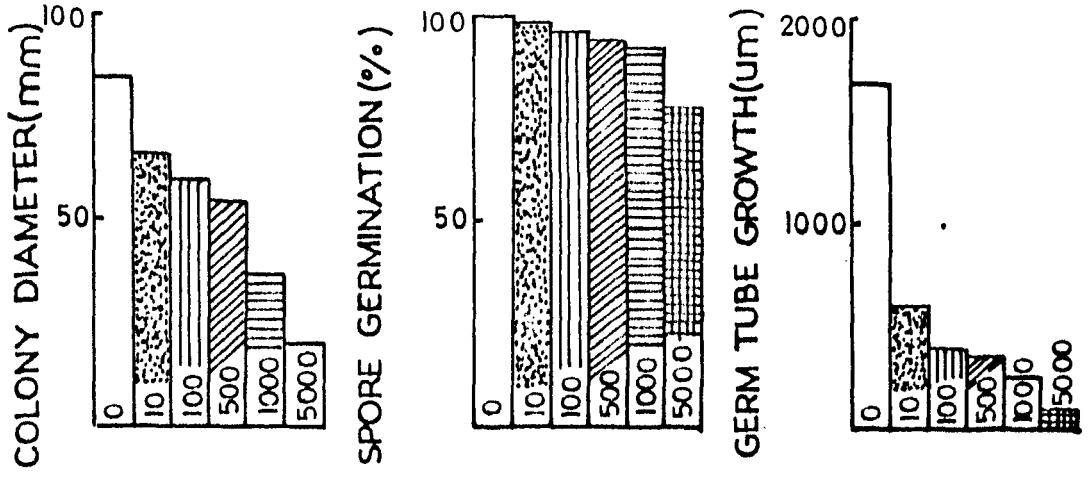

MANCOZEB
COLONY DIAMETER(mm)
SPORE GERMINATION(%)
GERM TUBE GROWTH(um)
100
50
0
2000
1000
0
10
100
500
1000
5000
CONCENTRATION (PPm)
COPPER OXYCHLORIDE
BENOMYL
CONCENTRATION (ppm)

Fig. 4.4. Effect of different concentration of herbicides on colony growth (after 7 days) spore germination (after 72 h) and germ tube growth (after 72 h).

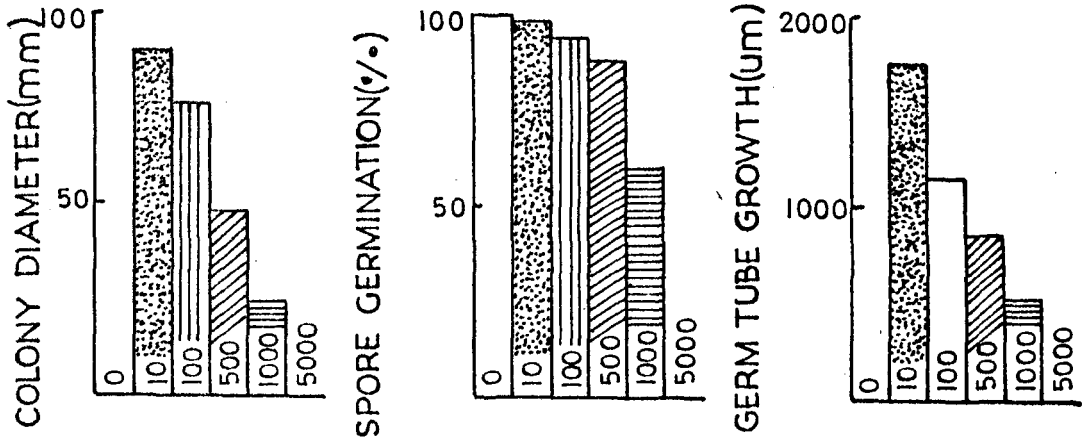
FIG-4·4

FLUCHLORALIN



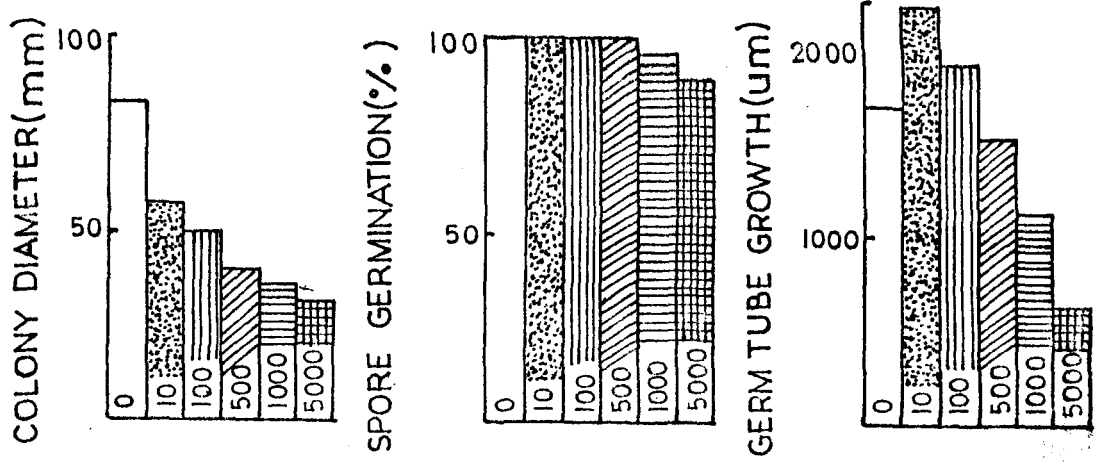
CONCENTRATION (ppm)

2 , 4 - D



CONCENTRATION (ppm)

BENTHIOCARB



CONCENTRATION(ppm)

Table 4.1. Colony diameter (mm) of *A. alternata* in various concentration of Benomyl.

Incubation period (days)	Concentrations (ppm)					
	0	10	100	500	1000	5000
1	22.9	22.7	15.6	14.2	11.2	0.0
2	35.6	30.3	22.3	18.8	15.9	0.0
3	45.6	38.0	30.6	26.6	20.4	0.0
4	55.8	51.5	40.3	32.3	26.4	0.0
5	64.8	63.5	52.4	40.2	32.7	0.0
6	76.7	72.4	61.8	48.0	39.8	0.0
7	83.0	75.0	69.7	59.5	42.2	0.0

Table 4.2. Colony diameter (mm) of A. alternata in various concentrations of Copper oxychloride.

Incubation period (days)	Concentrations (ppm)					
	0	10	100	500	1000	5000
1	22.9	21.3	13.5	0.0	0.0	0.0
2	35.6	31.0	20.7	0.0	0.0	0.0
3	45.6	37.4	26.9	0.0	0.0	0.0
4	55.8	43.9	33.7	0.0	0.0	0.0
5	64.8	55.5	41.1	0.0	0.0	0.0
6	76.7	88.3	50.2	0.0	0.0	0.0
7	83.0	74.9	69.6	0.0	0.0	0.0

Table 4.3. Colony diameter (mm) of A. alternata in various concentration of Mancozeb.

Incubation period (days)	Concentrations (ppm)					
	0	10	1000	500	1000	5000
1	22.9	21.1	17.0	13.0	6.5	0.0
2	35.6	31.3	24.3	17.2	11.1	0.0
3	45.6	41.3	33.4	23.4	17.7	0.0
4	55.8	52.5	43.5	29.7	22.1	0.0
5	64.8	62.7	52.9	37.7	27.3	0.0
6	76.7	73.3	61.6	46.8	32.1	0.0
7	83.0	81.5	71.8	54.1	35.8	0.0

Table 4.4. Colony diameter (mm) of A. alternata in various concentrations of Benthiocarb.

Incubation period (days)	Concentrations (ppm)					
	0	10	100	500	1000	5000
1	22.9	15.1	14.4	11.8	10.4	8.8
2	35.6	22.5	19.9	17.8	14.9	13.3
3	45.6	29.7	27.2	23.4	19.8	17.9
4	55.8	37.6	32.9	27.1	23.5	21.9
5	64.8	44.4	39.3	31.6	28.7	25.3
6	76.7	51.3	47.5	36.0	32.7	31.6
7	83.0	57.5	50.1	40.0	36.7	33.2

Table 4.5. Colony diameter (mm) of A. alternata in various concentrations of 2,4-D.

Incubation period (days)	Concentrations (ppm)					
	0	10	100	500	1000	5000
1	22.9	22.7	18.2	8.0	0.0	0.0
2	35.6	37.2	29.2	14.6	8.0	0.0
3	45.6	42.2	40.8	20.5	11.3	0.0
4	55.8	56.0	46.5	25.8	16.1	0.0
5	64.8	68.3	55.1	33.3	21.1	0.0
6	76.7	77.0	70.8	40.4	23.9	0.0
7	83.0	89.2	76.8	48.2	25.2	0.0

Table 4.6. Colony diameter (mm) of A. alternata in various concentrations of Fluchloralin.

Incubation period (days)	Concentrations (ppm)					
	0	10	100	500	1000	5000
1	22.9	18.4	17.0	14.8	10.7	0.0
2	35.6	31.9	26.5	22.7	18.7	0.0
3	45.6	38.7	32.2	28.6	22.0	0.0
4	55.8	46.8	39.5	35.2	27.1	0.0
5	64.8	57.2	46.6	41.5	33.3	7.0
6	76.7	68.5	55.2	51.1	38.8	10.0
7	83.0	65.8	59.8	55.3	37.8	19.1

Table 4.7. Effect of fungicides on Percentage germination of spore of *A. alternata*

Fungicides	Incubation period(h)	Concentrations (ppm)					
		0	10	100	500	1000	5000
Benomyl	24	99.4	88.0	83.2	76.0	56.0	15.2
	48	100.0	89.7	84.4	79.3	61.3	16.0
	72	100.0	91.8	89.7	82.5	65.4	18.3
Copper oxychloride	24	99.4	90.0	86.2	79.0	57.6	0.0
	48	100.0	92.0	88.4	82.5	58.5	0.0
	72	100.0	93.7	91.4	85.5	61.8	0.0
Mancozeb	24	99.4	87.7	81.3	71.1	56.5	0.0
	48	100.0	90.3	86.0	76.7	59.7	0.0
	72	100.0	92.7	87.4	79.6	80.4	0.0

Table 4.8. Effect of herbicides on Percentage germination of spore of *A. alternata*

Herbicides	Incubation period(h)	Concentration (ppm)					
		0	10	100	500	1000	5000
Benthiocarb	24	99.4	91.6	96.6	90.0	88.5	80.6
	48	100.00	100.0	99.4	98.8	92.0	80.7
	72	100.0	100.0	100.0	100.0	97.3	90.0
2, 4-D	24	99.4	95.8	91.8	85.9	54.2	0.0
	48	100.0	98.2	94.1	88.8	56.4	0.0
	72	100.0	99.0	95.6	88.9	61.4	0.0
Fluchloralin	24	99.4	95.8	93.7	85.4	76.0	70.0
	48	100.0	97.0	96.1	91.2	90.5	75.9
	72	100.0	98.7	97.6	94.8	93.2	77.9

Table 4.9. Effects of fungicides on growth of germ tube (length in μm) of A. alternata.

Fungicides	Incubation period(h)	Concentrations (ppm) 0	10	100	500	1000	5000
Benomyl	24	436.1	182.1	129.4	108.3	70.0	23.5
	48	831.5	519.5	374.6	253.0	151.6	66.1
	72	1675.0	801.2	569.6	371.7	200.8	112.5
Copper ocychloride	24	436.1	399.0	271.4	185.0	94.4	0.0
	48	831.5	688.6	353.9	242.0	165.8	0.0
	72	1675.0	763.4	469.2	332.7	227.1	0.0
Mancozeb	24	436.1	207.3	124.8	42.3	15.4	0.0
	48	831.5	452.3	215.0	90.8	45.2	0.0
	72	1675.0	821.5	405.4	247.7	163.0	0.0

Table 4.10. Effect of herbicides on growth of germ tube (length in μm) of *A. alternata*.

Herbicides	Incubation period (h)	Concentrations (ppm)					
		0	10	100	500	1000	5000
Benthiocarb	24	436.0	615.2	419.4	319.1	173.8	82.6
	48	831.5	780.5	725.0	720.3	448.8	208.1
	72	1675.0	2182.3	1878.6	1529.2	1114.1	628.3
2, 4-D	24	136.0	485.0	348.3	251.3	233.9	0.0
	48	831.5	1310.7	1071.4	587.5	444.4	0.0
	72	1675.0	1695.8	1151.3	851.8	529.7	0.0
Fluchloralin	24	436.0	273.8	204.6	208.5	147.9	40.3
	48	831.5	448.4	358.3	272.7	244.8	65.8
	72	1675.0	578.8	379.4	370.6	285.3	100.5

centrations i.e. 10, 100, 500, 1000 and 5000 ppm was 8, 5, 5, 4 and 1 um/h respectively.

DISCUSSION

It is well documented that fungicides are toxic against fungi, however, toxicity of fungicides varies depending on the chemical formulation of fungicides, species of fungi and also the climatic and edaphic factors at the application site. General tendency of dose dependent decrease in colony growth (Fig.4.1) shows that the inhibition was directly related with quantity of the fungicides. Similar results have been reported in cases of A. alternata, Sclerotium rolfsii and Phytophthora palmivora using different fungicides (Mathur and Sarbhoy, 1983; Sharma and Verma, 1985; and Tey and Wood, 1983). The three fungicides differed in their effect on the growth of the fungi which was more pronounced atthe higher concentrations. In general, copper fungicide was more toxic than the other two fungicides (Fig. 4.1). Mulinge and Griffith (1977) also observed that copper fungicide was more effective against the Coffee rust than benomyl and captafol. A number of other workers has also reported that different fungicides differ in their effect on the growth of fungi (Wilding and Brobyn, 1980; Singh and Bhowmik, 1985; Ramchandran and Sarma, 1985).

