STUDIES ON MICROBIAL COMMUNITIES AND THEIR ACTIVITIES IN SOILS OF PINEAPPLE PLANTATIONS

By

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THESIS
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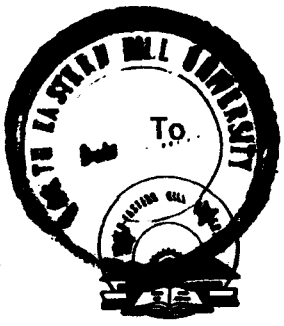

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We certify that the thesis entitled "STUDIES ON MICROBIAL COMMUNITIES AND THEIR ACTIVITIES IN SOILS OF PINEAPPLE PLANTATIONS" submitted by Mr. Subhash Chandra Tiwari, M.Sc. for the degree of Doctor of Philosophy of the North-Eastern Hill University, 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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Chandra

(Subhash Chandra Tiwari)

DEDICATED TO THE

LOVING MEMORY OF

MY FATHER

C O N T E N T S

GENERAL INTRODUCTION

Climate and edaphic conditions of north-eastern India is favourable for the cultivation of pineapple (Ananas comosus L.) and during recent years it is the most important cash crop of this region. Establishment of fruit pulp based industries and improved marketing facilities during recent years have given added boost to this crop. Total area under this crop is on increase and growers are getting better price for their produce. In addition to the direct economic gains, the cultivation of pineapple also helps in conservation of top soils on hill slopes as the roots of this plant have tremendous soil binding capacity. Importance of bacteria and fungi in soil ecosystem can hardly be over emphasised. They are responsible for the breakdown of complex organic compounds, transformation of nutrients in soil and for the improvement of soil structure. The population and activity of microbes are generally governed by the climate, physico-chemical characteristics of soil and plant cover (Waksman, 1952; Mishra and Kanaujia, 1972; Tyagi, 1975; Kauri, 1982; Dunn et al. 1985; Tiwari et al. 1987 a). During recent times much emphasis is laid on the activity of microorganisms in the soil. Generally, the rates of microbial mediated biochemical reactions are used for this purpose as they provide an index of microbial activity (Skujins, 1978). Dehydrogenase, urease and phosphatase are commonly used for this purpose. Dehydrogenase being a respiratory enzyme provides a measure of catabolic

activity (Lenhard, 1956; Stevenson, 1959; Casida et al. 1964. Urease acts as an intermediary enzyme in the transformation of organic nitrogen, while phosphatase provides an estimate of breakdown of organic phosphate compound and release of phosphate in the soil (Cosgrove, 1967). The estimation of the activity of these enzymes provides an assessment of three different microbe-mediated processes in soil and the estimation of the activity of the three enzymes in soil gives the most reliable measure of microbial activity.

During the last three decades a large number of studies on relationship of enzymes activities with the physico-chemical and biological characteristics of soils have been carried out. A close positive relationship of dehydrogenase has been reported with CO_2 release, O_2 uptake, microbial number, organic carbon, soil moisture, temperature, pH etc. (Kuprevich and Scherbakova, 1971; Skujins, 1973; 1976; Casida, 1977; Speir, 1977; Dash et al. 1981; Baruah and Mishra, 1984; Rao and Ghai, 1985; Das and Mishra, 1986; Tiwari et al. 1987 b). Contrary to the above, Gray and Williams (1971 b) did not find correlation between dehydrogenase activity and microbial numbers. Urease activity has been found to be positively correlated with microbial biomass and number, organic carbon, total nitrogen, available phosphorus, potassium, soil moisture, temperature, pH and cation exchange capacity of soils (Skujins, 1973; Dalal, 1975; O'Toole et al. 1982;1985; Dkhar and Mishra, 1983;

O'Toole and Morgan, 1984; Sahrawat, 1980, 1983, 1984; Baruah and Mishra, 1984). However, Zantua et al. (1977) reported that urease activity negatively correlates with the organic carbon, pH and cation exchange capacity of soils. Like dehydrogenase and urease, phosphatase activity has also been reported to be positively correlated with microbial biomass, organic carbon, total nitrogen, exchangeable phosphorus, soil moisture, pH and clay + silt content of soils (Speir, 1977; Ladd, 1978; Klein and Koths, 1980; Speir and Ross, 1981; Appiah and Thomas, 1982; Frankerberger and Dick, 1983· Harrison, 1983). The variations in the pattern of relationship between enzyme activities and soil characteristics have been generally attributed to the difference in soil characteristics, vegetation type, cropping system and use of agro-chemicals.

Studies of various workers (Warcup, 1957; Dwivedi, 1966; Mishra, 1966; 1968; Prakash and Khan, 1971; Wong, 1975; Martinez and Remirez, 1979) have demonstrated that climatic and edaphic factors modify the distribution of soil microbes. Agricultural activities and burning practices greatly affect the soil microflora (Tiwari and Rai, 1977; Hattori, 1973).

Most of the carbon dioxide evolved from the soils comes from the microbial respiration (Smith and Brown, 1932) and, therefore, it has been used as a measure of microbial activity Wagner, 1975; Julia and Pedziwilk,

1985). CO_2 concentration in the soil affects the soil pH, nutrient availability, redox potential, organic matter decomposition and microbes number (Bohn et al. 1979 ' Alexander, 1977). A positive correlation between CO_2 evolution and various physico-chemical and microbiological characteristics of the soil has been noted by several workers (Singh and Gupta, 1977; Singh, 1984; Keeney et al. 1985; Das and Mishra, 1986; Baruah and Mishra, 1986; Dkhar and Mishra, 1987; Tiwari et al. 1987 c).

Since soil enzyme-systems are associated with organic residue management burying of crop residues into the soil not only plays an important role in chemical and biological environment of the soil, it also affects the rate at which nutrients become available to crop plants as well as to other forms of life in the soil (Power and Legg, 1978). Fungi and bacteria play an important role in the process of plant litter decomposition. A large amount of plant litter is added annually to the soil through leaf fall and death of plants and animals. Studies on decomposition provide information on the rate of turn over of the nutrients. The rate of decomposition is governed by the climate (Shukla et al. 1978; Shukla and Singh, 1984), soil microbial population (Witkamp, 1963; Mishra, 1979) and chemical composition of litter (Christensen, 1986). It is envisaged that the study on the microbial succession and chemical change in the litter would help to understand the complex process

of decomposition of pineapple litters.

Earthworms are beneficial to the soil as they represent a large part of the soil faunal biomass. They play an important role in improving the soil fertility by influencing aeration, water retaining capacity and nutrient status (McColl et al. 1982). Earthworms also play an important role in plant litter decomposition. They are mainly responsible for the distribution of microbial communities by feeding on soil at one place and laying their casts at another (Lofty, 1974; Dash et al. 1979). Activities of earthworms significantly affect the physico-chemical and biological properties of soils. A comparative study on microbial population and their activities (dehydrogenase, urease, phosphatase) in earthworm casts and the surrounding soil would help to understand that how microbial population and their activities are altered in the soils after passing through the guts of earthworm.

The study has been dealt under following headings :

1. Temporal and depth-wise variations in physico-chemical characteristics of pineapple orchard soils.
2. Temporal and depth-wise variations in microbial population and their activities in pineapple orchard soil.
   (i) Estimations of microbial population (fungi and bacteria).
   (ii) Determination of dehydrogenase, urease, phosphatase activity and CO_2 evolution.

3. Microbial decomposition of pineapple litter (leaf and root).
4. Estimation of earthworm population in pineapple orchard soil.
5. Estimation of microbial population and their activities in casts of earthworms and in the surrounding soils of pineapple orchard.

STUDY AREA AND CLIMATE

The present study was conducted at Pineapple Research Station Nayabunglow situated at an altitude of 800 m from near seal level: latitude 25°44" N and longitude 91°53" E.The total size of farm was approximately 15ha. Plantations of 1 year, 5 year and 10 year age were selected for the study. The three plantations were situated side by side in the research station.The soil of the three plantations was of sandy loam type (Table1.1).

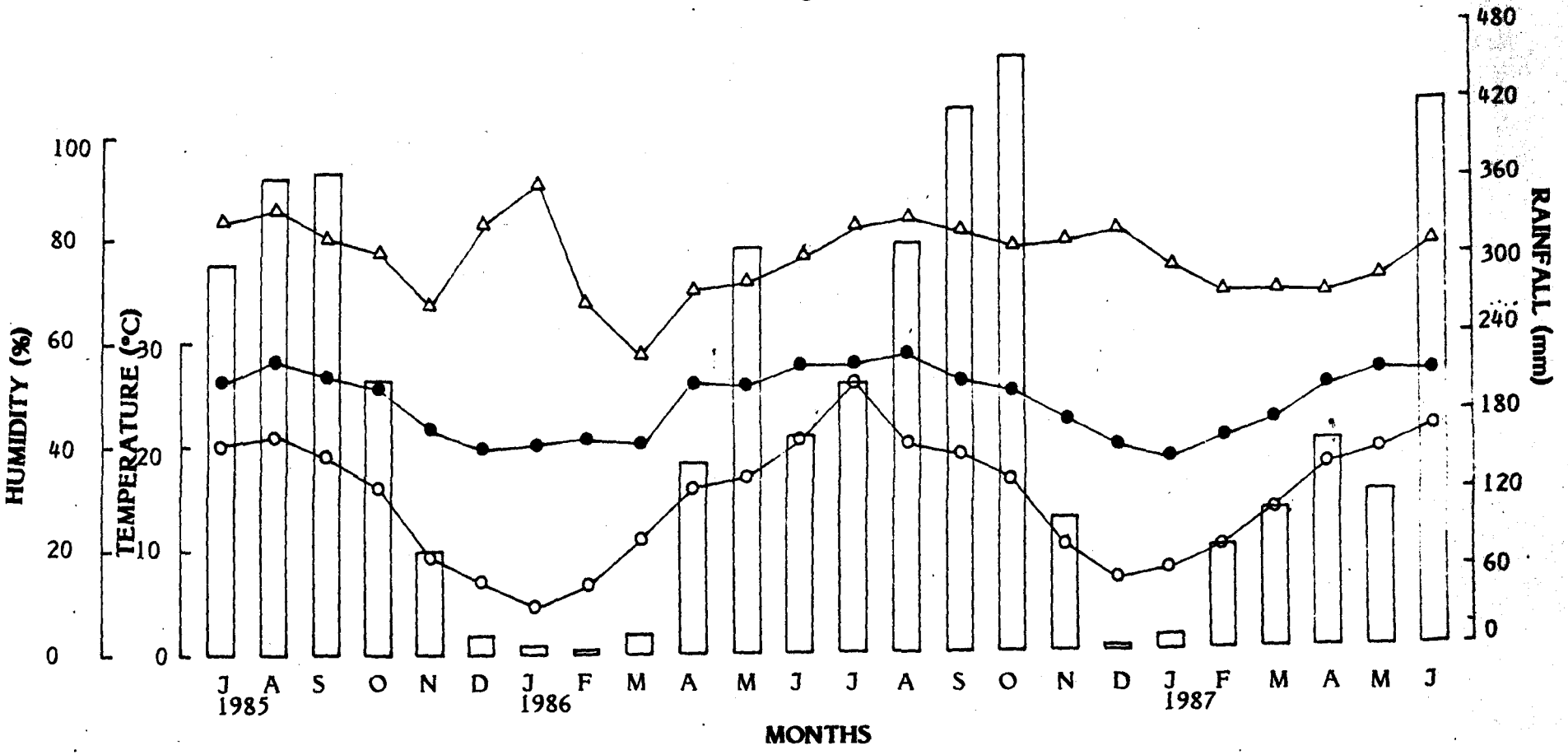
The climate of study area is cool with a minimum temperature of 4.5°C in the month of January.The average maximum temperature was found 23.8°C and average minimum temperature was 15.6°C. The rainfall occurs between March-November.December, January and February are generally dry months (Fig.I). The average annual rainfall is 201.4 mm. During winter months percentage relative humidity goes upto 90%. Generally, the percentage relative humidity of the study site ranges between 57 and 90%.

Climate of the study area can be divided into the following seasons :

The period from mid-February to mid-April is the spring which is followed by rainy season. Rainy season is the longest season of the year. It starts from mid-April and continues upto the middle of September. The early period of rainy season is warm while later period is comparatively cool. The autumn is the shortest season of the year.The period from mid-September to October is included in this season. The winter starts from the end of October and continues upto the middle of February.

Fig. I Monthly variation in rainfall (histogram), ambient temperature and relative humidity of the study area.
● Maximum temperature
○ Minimum temperature
△ Relative humidity

Fig. 1


HUMIDITY (%)
TEMPERATURE (°C)
RAINFALL (mm)
100
80
60
40
20
0
30
20
10
0
480
420
360
300
240
180
120
60
0
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
MONTHS

C H A P T E R I

TEMPORAL VARIATIONS IN PHYSICO-CHEMICAL CHARACTERISTICS OF PINEAPPLE ORCHARD SOILS

INTRODUCTION

The physico-chemical characteristics of the soil varies with time and space. Type of parent rock, climate, vegetation type and topography are most important factors which govern the physico-chemical characteristics of the soil. On annual basis nutrients are added to the soil in the form of chemical fertilizers or it may be incorporated as leaf litter, plant residues or animal remains. Dynamic equilibrium of nutrients in the soil is maintained by the phenomenon of nutrient uptake, return of nutrients and retention of nutrients within the bodies of plants, soil animal and microorganisms.

The biological availability of nitrogen, phosphorus and potassium is of considerable economic importance because they are the major plant nutrients that plants derive from the soil. Organic nitrogen is released in the form of ammonium ions which may be utilized by plants or may be oxidized to nitrate. Phosphorus is present in the soil, plants and microorganisms in the form of organic and inorganic compounds. Potassium is usually the most abundant of the plant nutrient element found in soils. It is the major cation that plant must obtain from the soil. The seasonal changes in weather results into variations in the physico-chemical characteristics of the soils. Soil microorganisms through their various activities also alter the physico-

chemical properties of soil.

Physico-chemical characteristics of the soil reflect the capacity of soil to provide the plant nutrients in the proper amount for the growth of plants. It is well known that physico-chemical characteristics such as soil pH, temperature, moisture, organic carbon, nitrogen, phosphorus and potassium regulate the population and activity of microorganisms in soils (Mishra, 1966; Tiwari et al. 1987 b). Therefore, in order to understand the population dynamics and activity of microorganisms of pineapple plantation field soils, the most important aspect to be worked out is the physico-chemical characteristics of the soils.

Studies on physico-chemical characteristics were generally, conducted in forest agriculture and grassland soils (Sing , 1968; Das, 1980; Dkhar, 1983). Possible relationships among microbial population their activities, nutrient dynamics, litter decomposition and physico-chemical characteristics have been also investigated in above soils by several workers (Seth et al. 1963; Switzer and Nelson, 1972; Dkhar and Mishra, 1987). However, little is known about the physico-chemical characteristics of orchard soils. The aim of the present study is to work out monthly and depth-wise variations in various physico-chemical characteristics of the soils of pineapple orchard.

REVIEW OF LITERATURE

Physico-chemical characteristics viz., temperature, moisture, pH and organic. C,N,P,K contents of soil regulate the population and activity of microorganisms in soil.Owing to this these parameters of soil properties have been widely investigated.