Results depicted in fig. 4.1 indicate that the effect of the fungicides on different stages of growth of

the fungus varied. In case of all the fungicides, the germ tube growth was most adversely affected followed by colony growth and spore germination. Mycelial growth was totally stopped at 5000 ppm of the fungicides, however, in case of benomyl, 18.3% of spores could germinate at this concentration (Fig.4.1). This shows that the actively growing mycelia of A. alternata are more severely affected than that of the comparatively thick walled spores. Similar findings have also been reported by Mathur and Sarbhoy (1983) in case of fentin acetate and fentin chloride fungicide, however, they did not elaborate their findings. From this result it could be inferred that the fungal propagules found in the form of mycelia are likely to be more severely affected by the fungicides than that of the spores. Tey and Wood (1983) while studying the effect of fungicide on Phytophthora palmivora also observed that actively growing mycelia and thin walled structures like zoospores are more severely affected by the fungicides.

Herbicides, benthiocarb and fluchloralin inhibited the fungal growth which was dose dependent. However, 2,4-D was stimulatory at low concentrations and inhibitory at higher concentration. That different herbicides differ in their fungal toxicity has been reported by a number of other workers (Bain, 1961; Chappel and Miller, 1956· Davis and Dimond, 1953; Shannanand Fletcher, 1965 and Smith and Fletcher, 1964). Wilkinson and Lucas (1969) reported that

herbicides inhibit the linear extension of fungi and form abnormalities in the spore structure. Abdalla and Manci (1979) found that stomp herbicide retarted the growth of Pythium sp. on agar medium which was dose dependent. Karr et al. (1979) also noted that herbicides inhibit the growth of Rhizoctonia solani, Sclerotinia homoeocarpa and Drechslera gynodontis on agar medium. The mechanisms for the inhibitory effect of herbicides on fungi may be similar to those operative in higher plants. Both inhibitory and stimulatory effect of 2,4-D on the growth of fungi have been reported by several workers (Bever and Slife, 1948; Richards, 1948; Arrilaga, 1949). Similar to the result of present study Hsia and Christensen (1951) found that when 2,4-D was added to PDA the growth rate of Helminthosporium sativum was inhibited in proportion to concentration of herbicide in the medium but at low concentration it was stimulatory. Hodges (1977) also found stimulation of mycelium growth by 2,4-D which was greatest at low concentrations. The stimulation in colony growth in 2,4-D treated medium may be due to utilization of herbicide as energy source by fungi (Chen et al. 1981). A lag phase of 4 days was observed in case of fluchloralin at 5000 ppm concentration. It seems the fungus was capable of degrading the herbicides, thus reducing the level of toxicity. The delayed growth phase may also be due to the recovery of the pathogen from deleterious effect implicated by the herbicide. The development of some resistance to the toxic effect of herbicides may also be possible

(Fletcher et al. 1970; Absidia and Manci, 1979).

The germination of spores and germ tube growth are important factors regulating the infection. In case of certain diseases it has been conclusively shown that herbicide treatment influences the disease development (Hsia and Christensen, 1951; Oka and Pimentel, 1976 and Richardson, 1957). In all the herbicide treatments percentage spore germination was inhibited which increased with increasing concentrations. Hodges (1977) found that at low concentration (10^{-12} - 10^{-4}M) of herbicides conidial germination of Drechslera sorokiniana was not effected, but at higher concentration (10^{-3}M) germination was prohibited and plasmolysis of conidial cells was observed. In 2,4-D and benthiocarb treatments at the concentration of 10 ppm stimulation in germ tube growth was recorded which is similar to the previous observation of Hsia and Christensen (1951) and Hodges (1977). 2,4-D is a plant harmone and benthiocarb a growth regulator, thus both the chemicals have growth promoting action at low concentration. Possibly the stimulation in germ tube growth of A. alternata is related to these properties of two herbicides (Fletcher, 1956).

Calculation of concentration of pesticides present in the soil after applications at prescribed dose shows that the concentration is lessthan 10 ppm in the top 6 inches (Bollen, 1961; Fletcher, 1956; Newman and Downing, 1958). Keeping above in view the concentrations used in the present

study are quite high and does not correspond to the concentrations in soil. However, above calculation assumes uniform spread of the chemicals throughout the specified layer, which is not found in practice. Contrary to the above, 'pockets' of higher concentration of these chemicals may always occur in soil. This is particularly important in case of herbicides and systemic fungicides which tend to accumulate in plants. The plant biomass at times may contain more than 1000 ppm of these chemicals (Calderbank and Tomlinson, 1968). Absorption of pesticides may also result in formation of localised 'pocket' (Mustafa and Gamar, 1971; Rushdi and Jeffers, 1956; Geissbuhler et al. 1975). The results of these laboratory studies, therefore, depict, at least to a limited extent, what may happen in soil or in plant litters. Stimulation of fungi by 2,4-D at low levels as noticed in the present study and also reported by a number of other workers (Hodges, 1977; Bever and Slife, 1948; Hsia and Christensen, 1951) prompts to propose that if similar stimulation occurs in the soil where generally the herbicide level are found below 10 ppm (Bollen, 1961) the community structure of soil fungi may tend to shift in favour of fungi stimulated by the herbicide (Fig.4.2).

CHAPTER - V

STUDY OF MICROFLORA WEIGHT LOSS AND NUTRENT LOSS IN DECOMPOSING LITTER OF POTATO

INTRODUCTION

Decomposition of litter is a natural process responsible for the breakdown of complex organic compounds. During the process, inorganic minerals locked up in organic residue are released making them available to the growing plants. Litter and humus are chemical carriers of nutrients and therefore, rate of their decomposition determines the rate of nutrient cycling in the system. The phenomenon assumes added significance in agro-ecosystems where crop litter is usually a principal amendment applied to the soil and plays an important role in maintaining soil fertility affecting both the physical structure of the soil and its nutrient status.

Most chemical degradation of litter is carried out by hetrotrophic microorganisms viz., bacteria and fungi.The number and species of microorganisms colonising organic matter is determined by the physical structure and chemical composition of the substrate and climate of the site. The population and activity of litter decomposing organisms is regulated by a number of ecological factors; temperature and moisture being the most important ones. Seasonal and spatial variation in these factors determine the rate of decomposition of litter(Swift et al. 1979; Nagy and Macauley, 1982; Moore, 1986). The activity of microorganisms and other physico-chemical agencies bring about change in the structure and chemical composition of organic matter.

and that determines the population and species composition of late colonizers. Microbial succession continues until all of the organic substances are mineralised.

The chemical component of the litter is an important factor regulating the rate of decomposition (Whitford, 1982; Berg and Staaf, 1980; Sorenson, 1983; Parker et al. 1984; Schwintzer, 1984). Nitrogen, tanin and lignin contents and the nature of chemical bond which attach the elements to the organic matter effect the rate of decomposition of plant litters (Melin, 1928; Harrison, 1971; Meentmeyer, 1978; Berg and Staaf, 1980; Staaf and Berg, 1982).

Some studies are available on the decomposition of crop litter in field and laboratory conditions. Chang (1967) studied the decomposition of wheat straw and reported that fungal community associated with the decomposing straw varies with variations in the temperature. Ladd (1981) found that the rate of wheat straw and root decomposition was nearly equal but in case of Medicago littoalis the root decomposed more slowly than the stem and leaves. Jawson and Elliott (1986) found that total carbon was higher in straw than that of the root, while lignin content was higher in the root. The weight loss and succession of fungi and bacteria on decomposing rice and maize straw have been studied by Baruah et al. (1986) and Dkhar (1983). A significant part of stem leaf and root litter of potato is amended to the

agricultural soils. As most plant parts remain green and live at the time of harvest of tubers, the potato litter are generally green at the time of amendment and therefore at the time of amendment in soil the potato litter differs to a great extent from the wheat, barley, maize and other crop litters. A persual of literature shows that there is no study available on the decomposition of potato litters.

The present study deals with the decomposition rate, changes in chemical composition and microbial populations associated with decomposing litter of potato.

REVIEW OF LITERATURE

Studies on decomposition of plant litter were initiated by Waksman and his co-workers (Waksman and Tenny, 1927; Waksman et al, 1928). Positive correlations between rate of decomposition and percentage of nitrogen in litter was reported by Melin (1928). He suggested that decomposition is affected by the intrinsic factors of the litter among which tennin content of litter has significant influence on the weight loss rate. Norman (1930) stated that decomposition of organic matter is essentially a microbiological process. According to him organic residue leads to the formation of humus which affects growth and development of plants and microorganisms. Waksman and Starkey (1931) studied the pattern of disappearance of chemical components of agricultural litter and noted that water soluble

components were degraded first, followed by hemicellulose, cellulose and lignin. Acharya (1935) reported that fungi and bacteria decompose hemicellulose which break down faster than cellulose. According to Linderberg (1946), the rate of decomposition in litter is inversely proportional to its lignin content. Lignin which occurs in the cell wall and in the middle lamella retards decay rate by acting as a physical barrier to the microbial enzymes. Marshall and Alexander (1960) reported that nitrogen in soil acts as the principal factor limiting the rate of decomposition of crop residue. Nykvist (1963) noticed that a significant amount of plant nutrients are released from the litter by mechanical leaching and the process of leaching is highly dependent on the litter type. Hering (1965) examined the succession of fungi on leaves of ash, birch, hazel and oat. He found that upto one year after leaf fall, all the litter types had a characteristic flora of pyrenomycetes and imperfect fungi. After one year decay they were replaced by a common flora dominated by Penicillium and Trichoderma. Macauley and Thrower (1966) reported that species of coelomycetes and some moniliales were the important initial elements of the microflora in the litter, but some species of Penicillium and Mucorales succeeded them in advanced stage of decomposition. Williams and Gray (1974) emphasized that litter of different plants does not decompose at the same rate even

under similar environmental conditions. This was undoubtedly due to differences in the structure and chemical composition of litter type. Pal and Broadbent (1975) reported that for rice straw decomposition, moisture was one of the principal environmental factor that determined the rate of decomposition by microorganisms. Kalekar et al. (1976) found that wheat straw decomposed more rapidly followed by rice husk, ground nut husk and saw dust. They suggested that the addition of fungal inoculum to the sterile straw enhanced the rate of decomposition. Herlitzius and Herlitzius (1977) studied the decomposition of different qualities of leaves in acid soil and in lime soil under various conditions. They found faster decomposition rate in lime soil than in acid soil, Aneja and Mehrotra (1979) studied biodegradation of above ground parts of Desmostachya bipinnata buried in soil for a period of 13 months. They found that microbial population showed a gradual fall from initial to final stage of decomposition. Whithead et al. (1979) studied decomposition and change in chemical composition of roots of rye grass and red clover. He reported that red clover root contained more lignin, pectin and cellulose than rye grass. Mehrotra and Aneja (1979) reported that at the initial stage of the decomposition deuteromycetes were predominant while at the final stage in addition to deuteromycetes, a number of ascomycetes were also recorded. The most dominant taxa were Myrothecium rosidum, Aspergillus, Curvularia sp, Penicillium

and Fusarium. Mishra (1979) studied the distribution pattern of fungal species on and within the decomposing roots. He noted that besides a number of other factors the rate of decomposition of root is regulated by the enzymetic activity of microorganisms such as saccharase pectinase, cellulase and lignase. Howard and Howard (1980) reported that microbial break-down of litter depends on the litter type. Other factors such as soil on which the plant grow and local climate appear to be less important in the process of decomposition. Harper and Lynch (1981) studied the losses of total weight and of individual components of oat straw during decomposition in field condition. They found that decomposition rates of cellulose and hemicellulose were closely similar and these polysaccharides accounted for most of the losses. Rice et al. (1981) reported that pheholic compounds produced by decomposing rice straw and found that sterile extracts of decomposing straw were inhibitory to the growth of Rhizobium. Berg et al. (1982) reported significant drop in sugar, ethyl easter and triglycerides contents of litter during the first year of decomposition. They reported that cellulose decomposed faster than hemicellulose while lignin decomposition was the slowest. Rai and Srivastava (1982) reported that in decomposing litter CO_2 evolution positively correlated with microbial number. The bacterial population of litter showed a steady increase with the progress of litter decay. During the course of study on decomposition of

teak leaf litter Sinha and Dayal (1983) isolated some weak parasitic and phycomycetous fungi in the initial stage which were later on replaced by cellulose and lignin decomposing ascomycetes and deuteromycetes.Christensen (1985,1986) found faster decomposition rate in fallow than in planted plots of barley straw. Initial straw N content differed but over all N dynamics, was less influenced by straw type than by the soil type. Wessen and Berg (1986) found that in the long term decomposition weight loss was faster during the first year than the second year. Concentration of total soluble minerals decreased initially to a low but fairly constant level which was maintained for the two years. Lower CO_2 evolution recorded from root was attributed to the smaller microbial biomass associated with decomposing root. Adedeji (1986) reported that treatment of fertilizers (N,P,K and urea) increased the rate of decomposition as well as microbial population on decomposing litter. Jawson and Elliott (1986) noticed that wheat straw decomposed faster than root and lower CO_2 evolution from the roots was related to smaller microbial population which developed during the decomposition. Geoffreya(1986) found that change in chemical composition of litter affect the species composition of fungi. Baruah et al. (1986) studied decomposition of paddy straw and root litter under laboratory conditions using two dominant litter fungi Mucor racemosus and Fusarium moniliforme. They found that the rate of weight loss of paddy straw and root litter was

higher in the set inoculated with mixed cultures than the ones inoculated with pure cultures and in general decomposition of root was slower as compared to the straw. Enright and Ogden(1987) found faster weight loss of mesophyllous species i.e. Malicytus remiflorus and slow in gymnosperms.They noticed that Na and K mineral content lost rapidly from litter. Connell (1987) reported 40-54% weight loss after 82 weeks of Eucalptus litter. He also noticed the order in which nutrient were released from decomposing litter was Na > cl > k > mg > s > Ca > N > P.

MATERIALS AND METHODS

Rate of litter decomposition :

Litter bag technique (Bocock et al., 1960) was used to study the rate of decomposition. Plastic nets of 1 mm size were stitched into 20x20 cm^2 size. Leaf, stem and root of potato plant was collected at the time of harvest and air dried for three weeks and an oven dry ($60^{o}C$ for 48 hours) weight correction factor was determined. 10 g of air dried litter was placed in each bag.The bags containing leaf and stem litter were placed randomly in the field, while those containing root litter were buried under the soil (5.0 cm) in the same field. Collection of litter bags were done at monthly interval. 5 replicate bags of each litter type were collected aseptically in sterilized polythene bags and were brought to the laboratory. Bags were

then washed on a 200um mesh sieve to remove all the adhering soil particle and allowed to dry in a hot air oven at a temperature of 60°C until a constant weight was recorded. The percentage weight loss of litter was calculated on the basis of oven dry weight of the sample.

Fungi and bacteria associated with decomposing litters :

The litter was washed gently in sterilized water to remove surface contaminants. The litter was cut into small pieces of 10 mm with the help of sterile scissors in a sterilized petriplates and added into a 250 ml conical flask, containing 100 ml of sterilized distilled water. Dilution plate method was followed for the isolation of litter microflora (fungi, bacteria). A minimum of 10,000 dilution was used for bacteria and 1000 for the fungi. 0,5 ml litter suspension was inoculated from suitable dilution into each of the sterilized petriplates containing 20 ml of cooled solidified rose bengal agar (Martin, 1950) and nutrient agar (Johnson and Curl, 1972) media for the isolation of fungi and bacteria respectively. Three replicates were maintained for each samples.The assessment of litter microflora was done preferably on the day of collection, Occassionally, the bags were stored over night in a fridge at 4°C when the processing could not be completed on the same day (Ruscoe, 1971).The initial microbial population associated with the litters was estimated before putting the bags in the field.

Chemical Analysis :

Samples were ground in laboratory and analysed for C,N,P,K, Ca and Mg.

Carbon :

Organic carbon was estimated by rapid titration as described by Allen(1974). 50 mg of powdered sample was taken in 250 ml conical flask. 20 ml of chromic acid (19.86 g. $K_2Cr_2O_7$ and 200 ml H_3PO_4 was mixed with 400 ml Conc. H_2SO_4 for 1 h. After cooling the solution was diluated with 100 ml distilled water and mixed 5 ml indicator solution (5 g. $BaCl_2$ $2H_2O$ and 0.3 g barium diphenyl amine sulphonate were dissolved in 100 ml distilled water). Further, added 2.5 ml chromic acid and titrated with 0.4 M ferrous ammonium sulphate solution (156.86 g $(NH_4)_2$ SO_4. $2H_2O$ was mixed with 20 ml Conc H_2SO_4 and diluted to 1 litre with distilled water). Carbon was calculated as follows :

$$C\% = \frac{(27.5-T) \text{ ml} \times 0.12}{\text{Sample weight (g)}}$$

where T = ml 0.4 M ferrous ammonium sulphate used in titration.

Nitrogen :

Nitrogen was estimated by semi micro Kjeldahl method as described by Allen (1974). 100 mg of powedered litter was taken in a Kjeldahl flask and 2 gram K_2SO_4-HgO mixture and 3 ml conc H_2SO_4 containing salycy-lic acid were added and the mixture was digested on digestion rack

till the solution became pale green in colour. 50 ml distilled water was added to the cooled solution and mixed carefully. The solution was filtered through Whatman No.1 filter paper and left to settle for 12 h. 1 ml of the filtrate was taken in a 50 ml volumetric flask and 8 ml alkaline rochelle reagent (60 g sodium potassium tartrate dissolved in distilled water and diluted to 600 ml with distilled water) 1 ml 0.16% w/V sodium nitro-pruside, 2 ml fresh sodium phenate reagent (50 g phenol dissolved in 250 ml 40% NaOH and diluted to 40 ml with distilled water) and 1 ml sodium hypochlorite reagent containing 5% active chlorine were added and the volume was made upto 50 ml. Flasks were kept in a water bath at 40°C for 20 minutes. One blank sample was also run with it, after cooling the solution, the O.D. was measured at 625 nm. Percentage nitrogen was calculated as follows :-

$$N\% = \frac{C(mg) \times \text{Solution volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample weight (g)}}$$

where C = NH_4^+ in mg obtained from the standard curve.

To determine phosphorus, potassium, calcium and magnesium the wet oxidation of plant material was carried out. 100 mg of milled water was taken in a flask and 5 ml HNO_3, 0.5 ml H_2SO_4 and 2 ml $HClO_4$ were added and it was heated 18°C till all the acid evaporated.

Phosphorus :

Sulphomolybdic method was followed for the estimation of phosphorus (Jackson, 1973). The digested material was diluted with 50 ml of Bray's solution (1.11 g of Ammonium flouride dissolved in 1 litre of 0.1 N HCl) and shaked well. The solution was filtered through a Whatman No.44 filter paper. 1 ml of filtrate was taken in a test tube and to it 5 ml sulphomolybdate solution (25 g of ammonium molybdate in 250 ml distilled water; 275 ml conc. H_2SO_4 in 650 ml water mixed with the ammonium molybdate solution when cooled, 100 ml aquaous solution of 5% antimony potassium tartrate was added and solution was made to 2 litre)and 5 ml 1.5% ascorbic acid solution was added and the volume was made to 50 ml.After 30 minutes O.D. was determined at 660 nm using blank (without soil).

$$P\% = \frac{C(mg) \times \text{Solution volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample weight (g)}}$$

where C = mg p obtained from the standard curve.

Potassium :

Potassium was determined by flame photometre procedure as outlined by Peech and Tracy (1956). The digested material was taken in a flask and diluted with 50 ml 1% HCl and filtered through Whatman No.44 filter paper. Filtrate was taken and read in flame photometer.

$$K\% = \frac{C(ppm) \times \text{solution volume (ml)}}{10^4 \times \text{sample weight (g)}}$$

where C = ppm of K obtained from the solutions.

Calcium :

Calcium was estimated by EDTA titration method (Allen, 1974). The volume of digested material was made 50 ml by distilled water. 5 ml of sample solution was taken into another titration flask then 100 ml distilled water 5 ml 1M NaOH and 0.1 g murixide (indicator) were added. The pink coloured solution was titrated with EDTA solution (0.931 g) of disodium ethylene diamine tetra acetate was dissolved in 1 lit. of water) until the colour matches that of the reference end point. To obtain a reference and point 5 ml 1M NaOH was mixed with the indicator murixide and diluted to 100 ml with distilled water.

$$Ca\% = \frac{T(ml) \times \text{solution volume (ml)}}{10^2 \times \text{aliquot(ml)} \times \text{sample weight(g)}}$$

where T = ml EDTA solution required for the titration.

Magnesium :

Magnesium was estimated by EDTA titration method (Allen, 1974). The volume of digested material was made 50 ml by distilled water. 5 ml of sample solution was taken in a beaker then 50 ml distilled water, 10 ml sodium tung-

state solution (20 g $Na_2Wo_4 2H_{20}$ was dissolved in 100 ml distilled water and 15 ml buffer solution (67.5 g NH_4Cl was dissolved in distilled water added 57.0 ml 0.88 NH_3 diluted to 1 litre with distilled water) were added. The solution was warmed and filtered through Whatman No.1 filter paper with the help of 40 ml distilled water containing 2 ml buffer solution. Filtrate was taken in titration flask than 10 drop of erichrom black T indicator and 2 ml of triethanplamine were added, The solution was titrated with EDTA solution until the clear blue colour developed.

$$Mg(\%) = \frac{T(ml) \times \text{solution volume (ml)}}{10^2 \times \text{aliquot (ml)} \times \text{sample weight(g)}}$$

where T = ml EDTA solution required for the titration.

RESULTS

Rate of decomposition :

The percentage weight remaining of the litter given in fig.5.1. Loss in weight of leaf litter during the first month was 58.60 per cent; afterwards the rate of loss was slow but uniform, however, between the months of April and May (after 150 days) weight loss increased considerably. In case of stem litter weight loss during furst month was 39.21 per cent and afterwards monthly differences in weight loss was less pronounced. In case of root 29.15% weight loss

was recorded during first month. In case of all the three litter types the rate of weight loss increased during rainy season and the rate of weight loss was rapid during first month which slowed down during subsequent periods.In general, the leaves decomposed faster than the stem and root. The percentage dry weight remaining at the end of study period varied from 0.30 - 1.40% depending upon the litter type.

The k value (Table 5.2) was calculated by using the model proposed by Olson (1963). $WT=wo^{-kt}$ where wo is the initial weight, wt is the weight at time t and k is the rate constant or rate co-efficient (per day). Values of k are calculated by equation k=(Log e 100-Log e %R)/t where R is the weight remaining after time t. Using above equation we can calculate the time required for 50 % or biological half life (0.693/k) and the time required for the loss of 95% (3/k) and the time required for 99% weight loss (4.6/k). The values obtained by the equation for the daily decomposition constant of leaf stem and root was 0.2752, 0.0195 and 0.0179 respectively. The estimated half life of leaf stem and root litter was 23.21, 32.68 and 38.64 days respectively. Likewise the time required for 95% weight loss of leaf, stem and root litter was 108.97%, 153.45 and 167.30 days, whereas for 99% weight loss it was 167.09, 235.30 and 256.53 days respectively (Table 5.2).

Microbial population of decomposing litter :

Microbial counts in litter at different stages of decomposition are given in fig.5.2. As figure showed, initially the number of fungi and bacteria was less but after the spreading of bags in field a rapid increase in population was noted. Maximum fungal and bacterial population on leaf litter was recorded at the interval of 180 days. Generally, stem litter harboured less fungal and bacterial population than the root and leaf litter.Maximum fungal and bacterial population in case of stem and root was found on 210 days which declined later. Always maximum fungal and bacterial population was recorded from the leaf litter. A rapid multiplication of microorganisms was noted on the leaf litter followed by the stem and root.

The composition of fungal species colonising the litters changed with time. From leaf litter Mucor hiemalis, Rhizopus oryzae and Penicillium chrysogenum were isolated initially. The number of fungal species increased continuously upto 90 days; the total number being 6. For next 30 days i.e. upto 120 days the species composition did not change. At this time the litter was colonised by 4 Phycomycetes namely, Mucor hiemalis, M. circinelloides, Rhizopus oryzae and R. stolonifer and 2 deuteromycetes viz., Fusarium moniliforme and P. chrysogenum. Rhizopus stolonifer, R. oryzae and M. circenelloides were not isolated after 120 days. Cladosporium sp., M. racemosus, M. mucedo, Nanizzia incurvata and Penicillium sp. appeared after 120 days.

Among late colonizer Cladosporium appeared consistently from 120 to 210 days while others were isolated sporadically. In stem litter Mucor plumbeus and P. chrysogenum were isolated initially. Out of the two P. chrysogenum was consistently isolated till the end of the study while M. plumbeus did not appear after 90 days. M. circenelloides was another early colonizer which remained associated with the litter till 210 days. Among late colonizers, Fursarium moniliforme and Cladosporium epiphyllum were the dominants ones. A number of other species viz., P. monialatum, R. oryzae, R. stolonifer, Trichoderma viride, Alternaria sp., Arthroderma currey, Chaetomium cochloides, Penicillium sp. and white sterile forms were isolated sporadically. In case of root litters P. chrysogenum and M. hiemalis were associated with the litter initially. Out of the two initial colonizers M. hiemalis remained associated with the litter for most period while P. chrysogenum disappeared after 90 days. Another early colonizer was M. plumbeus which remained associated with the litter for about 3 months. F. moniliforme colonized the litter after 60 days and almost till the end of study it was isolated in good number. F. culmorae, Arthrobotrys superta, Wardomyces simplex, T. sporiella and Torulla herbarum were isolated only at the time of last sampling.

Chemical analysis :

The pattern of plant nutrient change during litter decomposition differed markedly with the element and litter type. The percentage carbon content in leaf litter was

88% and after decomposition at the end of study only 33% carbon was estimated. In case of stem and root, initial concentration of carbon was 92% and 85% and at the end of study it was 38% and 60%. Maximum amount of carbon was estimated from the leaf litter and minimum from stem litter.