McCall et al. (1956) reported that 30% to 85% of the total phosphorus in agricultural soils is found in organic forms. Ahlgren and Ahlgren (1965) noted a positive correlation between soil temperature and soil pH.

Maliwal and Khangarot (1969) studied the extraction and fractionation of organic matter in Rajasthan soils.They noted that the amount of C and N increased with depth in light textured soils.

Bieleski (1973) studied the phosphate transport and its availability to the plants in soils. He stated that phosphate is relatively immobile and this may be the reason for the little variations noted along depths.

Mishra and Singh (1973) studied the leaching of applied nitrogen in soils. They reported that ammonium ions from N-fertilizers are retained in 0-4 cm depth of the soils but nitrate ions move out of it. Very little ammonium ions are able to move down to the bottom of the soils.

Singh and Pathak (1973) studied the forms of phosphorus in relation to physico-chemical characteristics of

soils in alluvial tract of the Uttar Pradesh (India). They observed a positive correlation between available P and Al-P, Fe-P, reductant and soluble Fe-P and Ca-P.

Yadav and Badolka (1973) found that soils of deodar forests of Uttar Pradesh (India) have a high water holding capacity and cation exchange capacity. They also noted that the soil contained moderate concentration of Ca and Mg and the soils were deficient in P.

Dunn and Debano (1977) studied the effect of fire on biological and chemical properties of chaparral soils. They reported that 20, 40, 60 and 80% loss in total nitrogen occurred at the temperatures 211°C, 287°C, 422°C and 528°C respeetively.

Zinke et al. (1978) reported that the high temperature releases cations in the surface soils thereby increasing the potassium concentration of the soil.

Singh (1980) studied the nutrient cycling in a subtropical humid forest of Meghalaya and reported that most of the nutrients were accumulated at 10-40 cm soil depth. He further, suggested that below this depth nutrient content declines drastically.

Sieving wet soil (Lynch and Panting,1980a) and grinding moist soil (Powlson,1980) were found to be affecting the C contents of soils.

Deka (1981) studied the seasonal variation i

organic matter content, nitrogen and available phosphorus in 1 year, 10 year and 20 year old fallows. He noted a sharp decline in NH_4^+-N level in February followed by a sharp increase during March-April. Lowest level of organic matter was noted during the period from June-August and then in subsequent period the level of organic matter remained almost uniform. Monthly variations in soil P contents of soils were not significant.

Baruah (1983) investigated the physico-chemical characteristics of rice field soils and recorded the higher concentration of C, N, P and K from the surface (0-10cm) soils which decreased with increase in depth. Similar findings were also recorded by Dkhar (1983) in maize field soils of Meghalaya (India).

Ross et al. (1985) reported that sieving markedly increased the contents of inorganic and organic P. They further, suggested that the rapid release and mineralization of organic N and P compounds from organisms killed during sieving could be a major factor contributing to the observed increments in these soil properties.

Baligar (1985) compared the mechanism of supply of K in wheat, corn and onion and reported that the mechanism of K supply to different crop species was dependent on the differences in their K requirement and was dependent on water flux rates and root parameters too.

Husin et al. (1986) noted a positive correlation (r=0.89) between plant uptake of K and exchangeable K in the soils.

Kuchenbuch et al. (1986) studied the effect of soil moisture on potassium availability to plants. They concluded that soil moisture affected K availability by affecting both K mobility and root growth.

Tripathi and Hazra (1987) reported that electrical conductivity, organic carbon, available N and P content of soil increased with an increase in the P application.

MATERIALS AND METHODS

Soil samples from various depths namely, 0-10cm, 10-20cm and 20-30cm were collected aseptically from each plantation soil and were used for the determination of pH, moisture and organic C, N, P, K contents of soils.

Soil temperature :

Soil temperature of three depths was recorded at the time of soil sampling with the help of a soil thermometer.

Determination of moisture content :

Moisture content of the soil was determined by drying 10 g of fresh soil in a hot air oven at 105°C for 24 hours. The percentage moisture content was calculated by

using the formula given below :

$$\%\text{Moisture content} = \frac{\text{Loss in weight on drying (g)}}{\text{Initial sample weight (g)}} \times 100$$

Determination of the pH:

10 g fresh soil was taken in a 100 ml glass beaker containing 50 ml distilled water and stirred for 20 minutes on a electric magnetic stirrer. The pH was then read out by electric digital pH meter.

Estimation of organic carbon:

Walkley and Black's (1934) rapid titration method was adapted for the determination of the organic carbon. 1 g air dried and sieved ($<.2$mm) soil was taken in a dry and cleaned 500 ml conical flask along with 10 ml of 1N K_2Cr_2O7 and 20 ml of conc. H_2SO_4. The flask was then left for 30 minutes. The mixture was diluted with 200 ml distilled water. Further, 10 ml of phosphoric acid (85%) was added and titrated with 1N $FeSO_4$ solution using diphenylamine as an indicator. For the blank (without soil) also the same procedure was followed. Three replicates were used for each sample analyses. The percentage organic carbon was calculated as follows :

$$\%\text{ Organic carbon} = \frac{B-S \times 0.003 \times 100}{W}$$

where,

B = ml volume of $FeSO_4$ used for blank titration

S = ml volume of $K_2Cr_2O_7$ used for sample titration

W = weight of sample (g).

Determination of percentage nitrogen :

Digestion : The semi-microkjeldahl method as described by Allen (1974) was used. 1.0 g air dried and sieved (<.2mm) soil was taken in dry and clean 10 ml Kjeldahl flask. 2 g, K_2SO_4-HgO and 3 ml conc. H_2So_4 were added to the flask. The mixture was then filtered through Whatman No.1 filter paper. The filtrate was used for estimation.

Estimation : Percentage nitrogen was estimated by using the Indophenol blue method as suggested by Allen (1974) and calculated by the following formula :

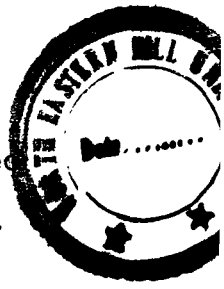
$$\% \text{ Nitrogen} = \frac{C(mg) \times \text{solution volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample weight(g)}}$$

where,

C = Concentration reading (mg) in the aliquot.

Determination of exchangeable potassium :

The method suggested by Allen (1974) was adapted for the extraction of exchangeable potassium.



Extraction : Ammonium acetate solution (pH = 7.0) was used for the extraction. It was prepared by mixing 575 ml glacial acetic acid with 600 ml of ammonia solution and dilu-

ted to 10 litre distilled water. 10 g air dried and sieved (<.2 mm) soil was taken in a 250 ml conical flask along with 150 ml of extracant solution. The suspension was then stirred on electric magnetic stirrer for a period of 30 minutes and filtered through Whatman No.44 filter paper.

Estimation : The exchangeable potassium in the filtrate was read out by the flame photometer and calculated by using the following formula :

$$K \text{ (mg } 100 \text{ g}^{-1}) = \frac{C(\text{ppm}) \times \text{solution volume(ml)} \times 10^3}{10^4 \times \text{sample weight (g)}}$$

Determination of available phosphorus :

For the estimation of available phosphorus Mobybdenum blue method was adapted (Allen, 1974). The available phosphorus was extracted in ammonium extraction solution. The extraction solution of ammonium fluoride was prepared by mixing 15 ml of ammonium fluoride solution (37 g/1000 ml) with 25 ml of 0.5N HCl and 460 ml of distilled water.

Extraction : 2.85 g air dried and sieved (<.2 mm) soil was taken in dry and clean 100 ml conical flask and 14 ml of ammonium fluoride extraction solution was added. The flask was wrist shaken for 5 minutes. The content of flask was filtered over Whatman No.44 filter paper. The filtrate was used for the determination of available phosphorus.

Estimation : 5 ml aliquot of the extract was taken in 50 ml volumetric flask and 1 ml of ammonium molybdate solution was added. The content of the flask was mixed. 2 ml of freshly prepared stannous chloride solution was added to the flask, and diluted the volume upto 50 ml by adding distilled water. The flask was left for 30 minutes. Blank (without soil)determination was also carried out in the same way and substracted from the samples estimations. Optical density of blue colour solution was read out spectrophotometrically at 660 nm. A calibration curve from the standards was used to determine phosphorus in the aliquot. Available phosphorus in the extract was calculated as follows :

$$\text{Extractable phosphorus } (\text{mg } 100\ g^{-1}) = \frac{C(\text{mg}) \times \text{solution volume(ml)} \times 10^3}{10 \times \text{aliquot (ml)} \times \text{sample weight(g)}}$$

where,

C = Concentration reading (mg) in the aliquot.

RESULTS

Soil Texture :

The soil of all the three plantations was of sandy loam type (Table 1.1).

Temperature :

Generally surface soils (0-10cm) of all the plantations showed higher temperature which decreased with increasing depth (Fig.1.1). During winter (November-

Table: 1.1. Soil texture.

Plantations	Sand %	Silt %	Clay %
1 year	66.68	15.87	17.45
5 year	65.10	15.10	19.80
10 year	67.31	13.29	19.40

February) temperature decreased and increased during March in most cases. Since July, 1985 to June, 1987 temperature varied from 10°C to 31°C (Fig.1.1). In general 1 year plantation soil showed maximum temperature followed by the 5 and 10 year plantations.

Moisture content :

Moisture content of the soil varied from 12.5 to 32.18% (Fig.1.2). Higher moisture content was generally recorded from the surface soil. Low soil moisture was recorded during winter months which increased with the onset of rains. During rainy season the surface soil generally contained higher moisture while during winter higher moisture was generally noted in deeper layers (Fig.1.2).

pH :

pH of the soil ranged between 4.2 and 5.82 (Fig. 1.3). Maximum pH (5.82) was noted from the surface soil (0-10cm) of 1 year old plantation during the month of November 1985 while minimum (4.20) was recorded from the deeper layer of 5 year plantation in the month of December 1986. pH did not differ significantly in all the three plantations and at different depths.

Organic carbon :

Temporal and depth-wise variation in organic carbon content of the soil is shown in Fig.1.4. Surface

soil (0-10cm) generally showed higher amount of organic carbon in all the plantations and it varied from 0.49 to 2.70% (Fig.1.4). Maximum (2.70%) organic carbon was noted from the surface soil of 5 year plantation during the month of May, 1987 while minimum (0.49%) was recorded from the deeper soil of the 1 year plantation in January, 1986. During both the years 5 year old plantation contained maximum organic carbon (1.80% - 2.24%; 0.50-2.70%) which was followed by 10 year (1.04 - 2.16%; 1.12 - 2.25%) and 1 year (0.49 - 2.20%; 0.75 - 2.20%) plantation soils. A drop in organic carbon content was recorded during the winter. In many cases it rose in the month of March followed by a drop in April and again increased in May.

Nitrogen :

Nitrogen ranged between 0.20 and 0.68% in all the studied plantations. Maximum nitrogen (0.68%) was noted from the surface soil of the 5 year plantation during March, 1986. Deeper soil of the same plantation exhibited minimum (0.20%) value in January,1986. Since July, 1985 - June, 1986 soil of 5 year plantation harboured higher nitrogen content than the 10 year and 1 year plantations (Fig.1.5). During the next study period (July 1986 - June 1987) the trend in nitrogen content was 1 year > 10 year > 5 year. Nitrogen content dropped in winter months. Rise in N content was observed during March in many cases (Fig.1.5). No definite pattern of depth-wise variation was recorded but in most

cases higher nitrogen was recorded from the surface (0-10cm) soil.

Phosphorus :

Available phosphorus of the soil varied from 3.5 mg to 11.6 mg 100 g^{-1} (Fig.1.6). Maximum available phosphorus was recorded from the surface soil of the 10 year plantation while minimum was noted from the deeper soil of the 5 year plantation (Fig.1.6). During the study period (July 1985 - June 1986) soils of 10 year plantation showed more available phosphorus than 1 and 5 year plantation while it did not differ significantly in all the three plantations since July 1986 - June 1987. Almost similar trend of monthly variation was noted in all the three plantations. During winter months phosphorus content was low which increased in March in many cases. Depth-wise available phosphorus varied within a narrow range, however, surface soils showed higher phosphorus content.

Exchangeable potassium :

Generally, exchangeable potassium was higher in surface (0-10cm) soils which decreased with increasing depth (Fig.1.7). It varied from 7.0 mg to 22.2 mg 100 g^{-1}. Maximum exchangeable potassium was noted from the surface soil of 5 year plantation in March 1986 while minimum was found in deeper soil of 10 year plantation in September 1985. During both the years, 5 year plantation soil showed

Fig. 1.1 Monthly variation in soil temperature of the different plantation soils.

Fig. 1.1

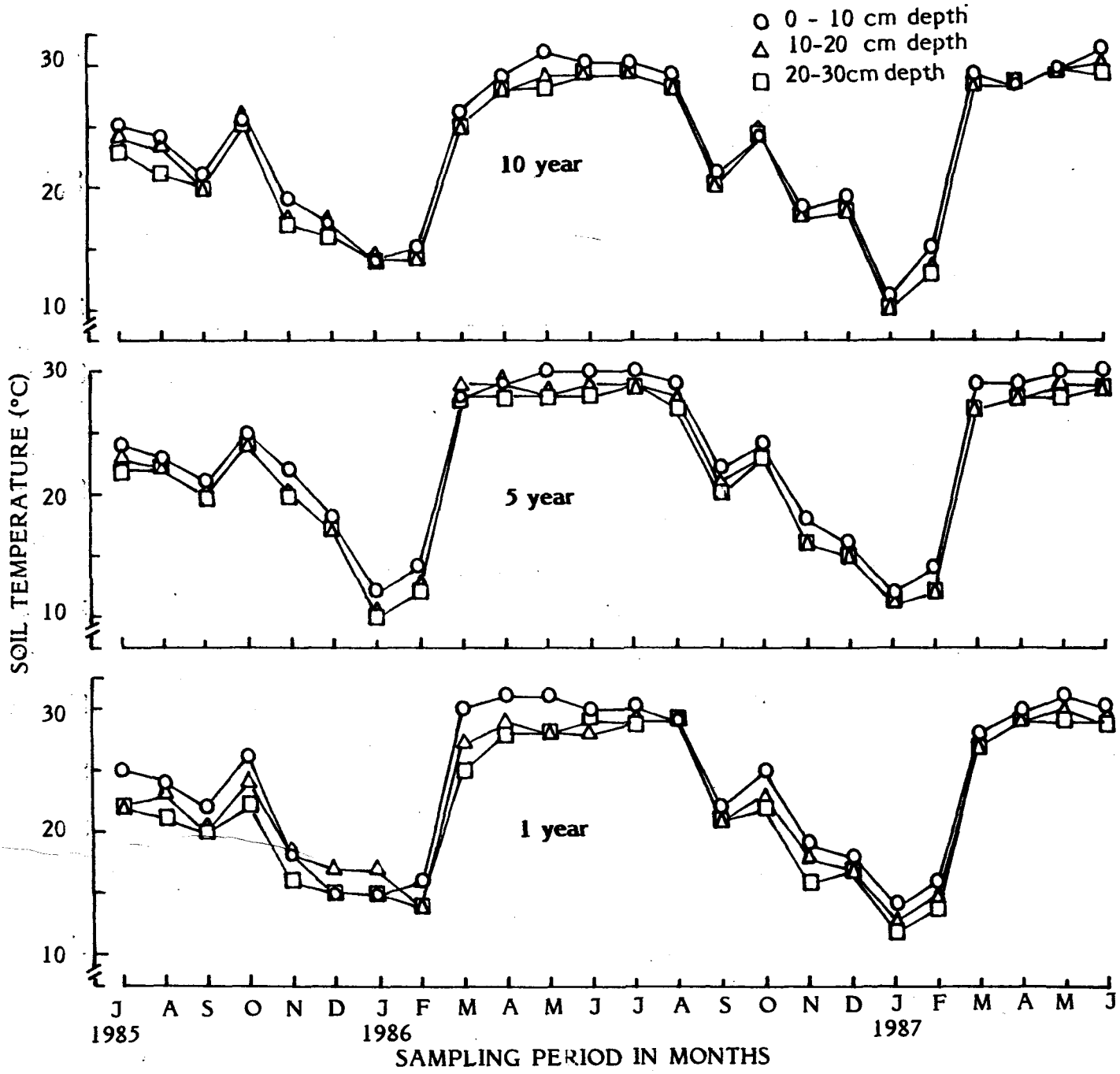

0 - 10 cm depth
10-20 cm depth
20-30cm depth
10 year
5 year
1 year
SOIL TEMPERATURE (°C)
30
20
10
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 1.2 Monthly variation in soil moisture content of the different plantation soils.