Initially, the nitrogen content in leaf litter was 0.83% and remaining percentage content after decomposition was 0.43%. In stem and root initial concentration of nitrogen was 0.65 and 0.70% and after the decomposition at the interval of 240 days it was 0.39 and 0.44%. As the figure 5.4 shows absolute value for nitrogen content was maximum in leaf litter and minimum in stem litter but after decomposition of litter remaining amount of nitrogen content was maximum in root and minimum in leaf litter.

C/N ratio of litter is given in table 5.6,5.7,5.8.At the initial stage ratio between C and N in case of leaf, stem and root litter was 106.07, 141.53 and 121.47 but at the end of study period it was 76.74, 120.50 and 115.90. It was noticed that C/N ratio decreased with the period of decomposing litter.

The percentage P content is given in fig.5.5.Initially P content in leaf, stem and root litter was 1.94, 1.40 and 1.30%. The maximum P content was recorded in leaf li and minimum in root litter. The pattern of phosphorus degradation was similar in all the three litters. After 210 days P content in leaf was 0.55%, whereas in stem and

root at the interval of 240 days it was 0.47%. The absolute values were given in fig.5.5. At the end of study, however, more amount of P was estimated in root and less in leaf. The root litter showed slow release of phosphorus.

Initially, the k content in leaf litter was 6.1% and after decomposition at the interval of 210 days remaining amount was 0.93%. In stem and root the concentration of k was 3.9 and 3.6% and after degradation at the interval of 240 days the remaining amount of k was 1.0 and 0.6%. Maximum concentration of k was in leaf litter and minimum in root litter and after degradation at the end of study maximum k content was recorded in stem and minimum in root litter.

In case of leaf litter initially Ca content was 2.33%. At the interval of 30 days and 90 days little accumulation of Ca was noticed. The percent calcium in stem and root litter was 2.33 and 1.53%. The maximum amount of Ca was found in leaf litter and minimum in root litter. The absolute values (fig.5.7) of calcium at the end of study was maximum in root litter and minimum in leaf litter.

Initially, the percentage of magnesium in leaf litter was 0.65% and at the end of study the remaining amount was 0.35%. In stem and root litter initial concentration of Mg was 0.55 and 0.51% and after decomposition at the end of 240 days the amount of Mg dropped to 0.35 and 0.26%. Maximum

Fig. 5.1. Percentage weight of potato litter remaining after different periods of decomposition.

FIG-5.1

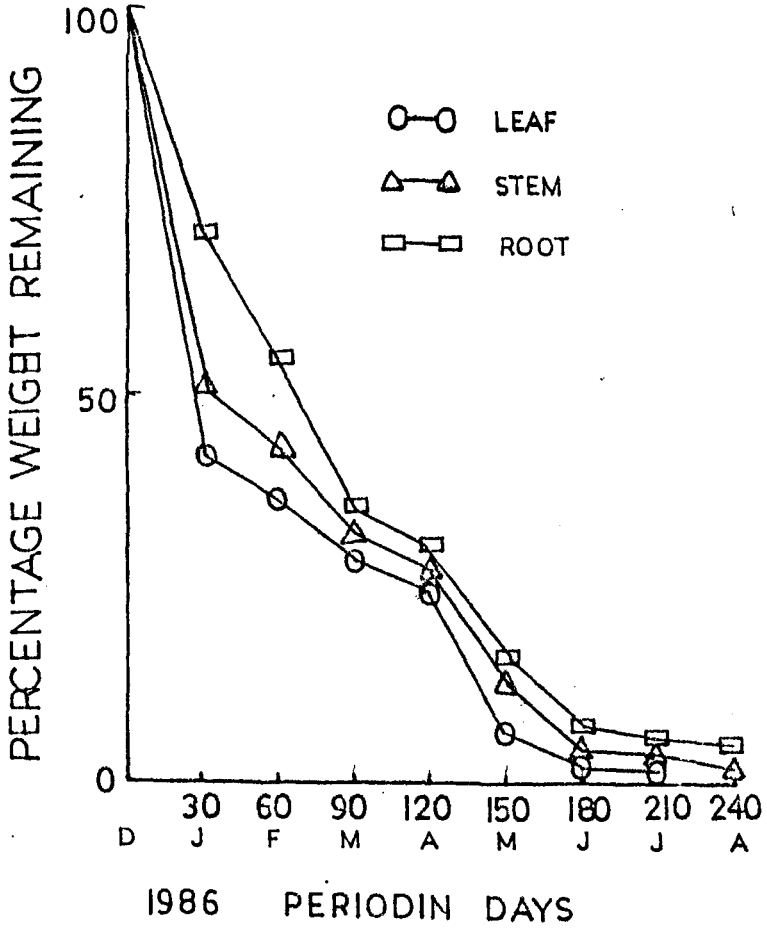

100
50
0
PERCENTAGE WEIGHT REMAINING
LEAF
STEM
ROOT
30
60
90
120
150
180
210
240
D
J
F
M
A
M
J
J
A
1986 PERIODIN DAYS

Fig. 5.2. Population of fungi and bacteria associated with potato litter at different periods of decomposition.

FIG·5·2

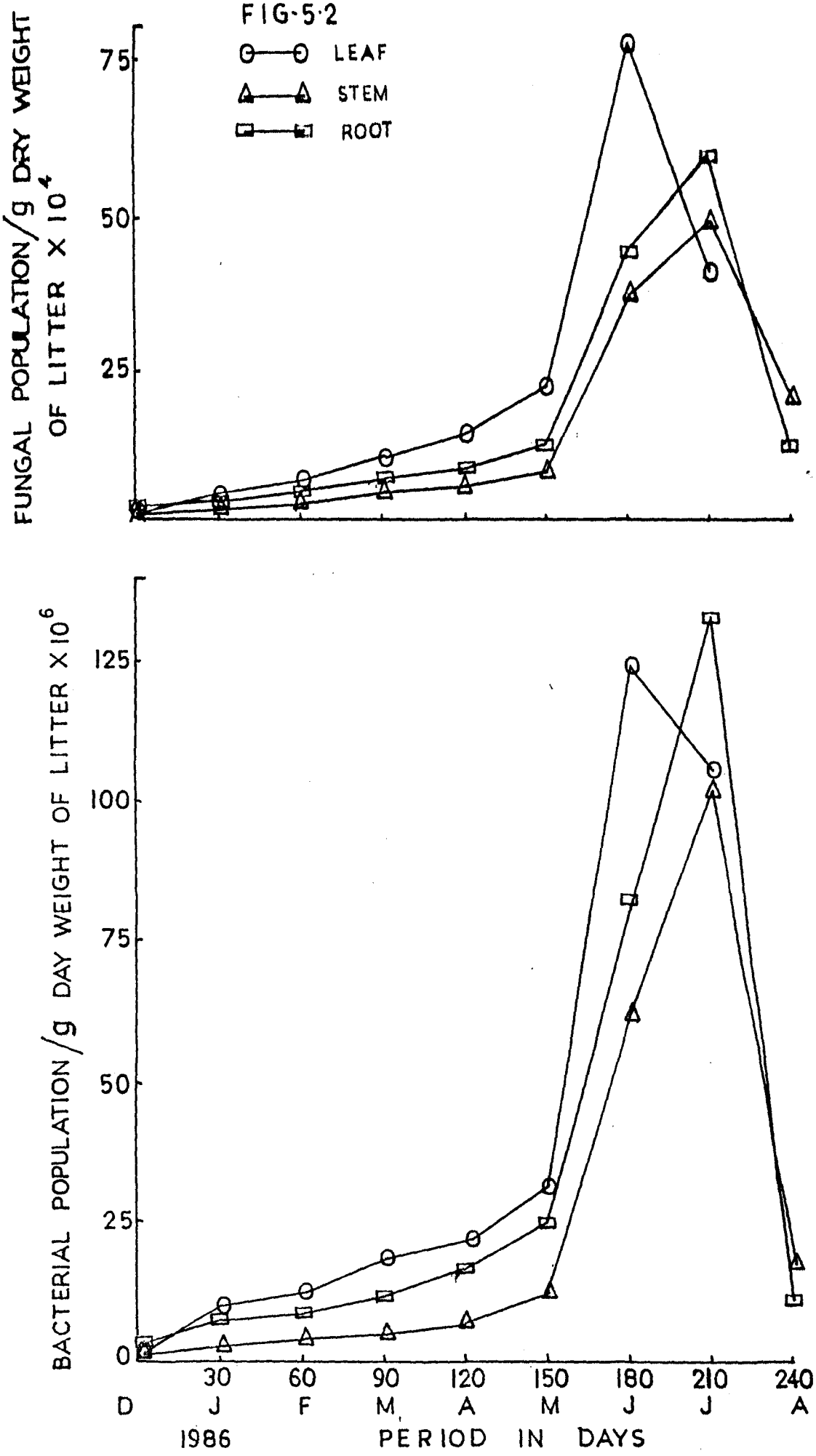

LEAF
STEM
ROOT
FUNGAL POPULATION/g DRY WEIGHT OF LITTER X 10⁴
75
50
25
BACTERIAL POPULATION/g DAY WEIGHT OF LITTER X 10⁶
125
100
75
50
25
0
30
60
90
120
150
180
210
240
D
J
F
M
A
M
J
J
A
1986
PERIOD IN DAYS

Fig. 5.3. (A) Percentage carbon concentration of potato litter at different periods of decomposition.
(B) Total amount of carbon (mg) remaining in the potato litter at different periods of decomposition.

FIG-5.3

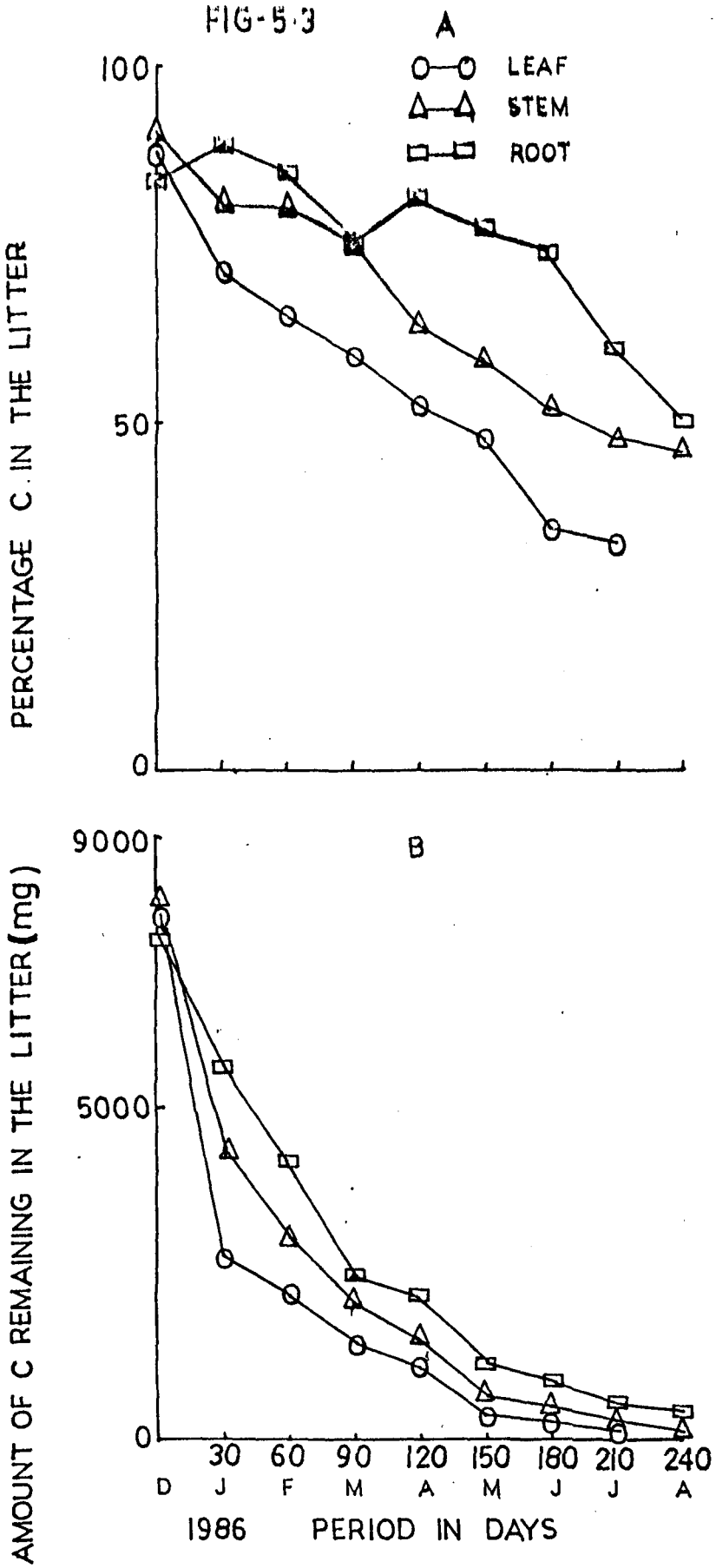

A
LEAF
STEM
ROOT
100
50
0
PERCENTAGE C IN THE LITTER
B
9000
5000
0
AMOUNT OF C REMAINING IN THE LITTER (mg)
30 60 90 120 150 180 210 240
D J F M A M J J A
1986 PERIOD IN DAYS

Fig. 5.4. (A) Percentage nitrogen concentration of potato litter at different periods of decomposition.

(B) Total amount of nitrogen (mg) remaining in the potato litter at different periods of decomposition.