Fig. 1.2

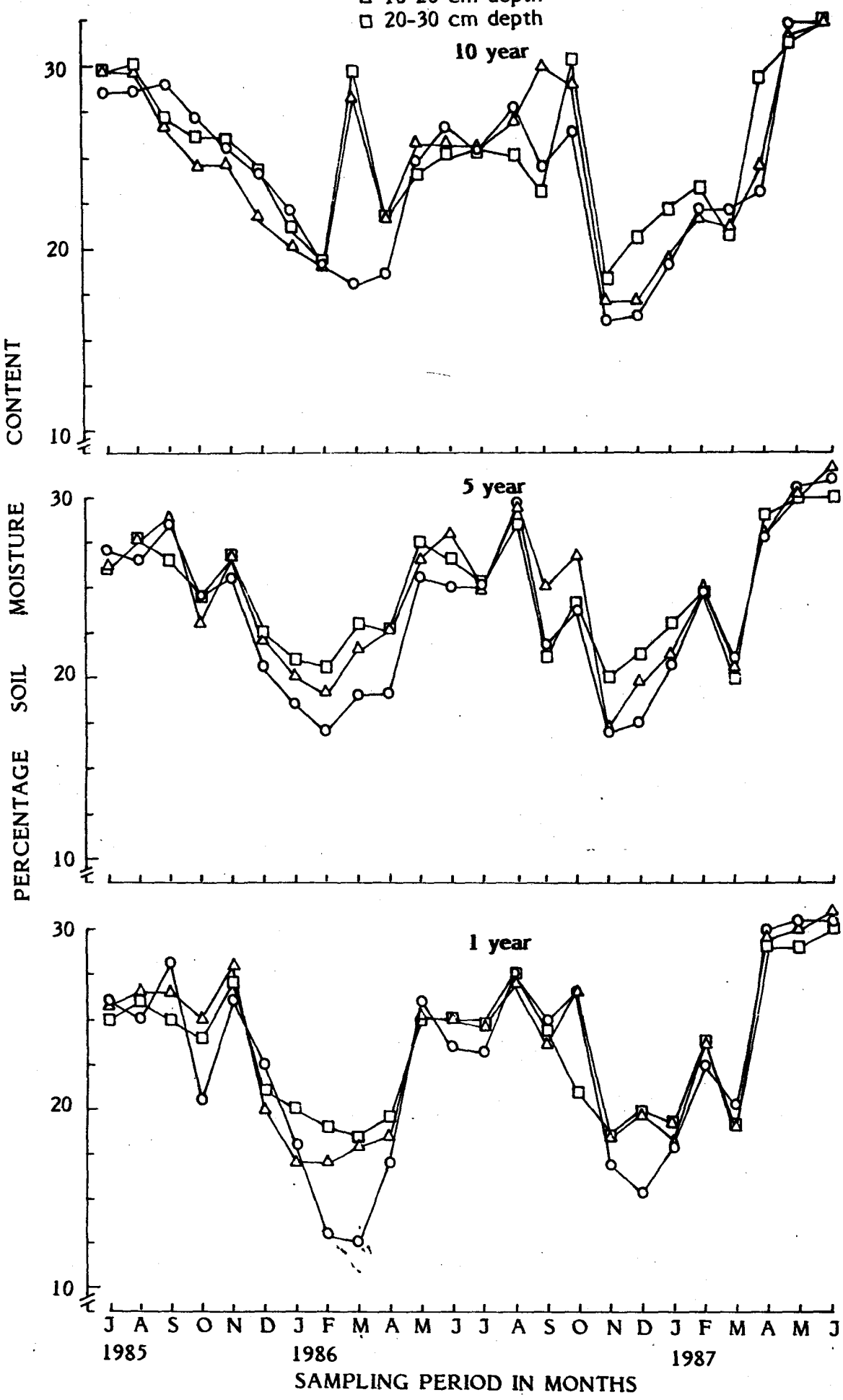

o 0 -10 cm depth
Δ 10-20 cm depth
□ 20-30 cm depth
10 year
5 year
1 year
PERCENTAGE SOIL MOISTURE CONTENT
30
20
10
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 1.3 Monthly variation in pH of different plantation soils.

Fig. 1.3

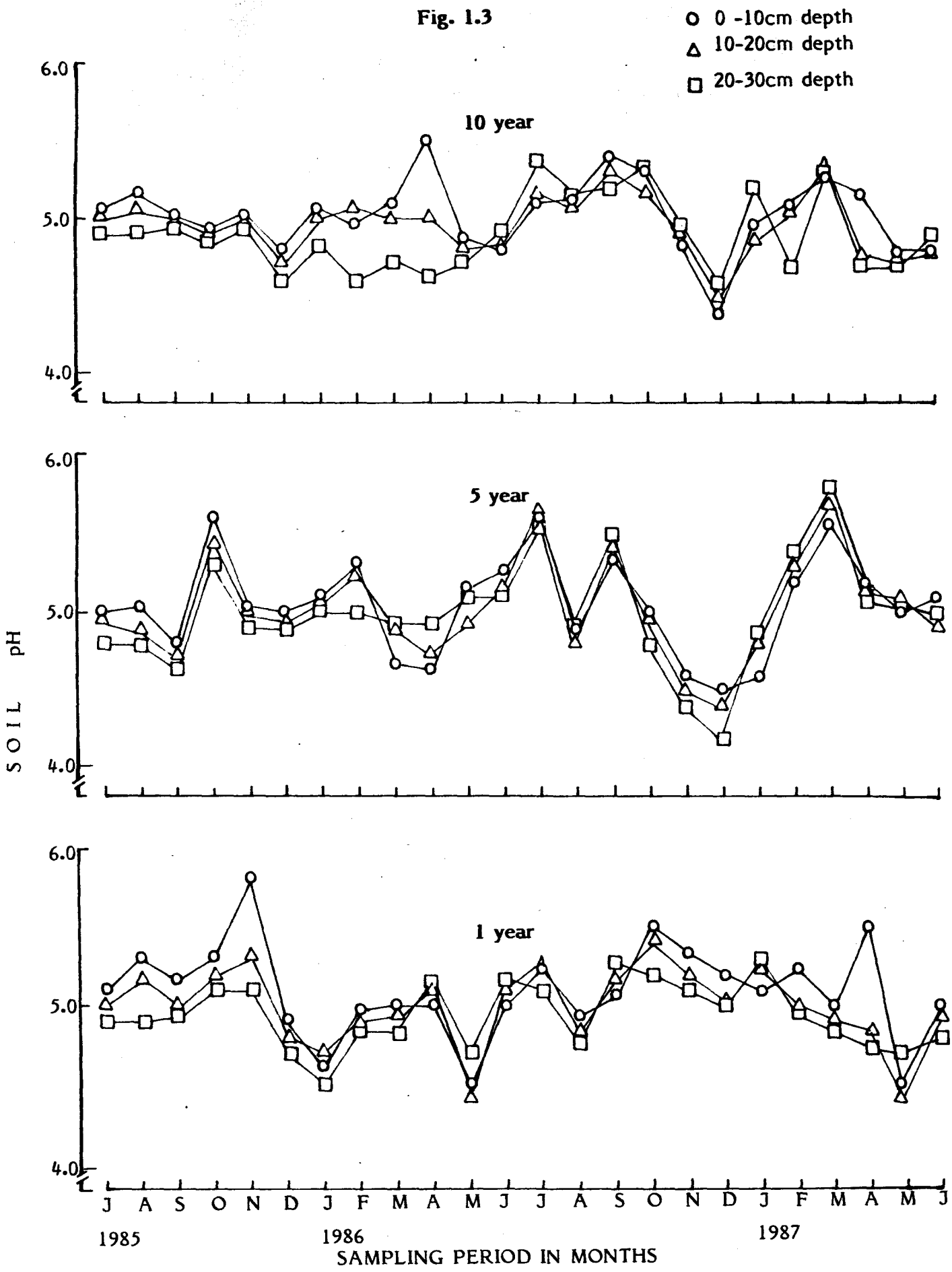

0 -10cm depth
10-20cm depth
20-30cm depth
10 year
5 year
1 year
6.0
5.0
4.0
SOIL pH
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 1.4 Monthly variation in organic carbon content of different plantation soils.

Fig. 1.4

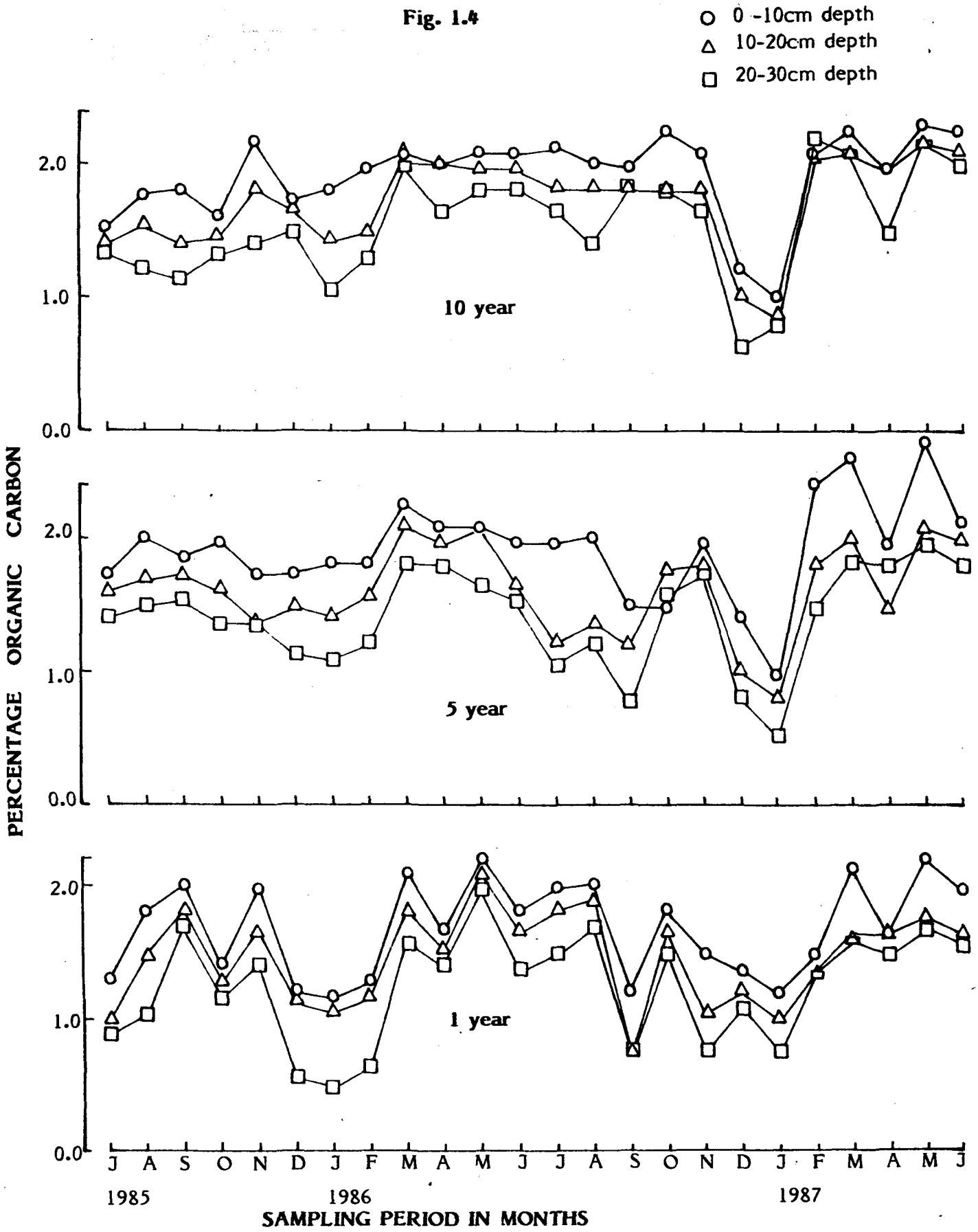

0 -10cm depth
10-20cm depth
20-30cm depth
PERCENTAGE ORGANIC CARBON
2.0
1.0
0.0
10 year
5 year
1 year
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 1.5 Monthly variation in total nitrogen content of different plantation soils.