A

FIG·5·4

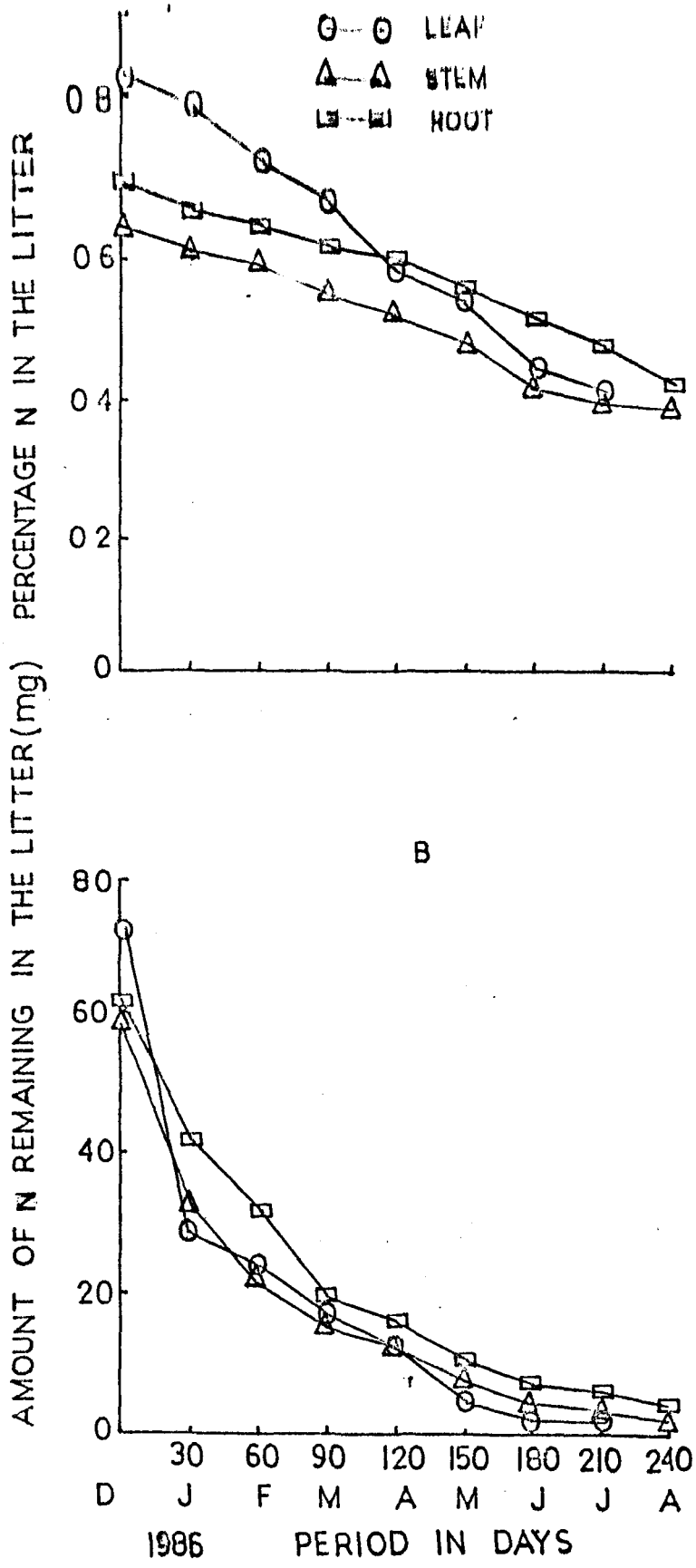
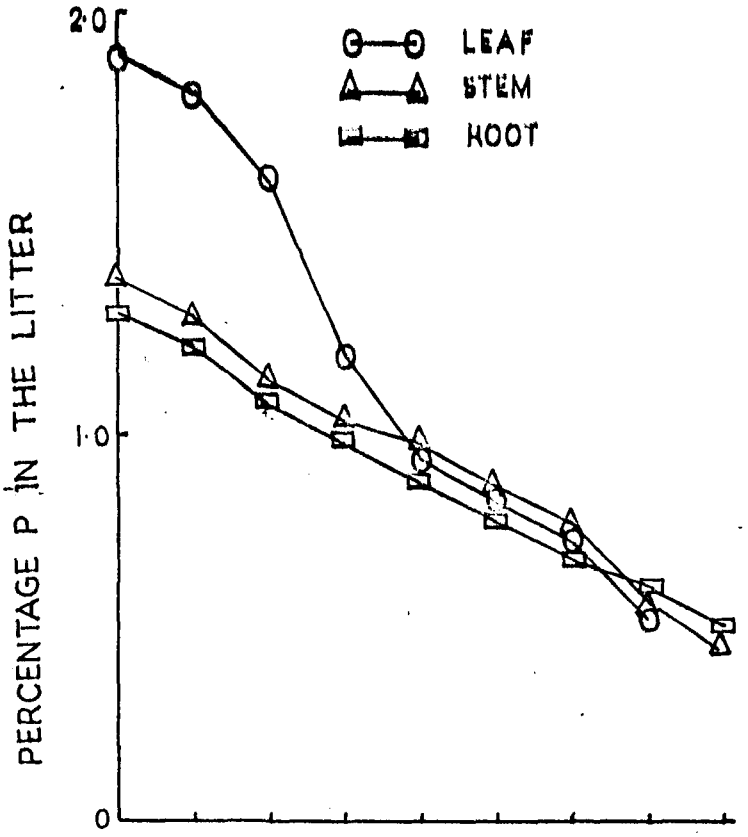

LEAF
STEM
ROOT
0 8
0 6
0 4
0 2
0
PERCENTAGE N IN THE LITTER
B
80
60
40
20
0
AMOUNT OF N REMAINING IN THE LITTER (mg)
30 60 90 120 150 180 210 240
D J F M A M J J A
1986
PERIOD IN DAYS

Fig. 5.5. (A) Percentage phosphorus concentration of potato litter at different periods of decomposition.

(B) Total amount of phosphorus (mg) remaining in the potato litter at different periods of decomposition.

FIG-5·5 A


2·0
1·0
0
LEAF
STEM
ROOT
PERCENTAGE P IN THE LITTER

B

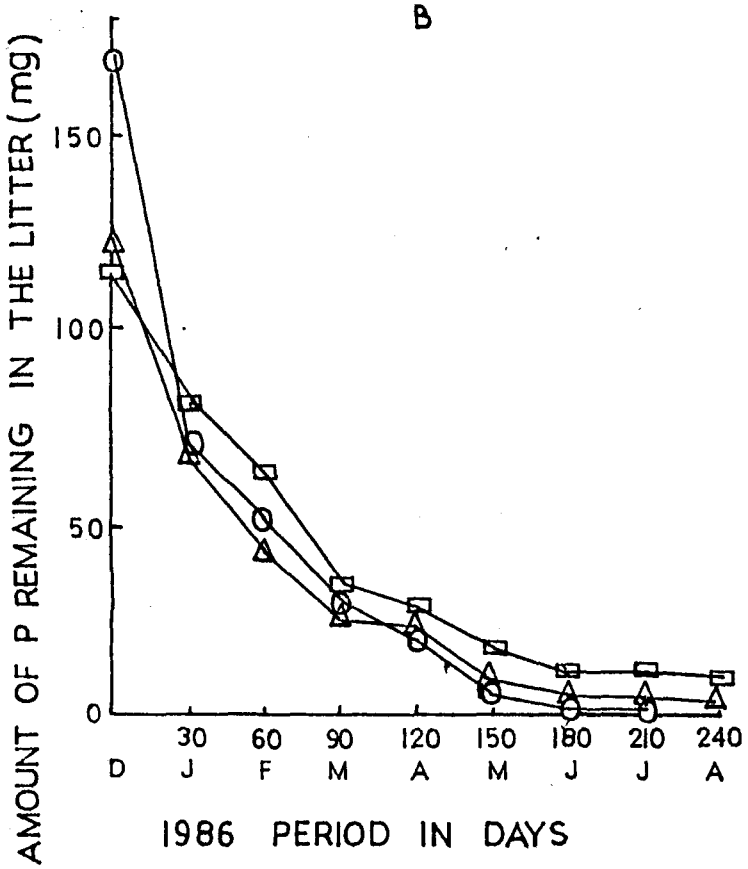
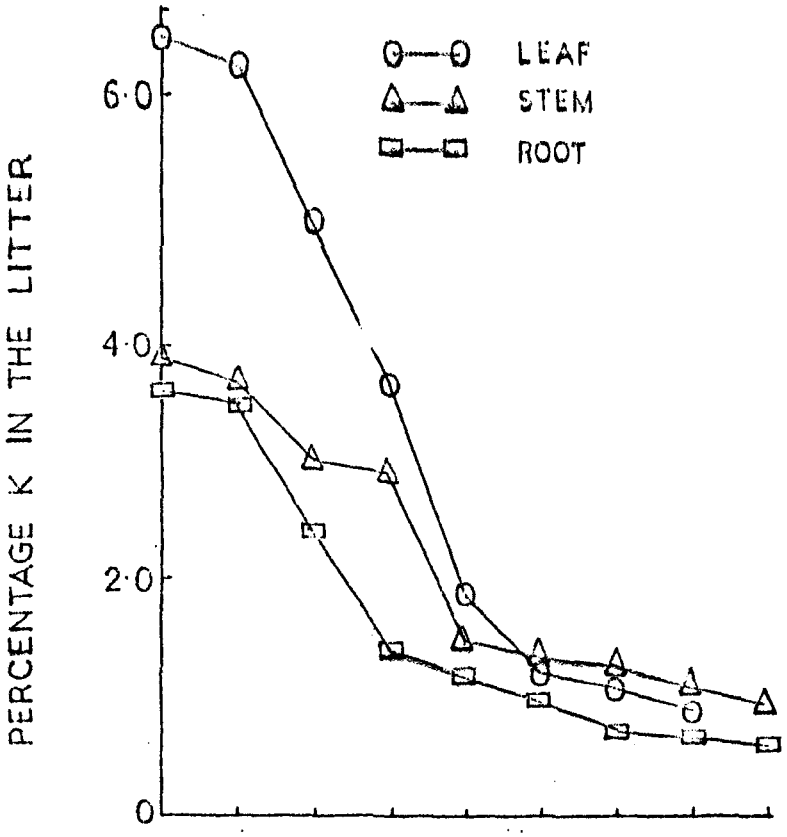

150
100
50
0
AMOUNT OF P REMAINING IN THE LITTER (mg)
30 60 90 120 150 180 210 240
D J F M A M J J A
1986 PERIOD IN DAYS

Fig. 5.6. (A) Percentage potassium concentration of potato litter at different periods of decomposition.

(B) Total amount of potassium (mg) remaining in the potato litter at different periods of decomposition.

FIG-5·6 A


LEAF
STEM
ROOT
PERCENTAGE K IN THE LITTER
6·0
4·0
2·0
0

B

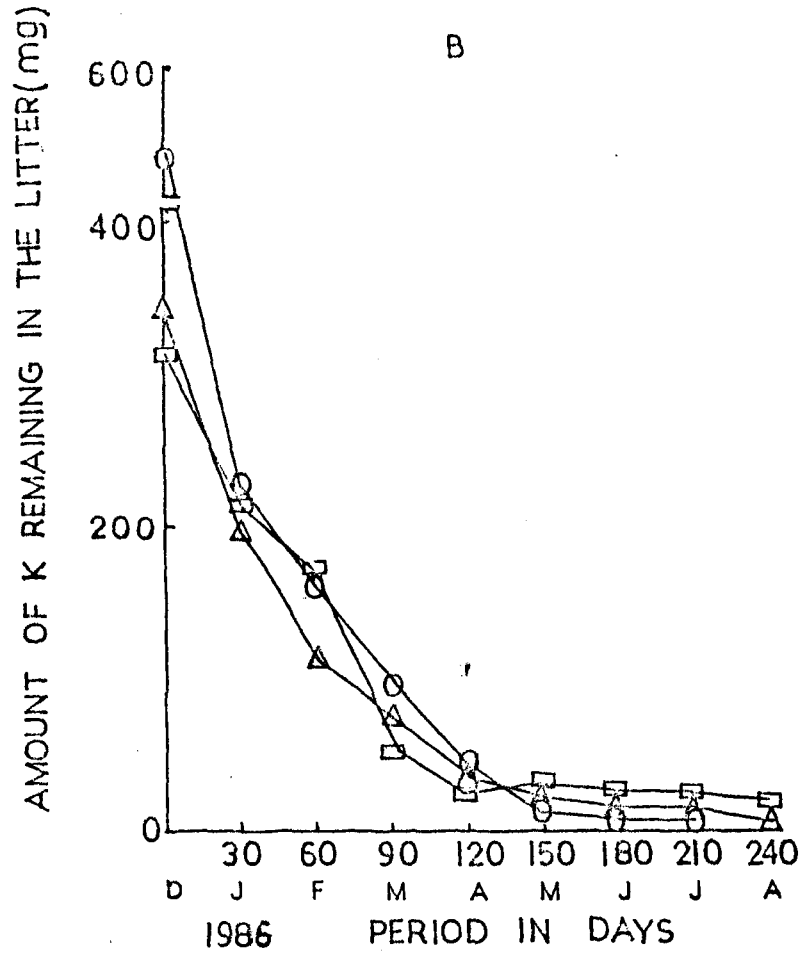

AMOUNT OF K REMAINING IN THE LITTER(mg)
600
400
200
0
30
60
90
120
150
180
210
240
D
J
F
M
A
M
J
J
A
1986
PERIOD IN DAYS

Fig. 5.7. (A) Percentage calcium concentration of potato litter at different periods of decomposition.

(B) Total amount of calcium (mg) remaining in the potato litter at different periods of decomposition.

FIG-5·7

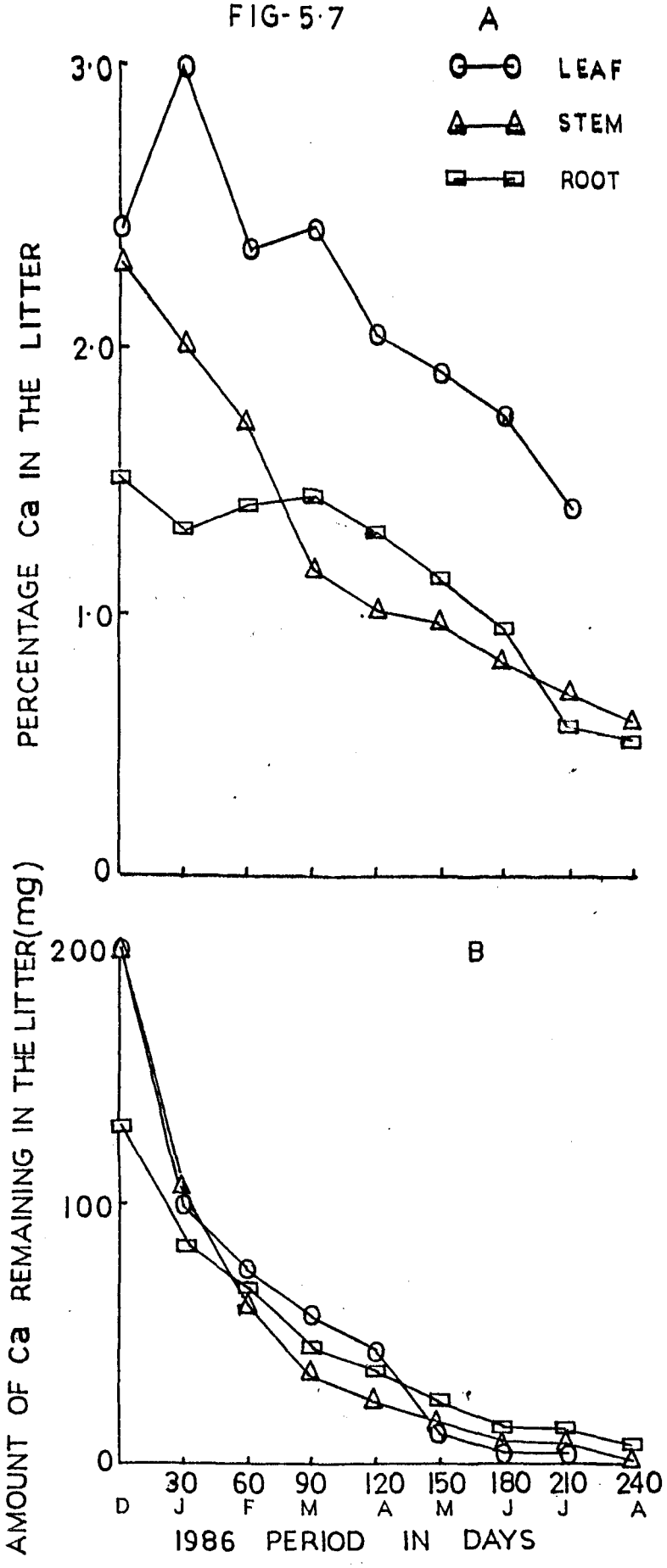

A
LEAF
STEM
ROOT
3·0
2·0
1·0
0
PERCENTAGE Ca IN THE LITTER
B
200
100
0
AMOUNT OF Ca REMAINING IN THE LITTER(mg)
D
30
J
60
F
90
M
120
A
150
M
180
J
210
J
240
A
1986 PERIOD IN DAYS

Fig. 5.8. (A) Percentage magnesium concentration of potato litter at different periods of decomposition.

(B) Total amount of magnesium (mg) remaining in the potato litter at different periods of decomposition.

FIG-5·8

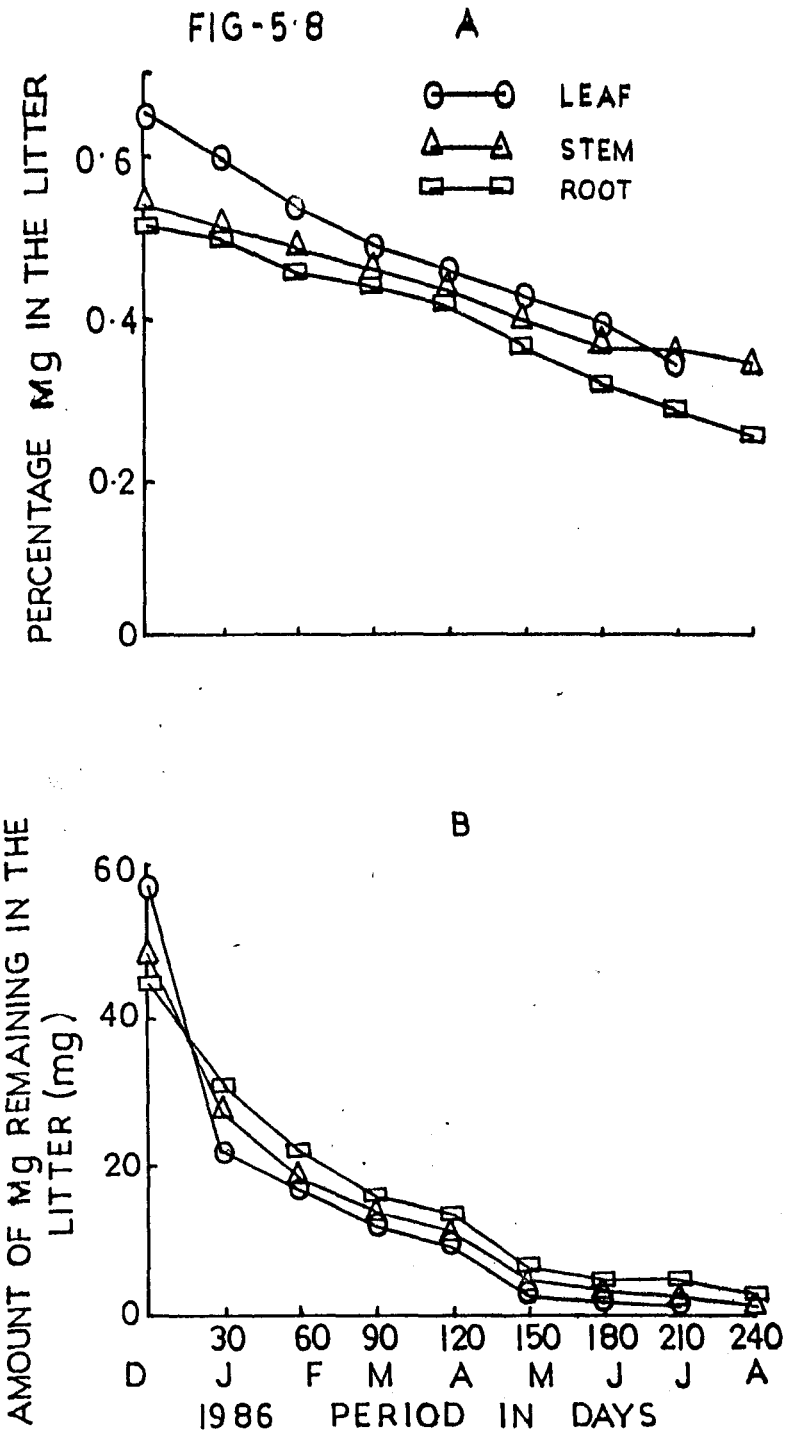

A
LEAF
STEM
ROOT
PERCENTAGE Mg IN THE LITTER
0·6
0·4
0·2
0
B
AMOUNT OF Mg REMAINING IN THE LITTER (mg)
60
40
20
0
30
60
90
120
150
180
210
240
D
J
F
M
A
M
J
J
A
1986 PERIOD IN DAYS

Table 5.1. Percentage weight loss of potato leaf, stem and root litters after different periods of decomposition.

Litter type	Dec. 0	Jan. 30	Feb. 60	March 90	April 120	May 150	June 180	July 210	Aug. 240
Leaf	0.0	58.6	63.9	71.9	75.8	94.0	99.6	99.6	-
Stem	0.0	39.2	57.6	68.2	72.7	87.7	98.2	98.9	99.0
Root	0.0	29.1	45.4	65.7	70.4	84.7	98.3	98.5	98.7

Table 5.2. Decay constant(K), half life, 95% life and 99% life of percentage weight remaining Vs time in days of Potato leaf, stem and root decomposition.

Litter type	K/day	Half life(days)	95%life (days)	99% life (days)
Leaf	0.275	23.21	108.97	167.09
Stem	.019	32.08	153.45	235.30
Root	.017	38.64	167.30	256.53

Table 5.3. Population of fungal species (per gram dry litter x 10^3) associated with decomposing leaf litter of Potato. Values in parentheses are percentage relative dominance.

Fungi	Months	Dec	Jan	Feb	Mareh	April	May	June	July	Aug
	Days	0	30	60	90	120	150	180	210	240
Mucor hiemalis		40.0 (7.0)	39.99 (16.9)	13.60 (9.0)	23.50 (28.0)	10.80 (15.6)	16.20 (37.3)	10.00 (76.9)	-	-
Fusarium moniliforme		-	13.30 (5.6)	-	11.70 (14.0)	16.20 (23.5)	18.60 (42.9)	30.00 (230.7)	-	-
Rhizopus oryzae		40.0 (7.0)	26.60 (11.2)	18.10 (12.0)	14.70 (17.5)	10.80 (15.6)	-	-	-	-
Rhizopus stolonifer		-	19.90 (8.4)	22.70 (15.0)	14.70 (17.5)	32.40 (47.0)	-	-	-	-
Mucor circinelloides		-	-	18.10 (12.0)	17.60 (21.0)	10.80 (15.6)	-	-	-	-
Penicillium chrysogenum		20.0 (3.5)	-	27.20 (18.0)	17.60 (21.0)	18.90 (27.4)	9.30 (21.3)	24.00 (184.6)	25.0 (96.0)	-
Cladosporium sp.		-	-	-	-	-	34.80 (79.9)	26.00 (199.9)	12.50 (48.0)	-
Mucor racemosus		-	-	-	-	-	20.90 (47.9)	-	-	-
Mucor mucedo		-	-	-	-	-	-	-	12.50 (48.0)	-
Nannizzia incurvata		-	-	-	-	-	-	-	8.30 (32.0)	-
Penicillium sp.		-	-	-	-	-	-	-	20.80 (80.0)	-
Sterile white		-	-	-	-	-	-	10.00 (76.9)	20.80 (80.0)	-

Table 5.4. Population of fungal species (per gram dry litter x 10^3) associated with decomposing stem litter of Potato. Values in parentheses are percentage relative dominance.

Fungi	Months / Days	Dec 0	Jan 30	Feb 60	March 90	April 120	May 150	June 180	Jul 210	Aug 240
Mucor plumbeus		60.0 (9.1)	40.0 (5.2)	27.27 (9.3)	26.66 (13.1)	-	-	-	-	-
Mucor circinelloides		-	40.00 (5.2)	36.36 (12.4)	26.66 (13.1)	11.76 (6.9)	11.11 (9.5)	3.12 (12.5)	2.85 (14.3)	-
Mucor racemosus		-	-	-	-	-	16.66 (14.2)	-	-	-
Penicillium chrysogenum		40.00 (4.5)	20.00 (2.6)	18.18 (6.2)	26.66 (13.1)	23.52 (13.9)	16.66 (14.2)	37.5 (150.0)	20.00 (100.7)	10.00 (3.3)
Penicillium moniolatum		-	-	18.18 (6.2)	19.99 (9.8)	-	-	-	8.57 (4.3)	-
Rhizopus oryzae		-	-	-	-	17.64 (10.4)	-	-	-	-
R. stolonifer		-	-	-	-	11.76 (6.9)	-	-	-	-
Fusarium moniliforme		-	-	-	-	23.52 (13.9)	33.33 (28.5)	21.87 (87.5)	17.14 (86.3)	-
Trichoderma viride		-	-	-	-	11.76 (6.9)	-	-	-	-
Cladosporium epiphyllum		-	-	-	-	-	22.22 (19.0)	25.00 (100.0)	22.85 (115.1)	-
Alternaria sp.		-	-	-	-	-	-	-	2.85 (14.3)	-
Arthroderma curreyi		-	-	-	-	-	-	-	11.42 (57.5)	-
Chaetomium cochliodes		-	-	-	-	-	-	-	-	52.0 (173.0
Penicillium sp.		-	-	-	-	-	-	-	8.57 (4.3)	10.0 (3.3)
White sterile		-	-	-	-	-	-	12.5 (50.0)	5.71 (28.7)	28.0 (93.3

Table 5.5. Population of fungal species (per gram dry litter x 10^3) associated with decomposing root litter of Potato. Values in parentheses are percentage relative dominance.