Fig. 1.5

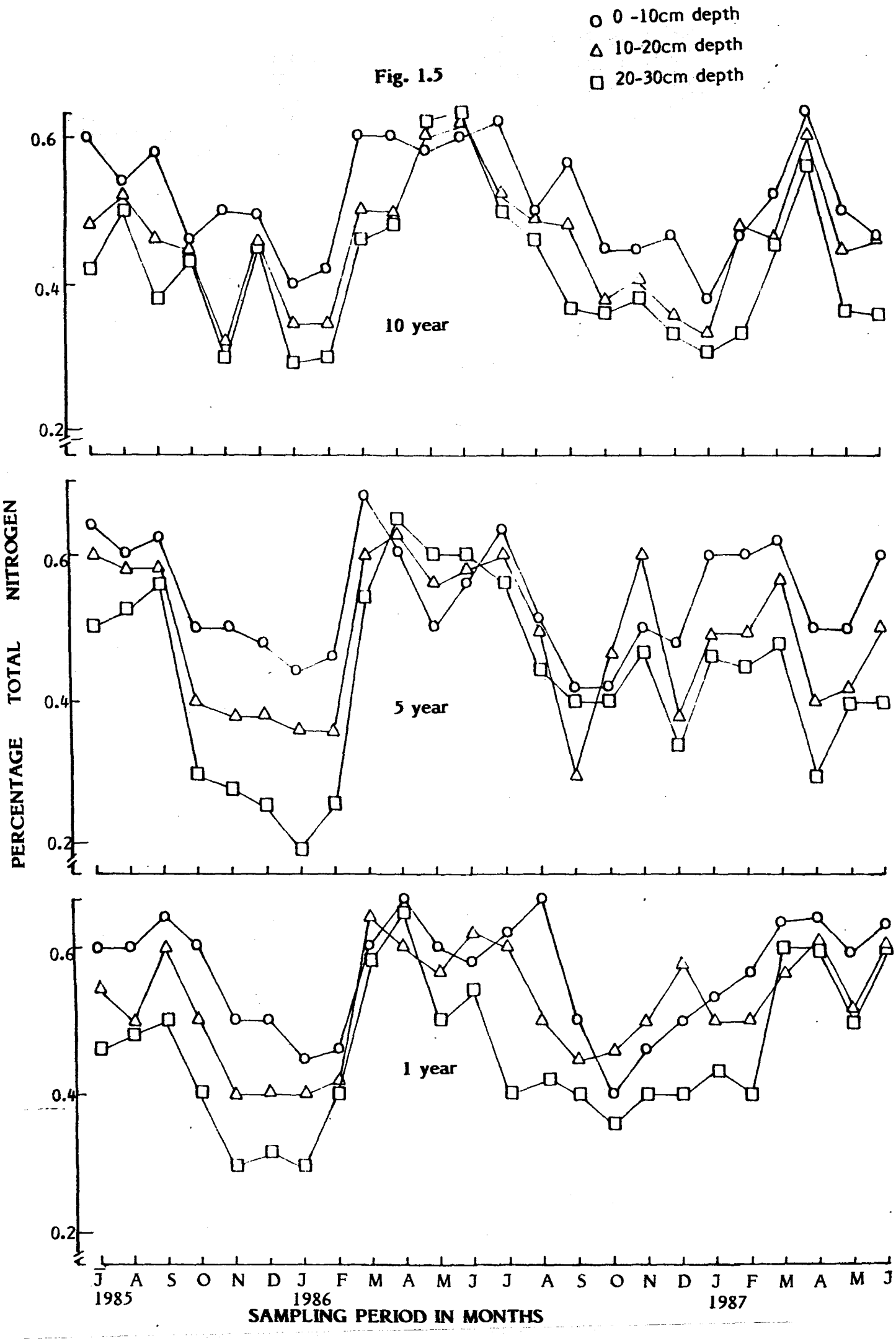

o 0 -10cm depth
Δ 10-20cm depth
□ 20-30cm depth
PERCENTAGE TOTAL NITROGEN
0.6
0.4
0.2
10 year
5 year
1 year
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig.1.6 Monthly variation in available phosphorus content of different plantation soils.

Fig. 1.6

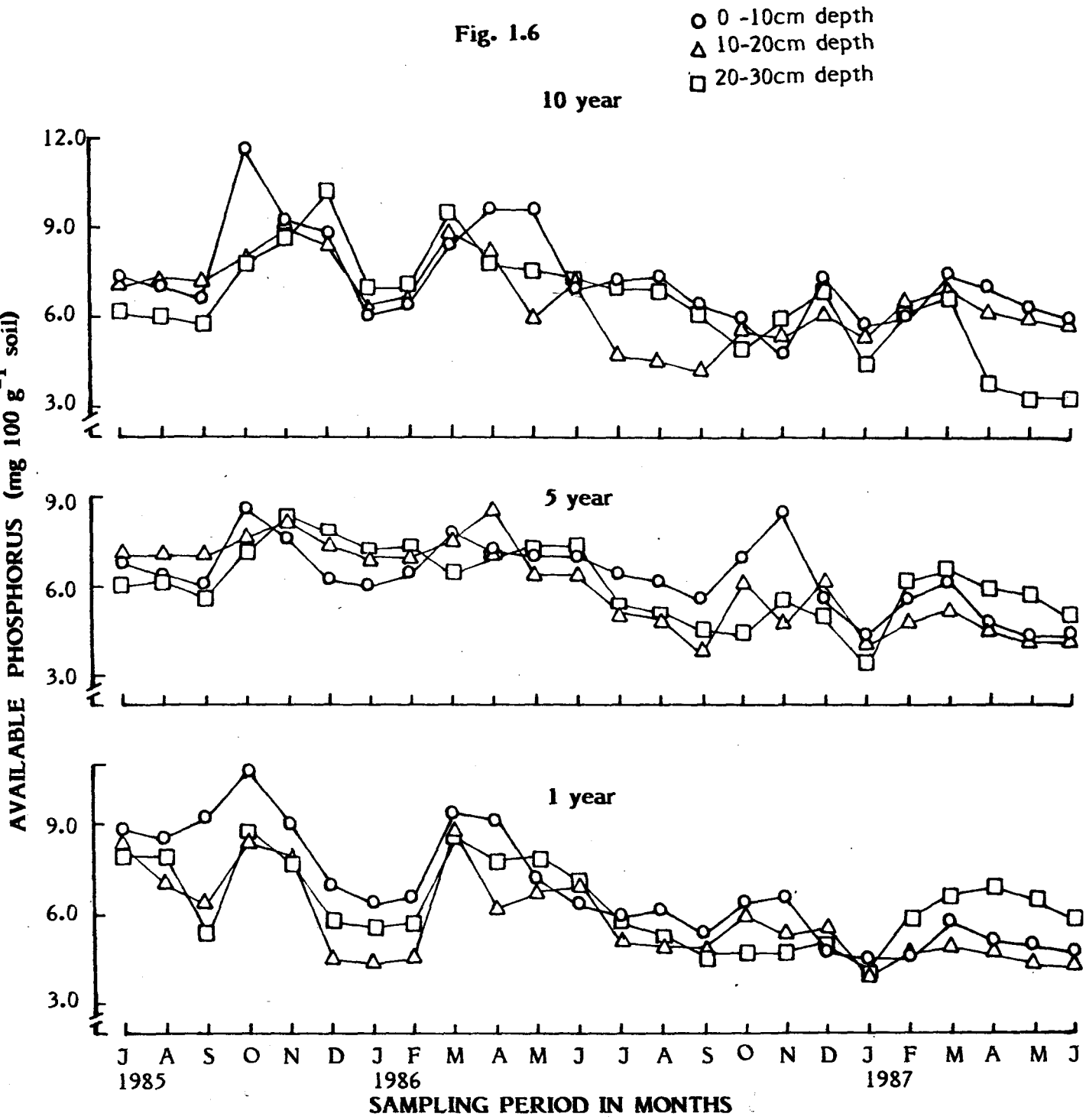
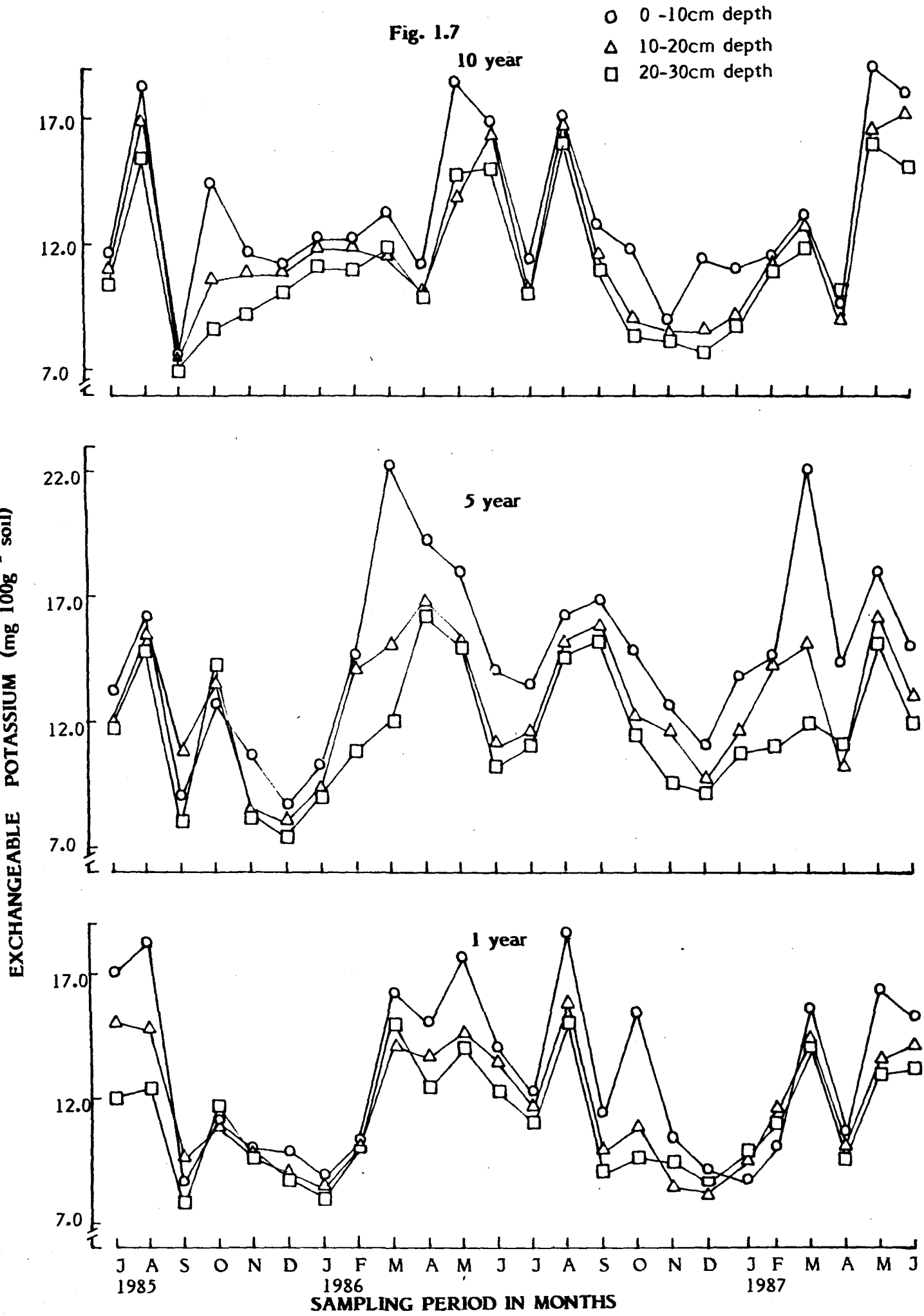

o 0 -10cm depth
Δ 10-20cm depth
□ 20-30cm depth
10 year
5 year
1 year
12.0
9.0
6.0
3.0
AVAILABLE PHOSPHORUS (mg 100 g^{-1} soil)
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 1.7 Monthly variation in exchangeable potassium content of different plantation soils.

Fig. 1.7


0 -10cm depth
10-20cm depth
20-30cm depth
10 year
5 year
1 year
EXCHANGEABLE POTASSIUM (mg 100g^{-1} soil)
22.0
17.0
12.0
7.0
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

maximum potassium (7.5 mg - 22.2 mg 100 g^{-1}; 9.3 mg - 22.2 mg 100 g^{-1}) followed by the 10 year (7.0 mg - 18.5 mg 100 g^{-1}; 7.8 mg - 19.0 mg 100 g^{-1}) and 1 year (7.8 mg - 18.2 mg 100 g^{-1}; 3.3 mg - 18.6 mg 100 g^{-1}). Lower values of exchangeable potassium were recorded during winter while it increased in March. Almost similar trend of temporal and depth-wise variation was noted in all the plantations.

DISCUSSION

Higher soil temperature of surface soils in all the plantations might be due to heating by solar radiation. Low soil temperature in deeper soils may be ascribed to the insulation effect of the upper soil and litter layer (Fig. 1.1). Lowering in soil temperature during winter (November - February) corresponds to the low atmospheric temperature at the period (Fig.I). Higher moisture content during rainy summer and autumn generally, corresponded to the rainfall (Fig.I). Drop in moisture content during winter is related to the less rainfall (Fig.I). Higher moisture content in surface (0-10 cm) soil during rainy season may be ascribed to the successive rains. Less rainfall (Fig.I) and high evaporation may be the reason for the low moisture content in surface soils and higher moisture content in deeper soils during winter months (Fig.1.2).

pH of the soils was found to be acidic; ranging

between 4.2) and 5.82 (Fig.1.3). pH did not differ significantly in all the three plantations and at different depths. Das (1980), Baruah (1983) and Dkhar (1983) also did not find any significant difference in soil pH of forest, rice and maize field soils respectively. In general, however, the surface soils of pineapple plantations were more acidic than the deeper soils (Fig.1.3).

Baruah (1983) studied the temporal and depth-wise variations in soil temperature, moisture and pH of rice fields soils and noted higher soil temperature and pH from surface (0-10 cm) soils which decreased with increasing depth. She noted the higher moisture content from the deeper soils. Similar findings were also obtained by Dkhar (1983) from maized field soils of this region. Das (1980) studied the physico-chemical ahcracteristics of this forest soils of Meghalaya (India) and noted higher moisture contend during the months of May-December and the values of moisture content dropped in the preceding months.

Physico-chemical properties of pineapple plantation soils was found to be quite similar to those of the rice and maize field soils. Generally, similar trend of temporal and depth-wise variations in soil temperature and soil pH was noted as it was noted from rice (Baruah, 1983) and maize (Dkhar, 1983) field soils. Depth-wise distribution of moisture content in pineapple plantations soils differed

from those of the rice and maize field soils as in these soils higher moisture content was recorded from the deeper soils while the reverse was true in pineapple plantation soil except during winter months (Fig.1.2). pH of the pineapple plantation soils was found lower than that of the forest soils (Das, 1980). Temporal variation in moisture content of pineapple plantation soils differed to those of the forest soils. In case of pineapple plantation soils, moisture content was lower during winter but during the same time Das (1980) recorded higher moisture content from the forest soils of the region. In general, the physico-chemical properties of the pineapple plantation soil varied much with time as well as along depth. Plantation-wise these properties of the soils did not differ much.

The higher concentration of nutrients in surface (0-10 cm) soils might be due to higher organic matter content in the surface layer (Blackmore, 1966; Gupta and Rorison, 1975; Dkhar, 1983). Surface layer is continuously enriched by the nutrients released from decomposing litters, The temporal variations in nutrients are attributable to the variations in 'biological activity' occurring in this zone. The nutrient levels of deeper soils mainly depend on the mineralization process at the surface layer because the nutrients released in this layer percolate down

the profile along with the water.

Generally, higher organic carbon was recorded from the surface (0-10cm) soil which decreased with increase in depth. Singh (1980) also noted the higher values of organic carbon from the 0-10cm depth in forest soils which declined with increasing depth. The monthly variation in organic carbon content was more pronounced in surface (0-10cm) soil than the deeper soils which may be partly related to the release of organic matter from the accumulated litter on the surface.Similar results were also obtained by Singh (1980) in broad leaved (Shorea robusta) forest soils of this region. Increased organic carbon was noted in spring (March) and lower values were recorded in winter (Fig.1.4). Similarly, Deka (1981) also noted the increased organic carbon during September - May from the jhum fallows. The addition of organic matter primarily occurs during spring (March - May) and during spring and following summer the activity of microorganisms is maximum (Fig.2.1). Thus, a large amount of soil organic matter is lost through soil respiration and mineralization resulting into lower values of organic carbon and nitrogen during winter months (Tiwari et al. 1987 c).

The pattern of distribution of N down the soil profile as well as monthly variation was closely related to that of the organic carbon. The fluctuations in the monthly variation was least in the lower layer of the soil. Similar

results were also reported by Singh (1980). Deka (1981) also noted a sharp decline in nitrogen content of soils of Jhum fallows during winter months which was followed by an increase during March-April. Monthly variation in nitrogen content of pineapple plantation soils was found to be quite similar to that of the Jhum fallows of this region (Deka, 1981).