Fungi	Months / Days	Dec 0	Jan 30	Feb 60	March 90	April 120	May 150	June 180	Jul 210	Aug 240
Mucor hiemalis		66.0 (6.8)	46.15 (15.0)	47.00 (22.5)	33.33 (23.5)	36.36 (29.3)	12.49 (15.1)	-	-	4.76 (9.0)
Mucor plumbeus		-	30.76 (10.0)	35.29 (16.9)	38.00 (26.8)	10.0	-	-	-	-
Penicillium chrysogenum		34.0 (3.4)	23.07 (7.5)	11.76 (5.6)	14.28 (10.0)	-	-	-	-	-
Fusarium moniliforme		-	-	5.88 (2.8)	14.28 (10.0)	9.09 (7.3)	45.83 (55.6)	26.47 (119.9)	26.47 (144.0)	-
Rhizopus oryzae		-	-	-	-	31.81 (25.6)	24.99 (30.3)	-	-	-
Penicillium lilaenum		-	-	-	-	22.72 (18.3)	- (119.	26.47 (119.9)	5.88 (32.0)	-
Fusarium culmorue		-	-	-	-	-	-	-	-	42.85 (81.8)
Fusarium morismoides		-	-	-	-	-	-	8.82 (39.9)	-	-
Arthrobotrys superta		-	-	-	-	-	-	-	-	9.52 (18.1)
Wardomyces simplex		-	-	-	-	-	-	-	-	23.80 (45.4)
Trichoderma sporiella		-	-	-	-	-	-	-	-	9.52 (18.1)
Torula herbarum		-	-	-	-	-	-	-	-	4.76 (9.0)
Cladosporium sp.		-	-	-	-	-	16.64 (20.2)	17.64 (79.9)	-	-
Sterile white		-	-	-	-	-	-	20.58 (93.3)	67.64 (368.0)	4.76 (9.0)

Table : 5.6. Carbon:element ratios in the decomposing leaf litter of potato at different periods.

Days	C/N	C/P	C/k	C/Ca	C/Mg
O,D	106	45	14	36	135
30,J	88	38	12	24	121
60,F	92	41	13	29	124
90,M	90	50	16	25	124
120,A	90	56	27	26	115
150,M	87	56	36	25	111
180,J	77	46	31	20	89
210,J	76	60	35	23	94

Table : 5.7. Carbon:element ratios in the decomposing stem litter of potato at different periods.

DAYS	C/N	C/P	C/k	C/Ca	C/Mg
0,D	141	65	23	40	167
30,J	134	63	22	42	160
60,F	136	71	27	48	167
90,M	138	73	29	64	164
120,A	124	68	44	66	146
150,M	127	70	43	63	148
180,J	123	68	40	63	139
210,J	122	85	44	70	136
240,A	120	98	47	78	134

Table : 5.8. Carbon:element ratios in the decomposing root litter of potato at different periods.

DAYS	C/N	C/P	C/k	C/Ca	C/Mg
O,D	121	65	24	56	164
30,J	134	73	25	69	180
60,F	132	78	35	61	186
90,M	124	77	55	51	175
120,A	138	92	69	62	193
150,M	141	96	79	68	213
180,J	146	101	100	78	237
210,J	129	103	88	109	213
240,A	115	107	85	95	196

concentration of magnesium was recorded in leaf litter followed by stem and root.

DISCUSSION

The rate of decomposition was rapid and in the cases of all the litter types more than 90% of the litter decomposed within 8 months. Mangenot (1966) found (85-90% weight loss of Melandrium litter in 130 days. He attributed the major weight loss to the activities of saprophytes. The weight loss of leaf was faster than stem and root. It might be due to high number of fungi and bacteria on leaf litter as compared to stem and root litter. In the month of May an increase in weight loss was found which may be due to increase in the number of bacteria and fungi during the same period.

The concentration of mineral nutrients in the litter also plays an important role in decomposition. The fast weight loss in leaf litter compared to stem and root could be attributed to the higher concentration of minerals (C,N, P,K,Ca,Mg) in leaf than in stem and root. It is reported that higher the concentration of minerals faster the rate of weight loss (Berg and Staaf, 1980). Christensen (1986) found that high nitrogen concentration (0.92%) was responsible for the greater loss in weight (44%) during first month of barley litter. Schwintzer (1984) reported that

although Myricagale litter contained high amount of nitrogen, the decomposition was slow due to high percentage (40%) of lignin, The result suggests that litter decomposition is governed by the concentration of C,N,P,K,Ca and Mg.During the process of decomposition carbon is used as an energy source by decomposers while nitrogen is assimilated in cell protein and other compounds. Thus, high nitrogen content in the original material promotes decomposition at least in early stages. That litter contains higher amount of nitrogen initially which declines during decomposition is reported by Christensen (1985). Initially, the concentration of nitrogen was more in root as compared to stem, however, the weight loss was higher in stem. Johnson and Elliott (1986) reported high concentration of nitrogen in root than in straw while the carbon concentration was high in straw. They found faster weight loss in straw than in root. C/N ratio also plays an important role in the weight loss and generally the rate of weight loss is faster in materials with high C/N ratios (Berg and Staaf, 1980). As weight loss increased the C/N ratio decreased (Table 5.6,5.7,5.8). Floate (1970) also found decrease in C/N ratio with increase in weight loss. Schlesinger and Hasey (1981) reported that during the decomposition of Caenothus leaf litter, the C/N ratio declined from 80 to 40. The decrease in C/N ratio with decomposition was also reported by many other workers (Aber and Melillo, 1980; Alexander, 1977; Edmonds, 1980). After spreading the litter bag in field during first month sudden

loss in weight may be due to leaching of water soluble compounds. The initial loss was more pronounced in the case of leaf litter as compared to the stem and root which may also be due to higher percentage of parenchymatous tissue in the case of leaf litters (Hering, 1965).

Physical factors also play a vital role in the weight loss of litter. The average monthly air temperature rainfall and humidity is given in Fig.1. The temperature varied between 1.2 and 22.9°C, rainfall between 109 mm, 279mm, the relative humidity between 44 and 90. The result suggests that temperatures rainfall and humidity also had a definite effect on the rate of weight loss as during the period of high temperature, moisture and relative humidity conditions the rate of weight loss was also higher.

Initially, the fungal and bacterial number on decomposing litter was less which increased with time. The improvement of moisture level moderation of temperature and higher relative humidity favoured the build up of the microbial population. The increase in microbial population in initial stage of the litter decomposition is also reported by Jensen (1971). The maximum fungal and bacterial population in leaf litter was isolated in the month of May-June while in case of stem and root in the month of June-July. The increase in microbial population at this period correspond with the faster rate of litter disappearance. The sudden increase in microbial population in the month of

May-June may partly be attributed to the increase moisture level of litter and soil. The maximum fungal and bacterial population was found in leaf litter followed by stem and root. It may be due to the higher concentration of nutrient in leaf litter as compared to stem and root litter. The rate of nutrient loss was also related to the microbial population as during period of higher microbial population the nutrient loss was maximum. It has been established that the fungal mycelium when breaking the litter substances, simultaneously utilise if for their own growth thereby retaining some amount of mineral in their body. These elements are then released slowly after the death of fungal body usually in ionic forms (Witkamp, 1971).

The fungal species composition is regulated by climatic factors and nutrient concentrations in the substrates (Adedeji, 1986). Initially, Mucor hiemalis, M. plumbeus, M. circenelloides, Penicillium chrysogenum and Fusarium moniliforme were isolated. Sadasivan (1939) found that Fusarium sp. and Mucor sp. were more abundant at the initial stage of decomposition of wheat straw but later the fungal population was dominated by Penicillium spp. Sinha and Dayal (1983) isolated some weak parasites and members of phycomycetes during initial stage which were later replaced by cellulose and lignin decomposing ascomycetes and deuteromycetes. At the middle stage of study period P. chrysogenum, Mucor spp., Rhizopus oryzae, R. stolonifer and F.

F. moniliforme were dominant. Towards the end of study, Cladosporium epiphyllum, Fusarium spp. and white sterile fungi were dominant. Witcamp (1960) reported that Mucor, Trichoderma, Penicillium and Alternaria were dominant on the decomposing leaf of Quercus ruber. Deka and Mishra (1982) found Penicillium, Trichoderma, Aspergillus, Cladosporium and Alterna__ as dominant fungi on decomposing bamboo litter cellulose decomposing capability of Penicillium is well known (Martin et al. 1942). Possibly the sterile forms isolated during later stage of decomposition belong to the class basidiomycetes which do not produce fruiting bodies on the agar media (Mishra and Tiwari, 1984). Garrett (1963) reported that fungi which are responsible for the decomposition of lignin appear in the last stage of decomposition and most of the basidiomycetes come in this category.

Some basic principles for element dynamics in decomposing litter have been outlined by Swift et al.(1979) According to their model the release of inorganic forms of an element will occur only as long as the carbon/element ratio of resource stay below a level where it becomes limiting to the organisms decomposing it. In a litter structure for which the carbon/element ratio exceeds this level, the element would be retained and possibly imported to it, until the critical level is reached and then released in proportion to weight loss (Berg and Staaf, 1981). Element in surplus (i.e. those where the initial carbon/element

ratio are below the limiting values) would then be in a release phase. In the present study, however, the carbon/element ratios never appeared to be limiting as the rate of decomposition was steady and the accumulation of element was not observed (Table 5.6, 5.7, 5.8). Thus, the present study shows that complete recycling of nutrients from the litter will take probably one year.

GENERAL DISCUSSION

The study showed that there was not marked variation in temperature and pH of soil of the three agricultural systems.The maximum moisture content was recorded in valley land soil and minimum in slope land soil. Valley land was surrounded by hillocks and therefore it receives less amount of solar heat in comparison to the fields situated on the hills. Less solar radiations were also responsible for the high soil moisture in valley land. In slope land almost all the rainfall water was lost through run off which was responsible for less moisture in the soil. Results showed (Figs.4.1,5.1, 1.6,1.7). that nutrient concentration was generally highest in valley land soil followed by terrace land and slope land soil. In case of slope land high rainfall and steep slopes caused maximum loss of nutrient through soil erosion. This may be the cause for the minimum nutrient concentration in the slope land soil. Erosion of soils on the hill slopes caused due to heavy rains resulted into the deposition of the nutrient rich soils in the valleys which was probably the cause of higher nutrient content of the valley land soils. Depth-wise distribution of nutrients showed a decreasing trend along with increase in soil depth. The surface layer of soil is enriched by the organic matter deposition from the ground vegetation and other inputs from adjoining areas. The nutrient status in lower profile depends on the leaching of nutrients along with the percolating water. In agricultural soils the ploughing mixes the soil, however,

the effect of these activities is not evident as a definite gradient is noted in case of most soil characteristics parameters studied. Figs. 1.8,1.9 shows that maximum fungal and bacterial population was found in surface soil. The population decreases along depth. Possibly it may be due to high concentration of nutrients and better aeration in surface soil. The higher population in surface soil as compared to lower proriles was also reported by Eicker (1970) Mishra and Kanaujia,(1972) and Acea and Carballas (1986). Generally, in all the three fields highest fungal and bacterial population was recorded in the month of October at the middle age of plant. The favourable climatic condition and higher nutrient concentration and a possible increment in root exudates at this period, seem to influence favourably the growth and development of microbes. The fall in the population thereafter may be ascribed to the decrease in nutrient content. (Fig. 1.6,1.7) and non-availability of substrates. Maximum fungal population was found in valley land soil which may be due to high concentration of nutrients in this field. The hill slope land soil always harboured less fungal and bacterial population which could be ascribed to its poor nutrients status. Fungal species composition of soil is governed by the edaphic factors of the soil. Mucor sp., Penicillium spp and Trichoderma spp. were found in all the three field soils. These species seem to have a wider range of tolerance to the environmental factors. The species of Mucor were common in all the three field soil which is similar to

the work of Herman and Kucera (1979). The comparative study on similarity index of species composition in different fields and at different depths (Table.1.22) showed that depth 1 (0-10 cm) was similartto depth 2 (10-20 cm) and depth 2 (10-20 cm) was similar to depths 3 (20-30 cm) while depth 1 was quite different to depth 3. It was observed that fungal species composition of valley land was more similar to terrace land and terrace land to the slope land but valley land differed. Significantly from the slope land. The similarity in species composition could be attributed to the homogenity in habitat, The soils rich in nutriens and microbial population exhibited maximum enzyme activity. It is apparent that the mineral content level and moisture play an important role towards regulating the enzyme activity in soil. Maximum dehydrogenase activity was recorded in valley land soil and minimum slope land soil. Depth-wise, maximum activity was in surface soil and along depth the activity decreased. The pattern of variation in the activity was more or less similar to the nutrient concentration, bacteria and fungal population. Dehydrogenase activity correlated with fungal population in all the three field soils while with bacteria it correlated only in two field soils. Figs. 1.10-1.13) showed that maximum activity was found in valley land and terrace land soil whibe minimum in slope land soil. During the study period peak occurred in the month of October, at the middle age of plant. Similar results were reported

by Speir (1977) and Baruah and Mishra (1984). Possibly the addition of enzyme may occur from the plant roots and associated microorganisms.In present study urease activity was positively correlated with nitrogen and fungal population in all the three fields. Das et al. (1981) found correlation of urease activity with organic C, N and P. Some studies have indicated that urease is controlled by organic carbon status of the soil (Beri et al. 1978, Dick, 1983) which was found true inthe present study also. Maximum phosphatase activity was recorded in the month of October. The highest activity may be due to the microbial population which also peaked at the same time.In general, the maximum phosphatase activity was recorded in valley land followed by terrace land and slope land soil. In valley land preesence of higher concentration of mineral nutrient may be responsible for the increased phosphatase activity. In all the three fields the activity decreased with depth which may be attributed to reduction in microbial population and its activity. Phosphatase activity was found correlated to physico-chemical characters and microbial population. The correlation of phosphatase activity with organic carbon, nitrogen, phosphorus and pH was also reported by Schlesinger (1977). Respiration is also an important index used for the measurement of microbial activity. The maximum CO_2 evolution occurred in valley land soil and minimum in slope land. The rate of respiration was maximum in surface layer soil which decreased along depth. It appeared that respiration rate is also

governed by the same set of factors as dehydrogenase, urease and phosphatase activity. The table 1.19,1.20 and 1.21 showed that respiration rate was more correlated to fungal population as compared to bacterial population. Tesavora and Olson (1976); Baruah and Mishra (1983) also found positive relation of soil respiration with fungal and bacterial population.

Fungicides viz., benomyl copper oxychloride and mancozeb and herbicides viz., benthiocarb, 2.4-D and fluchloraline differed in their effect on phyllosphere microflora of potato. The application of fungicides and herbicides decreased the microbial population. In treated plants, throughout the study period fungal population as well as bacterial population remained lower than the control.However, a recovery was found after some time of spray. Most possibly, the recovery was due to losses of biocides from leaf surface by biodegradation, evaporation and removal through rainwater. Sometimes degraded products of a biocides may be more detrimental for microbes than biocide itself. In case of benomyl recovery was late as compared to mancozeb and copper oxychloride. This may be because the degraded product of benomyl is more harmful for microbes than benomyl itself. In general, it was noticed that species composition on phyllosphere did not differ in fungicides treated plant than that of the control plants. Herbicides also initially decreased the fungal and bacterial population. In case of 2,4-D and fluchloralin treated plants recovery was speedy and at later stages the population became equal to

the control, but in benthiocarb treated plants microbial population was always lower than the control. Increase in the microbial population with the age of the crop may be due to deposition of microbes from air spora and/or multiplication of microbes in the phyllosphere of old leaves. The spray of biocides affect the phyllosphere microflora quantitatively and qualitatively.In general, fungicides were more detrimental to the microbes as compared to the herbicides.

The same fungicides and herbicides were also tested for the effects on the rhizosphere microflora. In case of fungicide treated plant fungal and bacterial population was always less than the control. The bacterial population recovered rapidly which may be due to its tolerance to the fungicides. It was noted that rhizosphere microbial population was more affected than the soil. It is speculated that the sprayed chemicals were absorbed by the plants and translocated to the roots which may directly affect the associated microbial population of the rhizosphere. In untreated soil continuous increasing in microbial population may be due to favourable factors. Generally R/S value was lower in fungicide treated plants which showed that the influence of fungicide was more pronounced on rhizosphere region than the soil. R/S value for bacteria showed that benomyl and mancozeb were less toxic as compared copper oxychloride. The fungicide application changes the species composition. The dominant fungi like C. cladosporioides, F. poae, M. hiemalis, M. plumbeus, M. racemosus and P. brevicompactum

were more severely affected than the fungi isolated in lesser numbers. The study showed that fungicides directly affect the rhizosphere environment. Initially, the herbicide treatment decreased the fungal population which was also reported by Chen et al. (1981). Initial drop in fungal and bacterial population may be due to its toxic effect but recovery during succeeding period may be due to dilution, leaching and degradation of herbicides in soil. Stimulation in microbial population was found in 2,4-D and fluchloralin treated plants. It may be due to utilization of these herbicides by fungi as food or energy source. Zelles et al. (1983) reported that at low concentration herbicides stimulate the microbial activity but at higher doses they are generally inhibitory. C. cladosporioides, F. oxysporum, Mucor spp. Penicillium spp. and Trichoderma sp. were found dominant throughout the study. It suggested that these fungi are resistant to the herbicides. The present study demonstrated that the qualitative or quantitative alterations in root exudation were possibly responsible for the more severe effect of biocides on the rhizosphere microflora as compared to the soil. Biocides change fungal community and disturbethe microbe mediated processess in soil which may affect the soil fertility. The effect of biocides on microbial population depends on the formulation and dose of the chemical.

The same three fungicides and herbicides were

tested for their efficacy against A. alternata. All the three fungicides inhibit the colony growth of A. alternata on P.D.A. medium. The inhibition in the colony growth was in correspondence to the concentration or dose of the fungicides. At the concentration of 5000 ppm in copper oxychloride and mancozeb colony did not grow, however, growth occurred in benomyl supplied medium. It showed that copper oxychloride was more toxic than benomyl and mancozeb at least at the higher concentration. Muling and Griffith (1977) also found copper fungicide more effective than benomyl and captafol. Herbicides benthiocarb and fluchloralin inhibited the fungal growth which was dose dependent, but 2,4-D was stimulatory at low concentration and inhibitory at higher concentration. The mechanism for the inhibition of colony growth may be similar as it operates in the case of higher plant. Inhibitory and stimulatory affects of 2, 4-D have been reported by Hsia and Christensen (1951). The stimulation in colony growth at low concentration may be due to utilization of herbicide as an energy source (Chen et al. 1981). In all the herbicides percentage spore germination was inhibited with increasing the concentration. The prohibition in the germination of spore at high concentration may be due to plasmolysis and/or toxic effect. At low concentration stimulation in germ tube growth was found in 2,4-D and benthiocarb treated spores. The stimulation in the germ tube growth be due to the growth promoting properties of the two herbicides. It was noticed that germ

tube growth was most severely affected followed by mycelial growth and spore germination. It is suggested that thin walled structures like germ tube and mycelia more prone to the toxic affects of the biocides than that of the spores.

In the decomposition study of potato leaf, stem and root litter, it was noted that decomposition rate was faster in the beginning of study. It may be due to the loss of water soluble components of the litter and favourable climatic factor which increased the activity of decomposer microorganisms. The rate of decomposition was higher in leaf than stem and root. Possibly, it is due to higher concentration of nutrients and microbial population.Higher concentration of C, N, P, K, Ca and Mg was found in the leaf than in stem and root. It may be suggested that the process of decomposition is largely governed by the chemical composition of the substrates. The break down of various chemical components is affected as a sequence of specific reaction with enzyme systems of the organisms. The variation in the loss of various component suggests that the rate of decomposition is closely linked with the activity of decomposer organisms. Parnas (1975) stated that the rate of decomposition of any substrate is generally proportional to the growth rate of its microbial decomposers. The increase in microbial population at the later stage of decomposition could be attributed to a favourable moisture condition, temperature and release of nutrient from the litter. Micro-

bial population was more in leaf than stem and root, which may be ascribed to the higher surface area available for the microbial colonization of the leaf.

SUMMARY

Microbial population their biochemical actigities and physico-chemical characters of potato field soil in different agricultural practices viz., valley land, terrace land and slope land have been investigated. Maximum mineral nutrients were in valley land soil followed by terrace land and slope land soil. Moisture content was also high in valley land as compared to terrace land and slope land soil.

Qualitative and quantitative enumeration of soil fungi was carried out for two crop cycles. Bacterial population was studied only quantatively. Higher fungal population was recorded from valley land soil followed by terrace land and slope land soil. Generally, bacterial population was higher in terrace land soil as compared to valley land and slope land soil. Both fungal and bacterial population decreased along depth. Mucor spp., Fusarium sp., Penicillium spp. and Trichoderma spp. were dominant fungi in all the three agricultural systems. Data on the estimation of dehydrogenase, urease and phosphatase activities demonstrate that maximum enzyme-activity was in valley land soil followed by terrace land and slope land soil. The biochemical activities decreased along depth in all the three agricultural systems. A significant correlation was observed between fungal population and enzyme activities. Carbon dioxide evolution was also found to be maximum in valley land followed by terrace land and slope

land soil. Maximum output of CO_2 was found from surface soil and along depth the CO_2 output decreased. Generally, microbial population, enzyme activities and CO_2 evolution followed a trend : valley land > terrace land > slope land.

Effect of fungicides, viz., benomyl, copper oxychloride and mancozeb and herbicides viz., benthiocarb 2,4-D and fluchloralin on leaf surface microflora has been studied. An initial drop in the microbial population of leaf surfaces was observed in all the fungicides treated plants. However, in all cases microbial population increased subsequently. Fungicide had only marginal effect on the species composition of phyllosphere fungi. Acremoniella sp. was restricted to fungicide treated plants only. Penicillium chrysogenum and sterile forms were isolated from phyllosphere of all the treated as well control plants. In general, herbicides application also resulted into a drop in microbial population, however, a recovery was noted 15 days after application and thereafter the population increased with time. Oidiodendron echinulatum was isolated only from treated plants. Arthrobotrys arthrobotryoides, Cladosporium cladosporioides, Mucor hiemalis, M. racemosus, Penicillium chrysogenum and sterile forms were isolated from the treated as well as control plants.

The fungal and bacterial population of rhizosphere

and non-rhizosphere soils dropped significantly following application of the fungicides and throughout the study, treated plots harboured lower population than the control plots. The effect of the fungicides was more pronounced in the rhizosphere than the non-rhizosphere region. The species composition was altered and dominant species were more severely affected. Acremonium rutilum, Aspergillus flavus and Necteria ventricosa were isolated only from fungicides treated plants. Microbial population in rhizosphere as well as in soil dropped after herbicide application, recovery in microbial population was observed 30 days after the application. The species composition of fungal community altered in favour of herbicide resistant forms. Cladosporium cladosporioides, Fusarium oxysporum, Mucor spp., Penicillium sp. and Trichoderma sp. were resistant to the herbicides.

Fungicides and berbicides generally reduced the colony growth of Alternaria alternata on agar medium. In case of 2,4-D, however, stimulation was found at low concentrations. All the three fungicides were inhibitory for the spore germination and germ tube growth of A. alternata. The inhibition increased with increasing concentrations. At higher concentrations all the herbicides inhibited the spore germination and germ tube growth, however, 2,4-D and benthiocarb were stimulatory for germ tube growth at low concentration. Inhibition of the growth of fungi in case of all the three herbicides was dose dependent.

The study on decomposition of leaf, stem and root litter of potato was carried out using plastic net bag technique.It was found that the rate of decomposition was dependent on the chemical composition of litter and associated microbial population. Weight loss of leaf litter was faster than stem and root. Higher concentration of C,N,P,K,Ca and Mg was found in leaf litter as compared to the stem and root. The concentration of elements decreased with time. Highest microbial population on leaf litter was found in the month of June while in case of stem and root the highest microbial population was recorded in the month of July. The species composition of fungi associated with the leaf stem and root litters did not vary significantly and most species were common to the three litter types. A total of 15,14.14 species of fungi were isolated from leaf stem and root litter respectively. Mucor hiemalis, Rhizopus oryzae, Penicillium chrysogenum, Fusarium moniliforme and Trichoderma were the dominant fungi on decomposing litter.

The higher amount of C,N,P and K, a higher microbial population and the biochemical activity in valley land showed that the valley land soil was rich in nutrient status and that the microbial mediated processes of soil were faster in this system as compared to terrace land and slope land soil. Thus, from the results it is clear that valley land cultivation and terrace land cultivation is better than slope land cultivation. The studies on the effect of herbicides and

fungicides showed that both altered the microbial population, however, fungicides were more toxic than the herbicides. Both phyllosphere and rhizosphere microflora were affected adversely, however, it recovered rapidly which shows that the effects of the biocides were not persistent. The study on the rate of decomposition and loss of elements from potato litters demonstrated that the turn over of nutrients will take probably 1 year.

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APPENDIX I

Host range of *Alternaria alternata*

Name of the host and plant part	Reference
Adhatoda vasica, leaves	Roy (1976)
Blumia lacianiata, leaves	Shukla and Singh(1975)
Bougainvillia spectabilis, leaves	Tandon and Jamaluddin (1971)
Carissa carandus, leaves	Tandon and Kumar(1974)
Clitoria ternatea, leaves	Jamaluddin and Tandon (1973)
Cocos nucifera, leaves	Rao and Subramanyam(1975)
Crataeva religiosa, leaves	Waraiteh et al.(1974)
Fagopyrum tataricum, leaves	Thakur (1974)
Gardenia florida, leaves	Narain and Saksena(1974)
Hordeum vulgare, leaves	Dhanraj (1970)
Ocimum sanctum, leaves	Narendra (1975)
Melia azadiracta, leaves	Roy et al. (1976)
Plumeria acutifolia, leaves	Bharatudu and Rao(1976)
Populus curamiricana, leaves	Chaturvedi (1972)
Prunus armeniaca, leaves	Sud and Agrawal(1972)
Rosa sp., leaves	Bedi and Singh(1972)
Triticum vulgare, leaves	Sokhi et al.(1972)
Vitex negando, leaves	Roy (1976)

APPENDIX

Research Publication

1. Effect of Benomyl, copper oxychloride and Mancozeb on Rhizosphere microflora of potato. Proc. Indian natn. Sci. Acad. B53 No.3 PP 273-278 (1987).
2. Effect of foliar application of herbicides Benthiocarb, 2,4-D and Fluchloralin on the leaf surface microflora of potato. Plant and Soil (1988). In Press.
3. Leaf surface microflora of potato as influenced by application tof fungicides. Proc. 74th. Ind. Sc. Cong. Part III : Abstract PP 61 (1986).
4. Leaf surface microflora of potato as influenced by application of fungicides. Indian Phytopathology. (Communicated).