Depth-wise variation in phosphorus content was not prominent, however, the surface (0-10cm) soils showed higher phosphorus content. The monthly variation showed that the concentration reached maximum during the spring (March) which may be related to the rapid release of this nutrient from the litter at the same period. Ahlgren and Ahlgren (1965) suggested that greater microbial activity releases the phosphorus at a faster rate and this may be the possible reason for increased phosphorus content during the spring as the higher microbial activity was observed during the same period (Fig.2.1). The drop in winter in the phosphorus content is in correspondence to the lower microbial activity during the same period (Fig.2.1). The concentration of available phosphorus remained more or less constant in the deeper soils in all the plantations studied. Phosphate is relatively immobile (Bieleski, 1973) and this may be the reason for the little variations noted along depths.

The concentration of the exchangeable potassium was

found to be maximum in surface (0-10cm) soil and it decreased with increase in soil depth. Exchangeable potassium concentration was lower during winter months. Similar results were also recorded by Singh (1980) from the Shorea robusta forest soils. Higher concentration of exchangeable potassium during spring (March) may be due to the rapid release of this nutrient from the decomposing organic matter (Tukey et al. 1958). Haagsma and Miller (1963) described that the rate of release of non-exchangeable potassium to exchangeable form has been found to be a temperature dependent phenomenon. Similar results were also observed in the present investigation as the higher levels of exchangeable potassium was recorded during the high temperature conditions. Moisture content of the soil was also found to be directly related to the availability of potassium. Similar results were also reported by Kuchenbuch et al. (1986).

Generally, the concentration of all the elements (C,N,P & K) was higher during the period from February - April of both the years which might be attributed to the greater microbial activity during the same period (McColl and Grigal 1977; Deka, 1981; Dkhar, 1983). Similarly, the low nutrient levels in all the studied plantation during winter correspond to the lower microbial activity at the same period.

In general, the higher concentrations of all

nutrients were recorded from the surface (0-10cm) soil of all the plantations which decreased with increase in depth. Monthly variation in the levels of all the nutrients was more pronounced in surface soil than that of the deeper soils. Maximum concentration of the nutrients was generally, recorded during the spring and minimum values were generally recorded in winter. Generally, similar trend of monthly variation in nutrient levels was noted from all the three plantation soils.

Temporal and depthwise variation in physico-chemical characteristics of the pineapple plantations was found to be more like the agricultural soils (Baruah, 1983; Dkhar, 1983) than that of the forest soils (Das, 1980; Singh,1980) of this region.

C H A P T E R II

TEMPORAL VARIATIONS IN MICROBIAL POPULATION AND THEIR ACTIVITIES OF PINEAPPLE ORCHARD SOILS

INTRODUCTION

The microbial communities constitute one of the most important component of the soil. They are responsible for breakdown of organic matter and nutrient transformations. Soil microflora thus exterts considerable influence on the soil fertility and plant growth. Therefore, for proper management and economic exploitation of the soil resource, knowledge of microorganisms inhabiting soil and their activities is a fundamental requisite. Soil microorganisms are influenced by physico-chemical characteristics of soil namely; organic matter content, pH, moisture content, aeration, temperature and depth (Waksman, 1952; Orprut and Curtis, 1957; Mishra, 1966; Prakash and Khan, 1971; Tyagi, 1973, Wong, 1975; Martinez and Ramirez, 1979; Behera and Mukerji, 1985; Tiwari et al. 1987a). Season of the year and type of vegetation are other important parameters that govern the population and activity of microorganisms in soil (Saksena, 1955; Roy and Dwivedi, 1962; Mishra and Kanaujia, 1972; Mishra and Sharma, 1977; Kauri, 1982).

The analysis of factors regulating the temporal dynamics of microbial populations and their activities in soils provide an insight into the structure and function of the soil ecosystem. Spatial and temporal variations in soil microbial populations have, generally, been studied

through viable counts on culture medium and direct microscopic observations (Hattari, 1973; Alexander, 1977; Soderstrom, 1979). These estimations, however, provide little insight into the activities of the microorganisms in soil. During recent years more emphasis has been laid on the functional attributes of the microorganisms in the soil ecosystem. These are generally, determined by the estimation of enzyme activities (Casida, 1977; Kersman and Temple, 1979; Sparling et al. 1981; Frankenberger and Dick, 1983) and respiration rates (Wagner, 1975; Julia,and Pedziwilk, 1985; Das and Mishra, 1986).

Soil enzyme activity estimates are often used as indices of microbial activity and soil fertility (Skujins, 1978). Dehydrogenase being a respiratory enzyme provides a measure of catabolic activity of soil and it correlates with the activity of microorganisms (Stevenson, 1959; Peterson, 1967; Skujins,1973;1976). Urease is involved in degradation of urea into carbon dioxide and ammonia. Due to its applied importance in the N economy of soil the urease activity has been extensively investigated. Urease activity correlates positively with microbial biomass, organic carbon, soil temperature, moisture, total nitrogen and phosphorus contents of soil (Beri et al. 1978; Nannipieri et al. 1978; Dash et al. 1981; Dkhar and Mishra, 1983; Baruah and Mishra, 1984; Sahrawat, 1984; Tiwari et al. 1987b). In mi-

neral soils, ester bound phosphate represents a potentially available source of phosphate required for plant nutrition (Cosgrove, 1967). Soil phosphatases hydrolyse phosphate esters to inorganic phosphate and thus make them available to higher plants. Phosphatase activity measurements provide an index of potentially available phosphate in soil.The size of microbial populations in soil can determine the levels of phosphatase activity as microorganisms are the major source of phosphatases in soils (Casida, 1959; Greaves and Webley, 1965; Speir and Ross, 1978). Vegetation type (Neal, 1973) cropping system (Khan, 1970; Beck, 1974) and soil organic matter content (Malcolm and Vaughan, 1979) are some of the important factors affecting phosphatase activity in soil. Thus, measurement of dehydrogenase, reliable index of microbial activity but it also gives understanding of the microbial transformations of carbon,nitrogen and phosphorus compounds in soil.

Carbon dioxide evolution has been used as an index of microbial activity of agricultural and forest soils (Julia and Pedziwilk, 1985; Stotzky, 1960; Smith and Brown, 1932). Rate of CO_2 evolution from soil reflects the metabolic activities of soil biota, including soil organisms responsible for decomposition. CO_2 is concomittantly released with nutrients during decomposition. Thus, it gives an

indication of mineralization rates and microbial activity (Witkamp, 1971).

A survey of literature showed that the studies on microbial population and their activities are generally confined with forest, atricultural and grassland soils (Baruah and Mishra, 1983;1984; Dormaar et al. 1984; Keeney et al. 1985; Das and Mishra, 1986; Dkhar and Mishra, 1987). The soils of pineapple orchard crop differ from the above soils in physical, chemical and biological characteristics as these soils are neither tilled annually nor left fallow for a very long time. Microbiological and biochemical studies on the soils under orchard crops have not received sufficient attention (Pavlenko, 1985; Tiwari, et al. 1987 a,b).

It was felt that simultaneous estimations of microbial populations and their activity in terms of dehydrogenase, urease, phosphatase and CO_2 evolution would provide better understanding of the structure and function of microbial communities in soil. Although the literature review reveals that a number of studies are available where these estimations have been carried out, however, there are very few studies where all the above parameter have been taken into consideration simultaneously. Therefore, the interrelationships among these parameters are not yet understood properly.

The purpose of the present study was to work out temporal and depth-wise variations in microbial populations (bacteria and fungi) CO_2 evolution, dehydrogenase, urease and phosphatase activities in pineapple plantation soils. An attempt has been made to study the interrelationship among microbial activity estimates and physico-chemical characteristics of the soils. The pineapple growers quite often maintain the crop upto a period of ten years. It was, therefore, felt desirable to study whether age of plantation exerts any effect on the microbial population and their activities.

REVIEW OF LITERATURE

Soil microflora :

Th microbial population in soil is of ecological importance because of the essential role that microorganisms play in the conservation and cycling of plant nutrients. Owing to this the microbial populations in the soils have been studied by several workers (Waksman, 1927; Thakur and Morris, 1928; Warcup, 1951). However, during recent years various workers have attempted to correlate the soil microbial population with season, physico-chemical characteristics and depth of soil and surface vegetation. Temporal and depthwise distribution of microorganisms in the soils have also been investigated (Martinez and Ramirez, 1979;

Behera and Mukerji, 1985).

Waksman (1952) noted that organic matter, soil reaction, moisture, temperature, aeration and nature of crop grown influenced the abundance of microorganisms in soil.

Saksena (1955) investigated the seasonal fluctuation in viable fungal propagules and counted less number of propagules in summer. He further, suggested that high soil moisture was more favourable for the growth of fungi as long as there was no waterlogging. Similarly, Orpurt and Curtis (1957) also found that moisture was an important factor controlling the distribution of fungi in soil.

Roy and Dwivedi (1962) studied the fungal flora of grassland soils. They found marked variation in fungal flora of soil which was related to the types of grasses.

Mishra (1966) investigated the ecological factors which govern the distribution of soil microflora. He found the organic matter content, pH, moisture content, aeration, temperature, soil depth, season of year and state of decomposition of litter as the most important factors governing the distribution of microorganisms in the soil.

Prakash and Khan (1971) found that soil moisture content and season were most important factors which govern the frequency and population of soil microflora.

Mishra and Kanaujia (1972) investigated certain

ecological aspects of soil fungi in relation to varying cover vegetation, climati conditions, and physico-chemical characteristics. They observed that fungal population was generally found to be highest in upper layer and with an increase in depth the fungi per gram dry soil decreased gradually, organic matter content, pH, soil depth and season seemed to play an important role in distribution of mycoflora.

The viable counts of bacteria decreased with increase in depth and was found to be positively correlated with the moisture content, organic matter and inorganic nutrients (Holding et al. 1974).

Wong (1975) investigated the distribution of fungi and found that the number of species positively correlated with the soil moisture and pH.

Soil microflora of sugarcane field was studied by Singh and Charaya (1975). They noted appreciable decrease in fungal population with increase in depth.

A number of studies indicated that the vegetational cover had significant influence on the microbial population (Cobb, 1932; Christensen and Whittingham, 1965; Dwivedi, 1966; Mishra and Kanaujia, 1972). But contrary to the above Jones and Richard (1977) did not find any such type of effect of vegetation on the microbial population.

Martinez and Remirez (1979) studied the depth-wise distribution in fungal population and biomass and noted marked decrease in both cases with increase in depth.

Baruah (1980) recorded the Trichoderma viride from acidic soils. Similarly, Warcup (1951) and Mishra (1965) also isolated this genus repeatedly from the acidic soils.

Deka (1981) reported the depth-wise decrease in the fungal and bacterial populations and suggested that it might be due to variations in the nutrient status at different depths.

Kauri (1982) studied the seasonal fluctuations in numbers of bacteria in beech forest soil and observed two peaks in bacterial population; one in autumn after leaf fall and another in spring.

Pati et al. (1983) pointed out the relative contribution of microbes and roots to the total soil metabolism in a tropical grassland soil. They observed that fungal and bacterial biomass ratio was 12:1 indicating dominance of fungal component. They further observed that contribution of bacteria to total soil metabolism was 5% whereas fungal contribution was 57%.

Behera and Mukerji (1985) studied the seasonal variation and distribution of microfungi in forest soils of Delhi and noted that surface soils harboured the highest population and species number which gradually declined with

increase in depth.

Schnuerer et al. (1986) investigated the effect of rain and irrigation on soil microorganisms and observed that in the rain fed plot, bacterial numbers doubled within three days and declined during the following period of drought, while in the irrigated plot numbers of bacteria increased by 50% and then remained constant over the duration of the study.

Tiwari et al. (1987 a) studied the influence of moisture regimes on the population and activities of microorganisms and noted appreciable changes in fungal and bacterial population within a very short interval of time. They further suggested that adequate care should be taken when considering results from long interval samplings as short term variations may confound the effects of monthly and seasonal variations.

In another study, Tiwari et al. (1987 b) reported that higher fungal and bacterial population was always recorded from surface (0-10 cm) soils which decreased with increasing depth except during winter season. They also reported that microbial population was positively correlated with soil organic carbon, moisture and temperature.

Dehydrogenase enzyme activity :

Lenhard (1956) was the first man who estimated the

dehydrogenase (EC 1.1.1.49) activity in soil by using Triphenyl Tetrazolium Chloride (TTC).

Skujins (1976) noted that seasonal variations in enzymatic activities were generally small, once the enzyme become stabilized in soil they manifest resistance to humidity, temperature and to various environmental changes.

Casida (1977) noted close relationship between dehydrogenase activity and soil respiration and pointed out that soil microbial metabolic activities can be predicted by the dehydrogenase estimations.

Burns (1982) reviewed the enzyme activity in soil. He suggested that at any one time the total activity of an enzyme in soil is comprised of activities associated with different soil constituents namely, viable microorganisms cell debris, clay and humic colloids.

Baruah and Mishra (1984) estimated the dehydrogenase activities in rice field soils and found greater dehydrogenase activity in flooded valley land and terrace land soils than in the upland soils.

Dormaar et al. (1984) studied the seasonal changes in carbon content and enzyme activities viz; dehydrogenase, urease and phosphatase of two different sites, mixed prairie and fescue grassland horizons. They noted higher enzyme activities from the fescue grassland site regardless of grazing intensity.

Das and Mishra (1986) estimated dehydrogenase activity and CO_2 evolution from pine forest soil. They did not find any correlation between dehydrogenase activity and to-total microbial population and suggested that these two parameters are governed by different environmental factors.

Tiwari et al. (1987 a) studied the influence of moisture regimes on dehydrogenase activity and reported that moisture plays a significant role in the regulation of dehydrogenase activity in soils. In another study Tiwari et al. (1987 b) recorded maximum dehydrogenase activity in summer. They suggested that soil temperature, moisture, and organic carbon were the most important factors regulating the dehydrogenase activity.

Grobler et al. (1987) used the dehydrogenase assay in estimation of heterotrophic bacterial activities in the soil. Further, they described the dehydrogenase assessment as more reproducible activity estimate than the glucose mineralization method.

Urease enzyme activity :

Urea added to soils as fertilizer or as an animal urine is hydrolyzed enzymatically by soil urease (EC 3.5. 1.5). Due to its importance in soil N-economy the urease activity in soils has been widely investigated (Dalal, 1975; Burns, 1977; Sahrawat, 1984; O'toole et al. 1985).

Dalal (1975) has shown that the urease activity in Trinidad and Iowa soils was significantly related to organic carbon, total nitrogen and cataion exchange capacity of soil.

Skujins (1976) reported that urease is primarily produced by microorganisms and its activity generally correlates with organic matter content.

Pettit et al. (1977) reviewed that soil urease showed more stability against the various degradative forces in soils in comparison to other soil enzymes. They further, suggested that the more stable fractions of soils urease apparently occur in active organic matter extracts.

Speir (1977) observedaa strong positive relationship between urease activity and soil pH. Studies of Tabatabai (1977) on urease activity showed that it is concentrated in surface soils and decreases with depth. Urease activity was proportional to organic carbon distribution in soil profile and was significantly correlated with organic carbon.

Zantua et al. (1977) studied the relationships between soil urease activity and other soil properties and found a weak correlation between urease activity and soil pH.

Nannipieri et al. (1978) studied the urease activity

in two grassland soils and found a positive correlation between urease activity and microbial biomass in both types of grassland soils.

Beri and Brar (1978) recorded a significant correlation between the half life of urea and organic carbon content of the soil.

Verstraeten (1978) found significant indirect effects of pH on soil urease activities. He further, suggested that soil pH greatly influenced the relationships between urease activity and organic matter content.

Dash et al. (1981) studied the effects of specific conductance and temperature on urease activity in Indian soils. They noted that specific conductance, organic C, and total N content were positively correlated with urease activity.

O'toole et al. (1982) reported the significant correlations between urease activity and Organic C and total N contents. They further, suggested that organic matter content, pH and temperature may be accounted for the variation in urease activity.

O'toole et al. (1985) in another study, made a comparative study of urease activities in pasture and tillage soils. They reported that variation in the activity was attributable to total-N, CEC, pH, silt content and C:N

ratio of the soil.

Dkhar and Mishra (1983) studied the urease activity in maize (Zea mays L.) field soils and found positive correlation between urease activity and organic carbon content of the soil.

Sahrawat (1983) investigated the relationships between soil urease activity and other properties of some tropical wetland soils. Results of his study indicated that urease activity was correlated significantly with total N and organic carbon content. In another study, Sahrawat (1984) studied the effects of temperature and moisture on urease activity in semi-arid tropical soils. He noted that the activity increased with increase in temperature from 10°C to a maximum at 60°C and further, increase in temperature, decreased urease activity which was nearly totally inhibited at 100°C. Urease activity increased with increase in moisture content up to field capacity and remained constant with further increase in moisture.

O'toole and Morgan (1984) investigated the thermal stabilities of urease enzymes in some Irish soils. Results showed that soil urease enzymes were quite resistant to thermal degradation although activities did not decline during incubation.

Rao and Ghai (1985) estimated the urease activity of alkaline and reclaimed soils. They found that urease

correlated positively with organic C and N and negatively correlated with the pH and $CaCO_3$ content of soil. They further, demonstrated that organic C may be accounted for most of the variations in the enzyme activity.

Baruah and Mishra (1986) studied the effect of herbicides on urease enzyme activity in paddy field soil and found that herbicides did not affect the urease activity. Tiwari et al. (1987 b) noted higher urease activity during April in the surface soil which was attributable to higher organic carbon, bacterial population, temperature and favourable moisture content.

Phosphatase enzyme activity :

Phosphatase activity (EC 3.1.3.2) measurements provide an index of potentially available phosphate in soil. Rogers et al. (1942) described that acid phosphatase, which is present in plant roots and is predominant in acid soils and is responsible for the hydrolysis of organic phosphorus in soils.

Conflicting reports are available in the literature on the effect of added fertilizers on phosphatase activity. Chunderova (1964) and Vlasyuk and Lisoval (1964) noted that phosphatase activity of soil increased with added mineral and organic fertilizers. However, Burangulova and Khajiev (1965) found that phosphatase activity decreased on application of phosphorus and potassium

fertilizers.

Greaves and Webley (1965) studied the breakdown of organic phosphates by microorganisms from root region of certain pasture grasses. They suggested that roots and microorganisms are major sources of phosphatases in soils.

Cosgrove (1967) described that soil phosphatases hydrolyse phosphate esters to inorganic P which is then available to higher plants and soil microorganisms.

Tabatabai and Bremner (1969) reported that the pH 6.5 - 6.9 buffers should be used for the determination of soil phosphatase because for most soils the optimum pH of acid phosphatase falls within this range.

Vegetation type (Neal, 1973) and cropping system (Khan, 1970; Beck, 1974) were found to be important factors affecting phosphatase activity in soil.

Skujins (1976) opined that phosphatase activity can be used to estimate the general microbial activity in soil.

The enzymes namely; acid and alkaline phosphatases, phosphodiesterase and inorganic pyrophosphatase in soils are believed to be derived from microorganisms (Speir and Ross, 1978) and from plant residues that persist in soil (Ladd, 1978).

Harrison and Piearce (1979) investigated the

seasonal variation of phosphatase activity in woodland soils. They noted two or three peaks of it in a year, one in summer, second after leaf fall in autumn and a minor peak in spring.

Nielsen and Eiland (1980) investigated the relationship between P-fertility, phosphatase activity and ATP content in soil. The study demonstrated that the most effective way of increasing phosphatase activity in soil is probably by increasing the content of microorganisms e.g. by supplying manure and other kinds of organic wastes. They further demonstrated that there is a natural regulation of the phosphatase activity in soil and it is enhanced when soils are depleted of available phosphorus.

Appiah and Thomas (1982) compared total organic phosphorus, inositol phosphates and phosphatase activity of some Canadian and Ghanaian soils. They noted that low activitity of phosphatase in the Ghanaian soils may be due to the lower content of organic matter, a lower microbial biomass and consequently a lower phosphatase production. They further, pointed out that fertilizer application decreased the phosphatase activity.

Harrison (1983) examined the relationships between the intensity of phosphatase activity and physicochemical characteristics of soil and their possible interactions with soil depth, soil type, season, vegetation

type and parent material in woodland soils. He noted significant relationships of phosphatase activity with organic matter, moisture, clay + silt, total nitrogen, isotopically-exchangeable phosphorus, extractable magnesium contents and soil pH. Results of the study demonstrated that intensity of phosphatase activity and soil properties differed with soil depth, soil type, season and vegetation type.

Chhonkar and Tarafdar (1984) found a significant positive correlation between phosphatase activity and the organic carbon, phosphorus and bacterial population but they did not find any correlation with soil pH. The results revealed that none of the phosphatases was found to be correlated with clay content and soil actinomycetes.

Camara et al. (1985) recorded the phosphatases activity between 435 and 654 ug p-nitrophenol h^{-1} g^{-1} of soil. The results showed greater enzyme substrate affinity in soil when the size of soil particles decreased.

Carbon dioxide evolution :

Carbon dioxide evolution has been used as an index of microbial activity in soil because most of it (90%) comes from the microorganisms inhabiting in the soil environment (Smith and Brown, 1932).

Stotzky(1960) working on the determination of the respiratory quotient of soils found that the changes in

CO_2 evolution were related to fungal biomass.

Ponnamperuma (1972) observed a positive correlation between soil respiration and fungal population in flooded rice field soils. Singh and Gupta (1977) studied the plant decomposition and soil respiration in terrestrial ecosystems. They noted positive correlation between soil temperature, moisture and soil respiration.

Bohn et al. (1979) reported that high CO_2 in the soil atmosphere affects the pH, nutrient availability, aeration status and root growth.

Siddiqui and Singh (1981) studied the seasonal variation in soil respiration of certain tropical grassland communities and noted higher and lower CO_2 evolution during rainy and winter seasons respectively. They found that the CO_2 evolution is correlated with soil moisture, temperature and root biomass.

Mishra and Dash (1982) while working on the determination of the rate of soil respiration in tropical pasture and forest soils at Sambalpur (India) found that temperature influenced the rate of CO_2 evolution.

Stroo and Jencks (1982) estimated soil respiration in mineral soils and found that oxidizable carbon and mineralizable nitrogen were most closely related factors with the rate of respiration.

Baruah and Mishra (1983) estimated the rate of CO_2 evolution and bacterial and fungal populations and fungal biomass of flooded and upland rice field soils. They noted positive correlation between CO_2 evolution and fungal population and fungal biomass.They further, inferred that, in flooded soils, fungal population was predominantly responsible for soil respiration.

Orchard and Cook (1983) determined the relationship between soil respiration and soil moisture and found the respiration rate directly proportional to gravimetric water content.

Viskowa (1983) observed a direct correlation between CO_2 evolution and activity of the soil microorganisms.

Singh (1984) studied the effects of temperature, rainfall and soil moisture on soil respiration in a subtropical humid forest ecosystem. He recorded maximum amount of CO_2 output (159-700 mg $CO_2/m^2/h$) during the period May-September when temperature, rainfall and soil moisture were higher.

Julia and Pedziwilk (1985) described the carbondioxide evolution as an index of biological activity of cultivated soil.

Baruah and Mishra (1986) studied the effect of herbicides on CO_2 evolution in submerged paddy field soil

and noted higher CO_2 output in herbicide treated soil. They described that the increased rate of CO_2 evolution may be attributed to the degradation of herbicides.

Das and Mishra (1986) estimated the dehydrogenase activity and CO_2 evolution from a pine forest soil. They noted significant correlation between CO_2 evolution and microbial population. They described the CO_2 evolution as more precise indicator for estimating the soil microbial activity than that of the dehydrogenase activity.

Ceulemans et al. (1987) recorded more CO_2 evolution from the soil covered with vegetation than the barren soils.

Dkhar and Mishra (1987) studied the microbial population, fungal biomass and CO_2 evolution in maize (Zea mays L.) field soils. A significant correlation among CO_2 evolution, fungal biomass, bacterial and fungal population organic carbon and total nitrogen was observed.

Tiwari et al. (1987 a) studied the influence of various moisture regimes on CO_2 evolution. They found that the moisture level of soil profoundly influences the rate, as well as quantity of CO_2 evolved from the soils. They further, described that waterlogging as well as drying, of soils reduces the CO_2 evolution.

MATERIALS AND METHODS

Sampling procedures :

Soil samples were collected randomly from five places of each plantation. Samples were collected with the help of soil sampler from three depths (viz; 0-10 cm; 10-20 cm; 20-30 cm). Extra care was taken during the soil sampling to avoid the contaminations. For this the sampler was cleaned and sterilized with alcohol between each sampling. Samples collected from five random places were mixed thoroughly and kept in a sterilized polythene bag. The samples were brought to the laboratory immediately. All aseptic precautions were taken at the time of soil sampling. Mostly samples were analysed for various physico-chemical and microbiological characteristics within 48 hours. Occassionally, samples were stored in a fridge at $4^{o}C$ until they were not processed.

Estimation of Fungal Population :

Warcup's (1950) soil plate method using Martin's (1950) rose bengal agar medium was followed for the estimation of the fungal population. A small amount (0.015 g) of soil was taken out from the composite sample with the help of a sterilized nichrome spatula having a flattened tip. A few drops of sterilized distilled water were poured at the bottom of the petridishes to disperse the soil aggregates uniformly. Approximately, 15 ml of molten and cooled (below

45°C) Martin's rose bengal agar medium supplemented with streptomycin sulphate, was poured into the petridishes which were then gently rotated to disperse the soil particles throughout the medium. Three petridishes were inoculated for each sample. The petridishes were then incubated upside down at a temperature of 25±1°C for 5 days in a BOD incubator. Fungal population was estimated by counting of the number of fungal colonies.Total number of fungi per gram soil was calculated on dry weight basis. The pure culture of fungi was maintained on the slants of malt agar medium in culture tubes for the identification. The books of Gilman (1957); Subramanian (1971); Barnett and Hunter (1972); Domsch et al. (1980); Raper and Thom (1984) and Ellis and Ellis (1985) were consulted for the identification of fungi. Inoculation and isolation of fungi were carried out in a "Laminar Flow Chamber".

Determination of Bacterial Population :

Waksman's (1922) dilution plate method was followed for the enumeration of the bacteria on nutrient agar medium (Johnson and Curl, 1972).

10 g of soil was taken in 250 ml conical flask containing 100 ml sterilized distilled water to make 1:10 dilution. To prepare homogenous solution flasks were wrist shaken for 15 minutes. 10 ml of this mixture was transferred aseptically with the help of sterilized 10 ml pipette to

another conical flask containing 90 ml of sterilized distilled water to get a suspension of 1:100 dilution. The process was repeated twice to obtain a suspension of 1:10,000 dilution which was finally used for the isolation of the bacteria. The same dilution (1:10,000) was used throughout the investigation for various samples. 0.5 ml of the suspension was inoculated onto sterilized petridishes containing 15 ml of solidified nutrient agar medium. The petridishes were rotated gently in a swirling motion to disperse the inoculum uniformly over the surface of the medium. Three petridishes were inoculated for the isolation of bacteria from the soil samples. Throughout the investigation the isolation of bacteria was carried out in "Laminar flow chamber". Separate pipette was used for transferring of the soil suspensions. Inoculated petridishes were incubated at $30\pm1^{o}C$ for 24 hours in a bacteriological incubator. Bacterial population per gram dry soil was calculated by taking the moisture content and dilution into consideration.

Composition of various media used in the study :

Peptone Dextrose-Rose Bengal Agar (Martin, 1950)

Agar	20.0 g
Dextrose	10.0 g
Peptone	5.0 g

KH_2PO_4	1.0 g
$Mg\ SO_4\ 7H_2O$	0.5 g
Rose Bengal (1%)	3.3 ml
Distilled water	1000.0 ml
Streptomycin	30.0 mg

Malt-Extract Agar :

Agar	25.0 g
Dextrose	20.0 g
Peptone	1.0 g
Malt Extract	20.0 g
Distilled water	1000.0 ml

Nutrient-Agar :

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

Determination of percentage relative abundance :

Following formula was used for the determination of percentage relative abundance of a particular fungal species :

$$\text{Relative abundance} = \frac{\text{Total no. of colonies of the particular species}}{\text{Total no. of colonies of all the species}} \times 100$$

Assessment of the enzyme activities :

Dehydrogenase activity :

2-3-5 triphenyl tetrazolium chloride (TTC) reduction technique was adapted for the assessment of the dehydrogenase activity (Casida, 1977). 5 g fresh soil was taken in a test tube. The soil was then treated with 0.1 g of $CaCO_3$ and 1 ml of 1% TTC solution. The content of the test tube was thoroughly mixed and plugged with a rubber stopper. The test tubes were incubated at 30°C for a period of 24 hours in an incubator. Usually, the dehydrogenase activity was assayed by using the fresh soil samples but when storage was necessary the soil was stored at 4°C (Lloyd and Sheaffe, 1973). Three replicates were maintained for each sample analysis.

The resulting slury was transferred on Whatman No.1 filter paper and extracted with suceessive aliquots of concentrated methanol.The volume of filtrate was made upto 50 ml by adding methanol. The optical density of pink colour extract was read out spectrophotometrically at 485 nm using methanol extract from the control (without soil) as the blank. Dehydrogenase activity in terms of concentration of formazan in each sample was calculated by a standard curve of triphenyl formazan in methanol.

The dehydrogenase activity per gram dry soil was calculated by taking into consideration the soil moisture

contents and expressed in terms of mg formazan per gram dry soil per 24 hour.

Urease activity :

McGarity and Myers' (1967) method was followed for the assessment of the urease activity.

10 g of soil was placed in 100 ml volumetric flask and treated with 1 ml of tolune and allowed to stand for 15 minutes, to permit its complete penetration into the soil. Thereafter, 10 ml of buffer (pH-7) and 5 ml of 10% urea solution was added. The flask was shaken and incubated at 37°C for 3 hours. In control, 10 ml urea solution was replaced by 10 ml of distilled water.

After incubation the volume of flask was made upto 100 ml by adding distilled water. The flasks were thoroughly shaken and their content was filtered through a Whatman No.5 filter paper.

Indophenol blue method was adapted for the measurement of ammonia released as a result of urease activity.

0.5 ml of filtrate was taken in 25 ml volumetric flask and 5 ml of distilled water was added. The mixture of the flask was treated with 2 ml of phenolate solution and 1.5 ml of sodium hypochlorite solution containing 0.9% active chlorine. The whole mixture of the flask was made upto 25 ml by adding distilled water. The optical density

of blue colour developed as a result of urease activity was read out spectrophotometrically at 630 nm. Similar procedure was followed for the control (without soil). The amount of NH_4^+ - N released was calculated by reference to a calibration curve and expressed in terms of NH_4^+ - N per gram dry soil per 3 hour.

Preparation of phenolate solution :

Phenol solution : 62.5 g phenol was dissolved in 20 ml of methanol, 18.5 ml of acetone was added and the mixture was then made upto 100 ml with ethyl alcohol.

Caustic soda solution : 27 g of sodium hydroxide was dissolved in 100 ml of distilled water. Phenolate solution was obtained by mixing 20 ml of phenol solution and 20 ml of caustic soda solution and making the whole volume upto 100 ml with distilled water. Both the solutions were stored in a fridge and phenolate solution was prepared freshly before use.

Phosphatase activity :

Phosphatase activity was assayed by the method of Tabatabai and Bremner (1969). Soil samples were air dried, grinded and sieved ($<$.2 mm). 0.1 g of air dried and sieved ($<$.2 mm) soil was taken in a 50 ml conical flask. 4 ml of modified universal buffer, (pH-6.5) Skujins (1962),0.25 ml of tolune and 1 ml of 0.115 M p-nitrophenyl phosphate (PNP) solution was added to the flask. The flask was then

swirled for a few seconds to mix the contents and was kept in a incubator at 37°C for one hour. After incubation the stopper was removed and 1 ml of 0.5M calcium chloride and 4 ml of 0.5M sodium hydroxide solution was added. Soil suspension was then filtered through the Whatman No.12 filter paper. Yellow colour developed as a result of phosphatase activity. The optical density of the filtrate was measured spectrophotometrically at 420 nm. A control was performed for each sample. For the control, similar procedure was followed as described for the assessment of phosphatase activity. In control, 1 ml PNP solution was added after the addition of 0.5M $Cacl_2$ and 0.5M NaoH (i.e. immediately before filtratation of the soil suspension.

Three replicates analysis were done for each sample. Phosphatase activity in terms of concentration of p-nitrophenol in each sample was calculated by a standard curve of p-nitrophenol in water and was expressed in terms of u moles p-nitrophenol released per gram of dry soil per hour.

Carbon-dioxide evolution :

The CO_2 evolution was measured in the laboratory by adapting the method of McFadyen (1970). 1 kg soil from each sample was placed in a glass jar. 100 ml glass beaker containing 20 ml of 0.1 N KOH solution was kept inside the the jar. The jar was then sealed by a glass lid using grease.

Thus, the jar was made air tight. After 24 hours jar was made open and CO_2 fixed by the KOH solution was measured by titration with 0.1N HCl solution using phenolpthpthaliane as an indicator. For the substraction of atmospheric CO_2 a suitable control was run by using sterilized sand instead of soil sample. Three replicates were maintained for each sample analysis. The CO_2 evolved was calculated on dry weight basis and was expressed in terms of mg CO_2 evolved per kg dry soil per 24 hour.

RESULTS

Estimation of fungal population :

The fungal population of soils exhibited more or less similar trend of monthly variation in three plantations (July 1985 to June 1987). Comparatively, lower population of fungi was recorded during the second year of study (1986 to June 1987) than that of the first year (July 1985 to June 1986). Generally, surface soil of all the plantations harboured higher population of fungi which decreased with increase in depth except during the months of December and January when higher fungal population was recorded from deeper soils (Fig.2.1). Low populations were recorded during the winter months in all the three plantation soils. In most cases fungal population increased in March which was followed by a drop in April and an increase in May (Fig.2.1). Fungal population correlates positively with

soil moisture, temperature, organic carbon, total nitrogen, available phosphorus, exchangeable potassium content, dehydrogenase and urease activity. However, a negative correlation was also observed between fungal population and CO_2 evolution (Tables 2.19-2.21).

Estimation of bacterial population :

Bacterial population of soil also showed a trend of monthly variation almost similar to that of the fungi in all the three plantations studied. From the figure 2.2 it is obvious that generally 10 year plantation soil harboured higher bacterial population than those of the 5 year and 1 year plantation soils.

Two peaks were recorded; one in September and another in April. During winter months the bacterial population dropped to a minimum. In most cases bacterial population increased during the onset of rains followed by a peak in April. Thereafter, it decreased. During both the year bacterial population showed similar trends of temporal and depth-wise variations. Higher bacterial population was generally noted from the surface soil which decreased with increase in depth (Fig.2.2). Bacterial population correlated positively with soil temperature, phosphatase activity and urease activity (Tables 2.19-2.21).

Temporal and depth-wise distribution of fungal species and their percentage relative abundance :

Qualitatively fungal flora of different planta-

Table 2.1 Monthly variation of fungal population(per gram dry soil x 10^3) in the soil of 1 year plantation at 0-10cm depth during the sampling period 1985-1986. Values in the parentheses are % relative abundance.

Fungi	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	.196(8.03)	-	-	-	.204(9.19)	.358(14.00)	-	-	-
Aspergillus flavas	-	.059(2.03)	-	-	-	-	-	-	-	-	-	-
A. nedulans	-	-	-	-	-	-	-	-	-	-	-	-
A. niger	-	.359(14.28)	-	.112(4.58)	-	-	-	-	-	-	-	.087(5.00)
Cunninghamella echinulata	-	.029(1.17)	-	-	-	-	-	-	-	-	-	-
Curvularia maculans	-	-	-	.056(2.29)	-	-	-	-	-	-	-	-
Fusarium moniliforme	.234(8.66)	.296(10.78)	.828(35.5)	.561(22.96)	.428(10.05)	.200(15.20)	.407(11.90)	.204(9.19)	-	.348(22.90)	.299(13.39)	.262(15.00)
F. solani	-	.239(8.5)	-	.308(12.64)	.183(6.45)	.085(7.14)	.407(11.90)	.307(20.71)	-	-	-	.058(3.34)
Gongronella butleri	-	-	-	-	-	-	-	-	.076(3.12)	.107(7.00)	-	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.742(3.20)	.214(14.03)	-	-
Mortierella ramanniana	-	-	-	-	-	-	-	-	.076(3.12)	-	-	-
Mucor hiemalis	.360(13.33)	-	-	.140(5.74)	-	.143(11.90)	-	.102(4.59)	.051(2.08)	.375(24.56)	--	-
M. plumbeus	-	-	-	.084(3.44)	.091(3.22)	-	-	-	-	-	-	-
M. racemosus	.390(14.33)	-	-	.084(3.44)	-	.171(10.28)	.054(4.76)	.153(6.89)	-	.107(7.00)	.149(6.66)	-
Mycogone alba	-	-	-	.055(2.14)	-	-	-	-	-	-	-	-
Paecilomyces lilliacinum	-	-	-	-	-	-	-	-	.332(13.51)	-	.179(8.00)	-
Penicillium chrysogenum	.420(16.55)	.209(8.33)	-	-	.703(20.73)	.286(20.78)	.190(16.66)	.640(20.73)	.291(11.45)	.026(1.70)	.718(32.00)	.349(20.00)
P. claviforme	-	-	-	.084(3.44)	.214(7.52)	.085(7.14)	.163(14.28)	.128(5.74)	.051(2.08)	.107(7.00)	.149(6.66)	-
P. fellutanum	.180(6.66)	.209(8.5)	-	-	-	-	-	-	-	-	-	-
P. funfculeaum	.090(3.33)	-	-	-	.183(6.45)	-	.108(9.61)	-	.102(4.16)	-	.209(9.33)	-
P. javanicum	-	-	-	-	-	-	-	-	-	.160(10.52)	.089(4.00)	-
P. liliacinum	-	-	-	-	-	-	-	-	.255(10.00)	-	.389(17.3)	-
P. vermiculatum	.297(11.59)	.149(5.95)	.303(13.75)	.084(3.44)	.305(9.03)	-	.135(11.85)	.102(4.59)	-	-	.059(2.66)	-
Trichoderma koningii	-	-	-	-	-	-	-	-	.102(4.16)	-	-	.087(5.00)
T. lignorum	-	.149(5.95)	.368(16.19)	.224(9.17)	-	.085(7.14)	-	-	-	-	-	-
T. viride	-	.209(8.33)	.245(11.11)	.196(8.03)	.122(4.30)	.257(20.42)	-	.128(5.74)	.051(2.08)	.053(3.5)	-	.320(18.32)
Verticillium chlamydosporum	-	-	-	-	-	-	-	-	-	-	-	-
White sterile	.690(25.55)	.389(15.47)	.214(9.70)	.252(10.66)	.917(22.25)	-	.163(14.28)	.079(3.44)	-	-	-	.320(18.32)
Yellow sterile	-	.269(10.71)	.303(13.75)	-	.428(10.00)	-	.054(4.76)	.204(9.19)	-	.025(1.26)	-	.262(15.00)

Table 2.2 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 1 year plantation at 0-10 cms depth during the sampling period 1986-1987. Values in the parentheses are % relative abundance.

Fungi	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Aspergillus niger	-	-	-	-	-	-	-	-	-	.097 (6.25)	-	.233 (17.77)
Fusarium moniliforme	.202 (16.16)	.245 (16.16)	.248 (18.75)	.453 (41.66)	.109 (10.25)	.157 (20.00)	.110 (29.07)	.205 (17.94)	.102 (6.66)	.227 (14.58)	.179 (11.76)	.145 (11.11)
F. salani	-	.183 (10.45)	.055 (4.16)	.120 (11.11)	-	.157 (20.00)	-	-	-	-	.059 (3.92)	.145 (11.11)
Gongronella butleri	-	.122 (8.33)	-	-	-	-	-	-	.051 (3.33)	.097 (6.25)	-	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.153 (15.05)	-	-	-
Mortierella ramanniana	-	-	-	-	-	-	-	-	.051 (3.33)	-	-	-
Mucor hiemalis	.086 (7,14)	-	-	-	-	-	-	-	-	-	-	-
M. plumbeus	-	-	.248 (18.75)	-	-	.157 (20.00)	-	-	.051 (3.33)	-	-	-
M. racemosus	.057 (4.76)	-	.137 (10.41)	-	-	.157 (20.00)	.027 (4.76)	-	-	-	.179 (11.76)	-
Paecilomyces liliacinum	-	-	-	-	-	-	-	.087 (7.69)	.332 (21.66)	-	.239 (14.79)	-
P. chrysogenum	.318 (26.64)	.214 (14.58)	.027 (2.08)	.151 (13.88)	.492 (41.05)	- (14.29)	.082 (14.28)	.322 (28.20)	.255 (16.65)	.227 (14.58)	.179 (11.76)	.087 (6.66)
P. fellutanum	.115 (9.52)	-	-	-	.109 (10.25)	-	-	-	.051 (3.33)	.129 (8.00)	.114 (7.84)	-
P. funiculosum	.057 (4.76)	-	-	-	.054 (5.12)	-	-	-	-	.097 (6.25)	.449 (26.41)	-
P. Javanicum	-	-	-	-	.082 (7.69)	-	-	-	-	-	.059 (3.92)	-
P. vermiculatum	.086 (7,14)	-	.303 (20.85)	-	-	-	-	-	.204 (13.33)	.227 (14.58)	.119 (7.84)	-
Trichoderma koningii	-	-	-	-	-	-	-	-	.076 (5.00)	-	-	.145 (11.11)
T. viride	-	.061 (4.16)	.082 (6.25)	.241 (22.28)	-	-	-	-	.051 (3.33)	.227 (14.58)	-	.262 (24.47)
White sterile	.289 (23.78)	.612 (41.66)	.248 (18.75)	- (	.136 (12.82)	.157 (20.00)	.110 (19.04)	.263 (23.07)	.076 (5.00)	.227 (14.58)	-	.174 (13.33)
Yellow sterile	-	.061 (4.16)	-	.120 (11.11)	.136 (12.82)	-	.248 (42.85)	.146 (23.10)	-	.129 (8.38)	-	.058 (4.44)

Table 2.3 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 1 year plantation at 10-20cm depth during the sampling period 1985-1986. values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	.029(1.44)	-	-	-	-	-	-	-	-
A. nedulans	-	-	-	.118(5.79)	-	-	-	-	-	-	.059(2.89)	-
A. niger	-	.212(10.60)	-	-	-	-	-	-	-	.165(10.50)	.179(8.69)	.029(1.51)
Cunninghamella echinulata	-	.030(1.57)	-	-	-	-	-	-	-	-	-	-
Curvularia maculans	-	-	-	-	-	-	-	.076(3.70)	-	-	-	.177(9.74)
Fusarium moniliforme	.240(14.11)	.302(15.13)	.734(36.36)	.565(27.53)	.306(11.48)	.194(14.58)	.108(8.88)	.153(7.40)	.216(8.52)	.276(20.91)	.149(7.24)	.296(15.13)
F. solani	-	-	.061(3.03)	.148(7.24)	.184(6.89)	.027(3.08)	.190(18.55)	.230(11.11)	-	-	-	.237(12.12)
Gongronella butleri	-	-	-	.208(10.14)	-	-	-	-	.108(4.76)	-	.357(18.39)	-
Humicola fuscoatra	-	--	-	-	-	-	-	-	.569(20.00)	-	-	-
Mortierella zamanniana	-	-	-	-	-	-	-	-	.054(2.38)	-	-	-
Mucor hiemalis	.390(18.74)	-	-	-	-	.027(3.08)	-	-	-	.331(25.00)	-	.207(19.60)
M. plumbeus	-	-	-	.059(2.89)	-	-	-	-	.091(1.19)	-	-	-
M. racemosus	.060(3.77)	-	-	.029(1.44)	-	-	-	.051(3.46)	-	.199(14.54)	.059(2.89)	-
Mycogone alba	-	-	-	.059(2.89)	-	-	-	-	-	-	-	-
Paecilomyces lilacinum	-	-	-	-	-	.055(4.19)	-	-	.487(20.42)	-	-	-
Penicillium chrysogenum	.360(17.66)	.120(6.04)	-	.148(7.24)	.245(9.19)	.194(14.58)	.326(26.66)	.742(35.80)	.406(15.80)	-	.149(7.24)	-
P. claviforme	-	-	-	-	.061(3.29)	.027(3.08)	-	-	-	-	-	-
P. fellutanum	-	--	.214(10.11)	.059(2.89)	.214(8.05)	.055(4.16)	.108(8.88)	-	.325(10.28)	.138(10.41)	.089(4.85)	-
P. funiculosum	-	-	-	-	.399(14.94)	-	.054(6.44)	.128(6.69)	-	-	.476(23.18)	-
P. javanicum	-	-	-	-	-	-	-	-	.054(2.38)	.138(10.41)	.238(11.51)	-
P. vermiculatum	-	-	-	.029(1.44)	.061(3.29)	.083(8.25)	.163(13.46)	.230(11.11)	.135(5.95)	-	-	-
Trichoderma koningii	-	--	-	-	-	-	-	-	.054(2.38)	-	-	-
T. lignorum	-	.181(9.09)	.397(19.69)	.148(7.24)	-	.027(3.08)	-	-	-	-	-	-
T. viride	.300(13.87)	.212(10.60)	.397(19.69)	.208(10.14)	-	.222(16.66)	-	.076(3.70)	.081(1.19)	.119(8.33)	-	.415(22.21)
Verticillium chlamydosporum	-	-	-	-	-	-	-	.051(3.46)	-	-	-	-
White sterile	.510(23.61)	.424(21.21)	.061(3.03)	.029(1.44)	.675(25.23)	.194(14.58)	.190(18.55)	.204(9.97)	.108(4.76)	-	.268(13.04)	.385(19.69)
Yellow sterile	.180(8.33)	.515(25.75)	.183(8.09)	.148(7.24)	.429(16.09)	.139(10.41)	.081(8.66)	.076(3.70)	-	-	-	-

Table 24 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 1 year plantation at 10-20cm depth during the sampling period 1986-1987. Values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	.244 (22.22)	-	-	-	-	-	-	.108 (7.19)	-	-	.266 (23.07)
Aspergillus nedulans	-	-	-	-	-	-	-	-	-	-	.119 (8.88)	-
A. niger	-	-	.058 (4.44)	-	-	-	-	-	-	.148 (11.53)	.059 (4.14)	-
Fusarium moniliforme	.149 (13.88)	.213 (19.44)	.145 (13.38)	.212 (29.16)	.163 (20.00)	.166 (20.00)	.136 (18.51)	.145 (15.15)	-	.297 (23.11)	.089 (6.66)	.177 (15.38)
F. solani	-	.122 (11.11)	.058 (4.44)	.030 (4.19)	.054 (6.66)	.166 (20.00)	-	.118 (12.12)	-	-	-	-
Gongronella butleri	-	-	-	-	-	-	-	-	.135 (10.41)	-	.238 (17.77)	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.189 (12.58)	-	-	-
Mortierella ramanniana	-	-	-	-	-	-	-	-	.081 (6.25)	-	-	-
Mucor hiemalis	.236 (22.22)	-	.087 (6.66)	-	-	-	-	-	.081 (6.25)	-	-	-
M. plumbeus	-	-	.058 (4.44)	-	-	.166 (20.00)	-	-	-	-	-	-
M. racemosus	-	-	.233 (17.77)	-	-	.166 (20.00)	-	-	-	.099 (7.69)	.059 (4.44)	-
Paecilomyces liliacinum	-	-	-	-	-	-	-	-	.189 (12.58)	-	-	.207 (17.94)
Penicillium chrysogenum	.236 (22.22)	.183 (16.66)	.262 (20.00)	.060 (8.33)	.245 (26.68)	-	.109 (14.85)	.116 (12.12)	.189 (12.58)	.248 (19.23)	.178 (17.82)	-
P. fellutanum	-	-	-	-	-	-	.027 (3.70)	-	.054 (4.16)	-	.149 (11.11)	-
P. funiculosum	-	.091 (8.33)	-	-	-	-	.027 (3.70)	-	.054 (4.16)	-	.238 (17.77)	-
P. Javanicum	-	-	-	.060 (8.33)	-	-	-	.058 (6.07)	-	-	-	-
P. liliacinum	-	-	-	-	-	-	-	-	.081 (6.25)	-	-	-
P. vermiculatum	-	-	.233 (17.77)	-	-	-	-	-	-	.198 (15.38)	-	-
Trichoderma koningii	-	-	-	.060 (8.33)	-	-	-	-	.135 (10.41)	-	-	-
T. viride	.059 (5.55)	-	-	.121 (16.66)	.163 (20.00)	-	-	-	.108 (7.19)	.148 (11.53)	-	.237 (20.51)
White sterile	.266 (27.80)	.244 (22.22)	.058 (4.44)	.181 (25.08)	.190 (23.33)	.166 (20.00)	.218 (29.62)	.262 (27.27)	-	.148 (11.53)	.149 (11.11)	.118 (10.28)
Yellow sterile	.088 (8.33)	-	.087 (6.66)	-	.027 (3.33)	-	.218 (29.62)	.262 (27.27)	-	-	-	.148 (12.82)

Table 2.5 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 1 year plantation at 20-30 cm depth during the sampling period 1985-1986 values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	.059(3.17)	-	-	-	-	-	-	-	.059(3.92)
Aspergillus nedulans	-	-	-	.059(3.18)	-	-	-	-	-	-	.114(5.34)	-
Aspergillus niger	-	-	-	-	-	-	-	-	-	.055(6.06)	-	-
Aspergillus versiculor	-	-	-	.088(4.76)	-	-	-	-	-	-	-	-
Cladosporium herbarus	-	-	-	-	-	-	-	.055(2.89)	-	-	-	-
Curvularia lunata	-	-	-	.088(4.76)	-	-	-	-	-	-	-	-
Fusarium moniliforme	.238(13.33)	.211(12.96)	.694(40.00)	.325(17.48)	.275(11.00)	.284(18.50)	.138(9.80)	.165(8.69)	.163(7.40)	.111(12.12)	.269(14.29)	.207(13.73)
Fusarium solani	.208(11.66)	.180(10.00)	-	.148(7.93)	.091(3.70)	.113(7.40)	.139(9.80)	.137(7.24)	-	-	-	.029(1.96)
Gongronella butleri	-	.271(16.66)	-	.414(22.22)	-	-	-	.082(4.34)	.300(10.69)	-	-	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.601(27.16)	.277(30.30)	-	-
Mucor hiemalis	-	-	-	-	-	-	-	-	-	.277(30.30)	-	-
Mucor plumbeus	-	-	-	.059(3.17)	.030(1.23)	-	-	-	-	-	-	-
Mucor racemosus	-	-	-	.059(3.17)	-	.113(7.40)	-	-	-	.138(15.15)	-	-
Paecilomyces lilliacinum	-	-	-	.029(1.58)	-	-	-	-	.409(18.51)	-	-	.029(1.96)
Penicillium chrysogenum	.238(13.33)	.211(11.66)	-	.059(3.17)	.244(9.87)	.313(20.37)	.305(21.56)	.220(17.04)	.245(10.11)	-	.328(17.46)	-
Penicillium fellutanum	-	-	-	.088(4.76)	.305(10.33)	-	.166(13.76)	.137(7.24)	.081(3.70)	-	.149(7.93)	-
P. funiculosum	-	-	-	.029(1.58)	.366(10.91)	.119(12.96)	.166(13.76)	.055(2.89)	.136(6.17)	-	.508(25.43)	-
P. javanicum	.179(10.00)	.180(11.11)	-	-	.030(1.23)	-	.111(9.30)	-	-	-	-	-
P. vermiculatum	.328(18.33)	-	-	.089(4.76)	.061(2.46)	.085(6.55)	.093(6.88)	.385(20.28)	.218(8.87)	-	.149(14.28)	-
Trichoderma koningii	-	-	-	-	-	-	-	.055(2.89)	.054(2.46)	-	-	-
T. lignotum	-	-	.513(28.82)	-	-	-	-	-	-	-	-	-
T. viride	-	.301(16.65)	.543(31.18)	.029(1.58)	-	.170(12.01)	-	.111(5.79)	.109(4.93)	.055(6.06)	-	.389(25.49)
Verticillium chlamydosporum	-	-	-	-	-	-	-	.027(1.44)	-	-	-	-
White sterile	.328(18.33)	.211(11.66)	-	.148(7.93)	.458(18.51)	.170(14.81)	.194(13.72)	.165(8.69)	-	-	.269(14.29)	.355(23.53)
Yellow sterile	.268(15.00)	.120(8.66)	-	.088(4.76)	.763(30.86)	-	.055(3.92)	.220(10.59)	-	-	-	.444(29.41)

Table 2.6 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 1 year plantation at 20-30cm depth during thessampling period 1986-1987. Values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	--	-	-	-	-	-	-	-	.119 (12.12)
Aspergillus niger	-	-	-	-	-	-	-	-	-	.031 (3.02)	.179 (14.29)	-
Fusarium moniliforme	-	.245 (26.66)	.206 (19.44)	.196 (25.92)	.160 (20.00)	.250 (25.00)	.135 (16.66)	.250 (30.00)	.081 (7.14)	.095 (9.09)	.149 (11.90)	.119 (12.12)
F. solani	-	-	.147 (13.88)	.084 (11.11)	.160 (20.00)	.083 (8.33)	-	-	-	.031 (3.02)	-	.089 (9.09)
Gloeosporella butleri	-	-	-	-	-	-	-	-	.163 (14.29)	-	-	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.109 (9.52)	-	-	-
Mucor hiemalis	.059 (7.40)	-	-	-	-	.292 (19.44)	-	-	-	-	-	-
M. plumbeus	-	-	-	-	-	-	-	-	-	-	-	-
M. racemosus	-	-	-	-	-	-	-	.057 (6.66)	-	-	-	-
Paecilomyces lilacinum	-	-	-	-	-	-	-	-	.191 (15.66)	-	-	-
Penicillium chrysogenum	.059 (7.40)	.215 (26.66)	.471 (41.70)	.195 (25.92)	.187 (23.33)	.167 (29.16)	.190 (23.33)	.200 (23.34)	.136 (11.90)	.239 (22.72)	.209 (16.66)	-
P. claviforme	-	.061 (6.66)	-	-	-	-	-	-	-	-	-	-
P. fellutanum	.059 (7.40)	-	-	-	-	-	-	.086 (10.00)	.054 (4.80)	.143 (21.26)	.119 (9.56)	-
P. funiculosum	-	-	-	-	-	-	-	-	.109 (9.52)	-	.209 (16.66)	-
P. Javanicum	.059 (7.40)	-	-	-	.080 (10.02)	-	-	-	-	-	-	-
P. vermiculatum	.059 (7.40)	-	.029 (2.77)	-	-	-	.054 (6.66)	-	.109 (9.52)	.047 (4.54)	.209 (16.66)	-
Trichoderma koningii	.059 (7.40)	-	-	-	-	-	-	-	.081 (7.14)	-	-	-
T. viride	-	.061 (6.66)	.088 (8.33)	.084 (11.11)	.026 (3.33)	-	-	-	.109 (9.52)	.047 (4.54)	-	.237 (24.25)
White sterile	.295 (37.00)	.276 (30.00)	.145 (13.88)	.112 (14.83)	.134 (16.66)	.111 (19.07)	.244 (23.05)	.172 (20.00)	-	.239 (22.72)	.179 (14.28)	.118 (12.12)
Yellow sterile	.207 (18.60)	.276 (30.00)	-	.084 (11.11)	.053 (6.66)	-	.271 (30.30)	.086 (10.00)	-	.095 (9.09)	-	.148 (15.15)

Table 2.7 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 5 year plantation at 0-10 cm depth during the sampling period 1985-1986. values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	.196(10.33)	.059(3.92)	-	-	-	.053(4.50)	.192(12.28)	-	-	-
Aspergillus flavus	-	-	-	.059(3.92)	-	-	-	-	-	-	-	-
Curvularia maculans	-	-	-	-	-	-	-	-	-	-	-	.059(12.33)
Fusarium moniliforme	.244(11.59)	.213(11.11)	.529(23.61)	.383(25.49)	.417(20.28)	.168(18.16)	.163(16.66)	.215(16.03)	.412(26.31)	.275(22.20)	.418(25.92)	.267(18.00)
F. solani	.183(8.69)	.304(15.85)	-	.265(17.64)	.328(15.94)	.056(7.55)	.054(5.55)	.242(15.78)	-	-	.119(8.40)	.148(7.11)
Gongronella butleri	.274(13.08)	.243(12.69)	-	-	-	-	-	-	-	-	.119(8.40)	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	-	.248(20.00)	-	-
Mucor hiemalis	-	-	-	.118(7.84)	.179(8.69)	-	-	-	-	.275(22.20)	-	.089(4.66)
Mucor racemosus	-	-	-	-	-	.056(7.55)	.163(16.66)	-	-	.192(15.55)	-	-
Paecilomyces lilliacinum	-	-	-	-	-	-	-	-	-	-	.059(4.15)	.119(8.14)
Penicillium chrysogenum	.335(15.94)	.456(23.80)	.031(2.38)	-	.119(5.79)	.224(23.22)	.218(22.22)	.242(15.79)	.302(19.29)	-	.358(23.22)	.089(4.66)
P. fellutanum	.244(11.59)	.243(12.69)	.124(6.55)	.118(7.84)	.029(2.39)	-	-	-	-	.055(4.48)	-	-
P. funiculosum	-	-	-	-	-	-	-	-	.082(5.26)	-	-	-
P. javanicum	.183(8.69)	.09144.76)	-	-	-	-	-	-	-	-	-	-
P. liliacinum	-	-	-	-	-	-	-	-	-	-	.209(13.96)	-
P. vermiculatum	.193(8.69)	-	.031(2.38)	.029(1.99)	.149(9.24)	.196(19.59)	.190(19.48)	.161(1 .35)	.247(15.78)	-	.089(6.55)	-
Trichoderma koningii	-	-	-	-	-	-	-	-	.329(21.08)	-	-	.059(12.33)
T. lignorum	-	-	.249(11.43)	.059(3.92)	-	-	-	-	-	-	-	-
T. viride	-	-	.249(11.43)	.236(15.68)	.208(10.14)	-	-	.261(16.03)	-	.192(15.55)	-	.267(18.00)
White sterile	.335(15.94)	.365(19.08)	.436(19.44)	-	.238(11.59)	.168(18.16)	.163(16.66)	.261(16.03)	-	-	.119(8.40)	.237(14.77)
Yellow sterile	.122(5.79)	-	.249(11.43)	-	.328(15.94)	.029(4.77)	.027(2.77)	.053(4.50)	-	-	-	-

Table 2.8 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 5 year plantation at 0-10cm depth during the sampling period 1986-1987. Values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.247 (15.78)	-	-	-
Curvularia maculana	-	-	-	-	-	-	-	-	-	-	-	.118 (8.33)
Fusarium moniliforme	.356 (28.57)	.315 (18.50)	.283 (25.61)	.232 (16.66)	.214 (29.62)	.121 (21.42)	.134 (27.81)	.325 (26.19)	.192 (12.28)	.231 (16.66)	.119 (7.40)	.267 (18.75)
F. solani	.029 (2.38)	.410 (24.07)	-	.145 (12.61)	.026 (3.70)	-	.026 (5.55)	.118 (9.52)	-	.185 (13.30)	.059 (3.70)	.178 (12.58)
Gongronella butleri	.178 (14.28)	.031 (1.85)	-	.058 (4.16)	-	-	-	-	-	-	.209 (12.96)	
Mucor hiemalis	-	-	-	.058 (4.16)	-	.323 (57.14)	-	-	-	-	-	.089 (6.25)
M. plumbeus	-	-	-	-	-	.040 (7.16)	-	-	-	-	.059 (3.70)	-
M. racemosus	-	-	-	.029 (2.08)	.053 (7.40)	-	.053 (11.11)	-	-	.277 (20.00)	-	-
Paecilomyces liliacinum	-	-	-	-	-	-	-	-	-	-	.179 (13.01)	-
Penicillium chrysogenum	.207 (19.09)	.126 (7.40)	.142 (12.82)	.290 (20.81)	.080 (11.11)	-	.026 (5.55)	.118 (9.59)	.384 (24.56)	.277 (20.00)	.448 (27.77)	.089 (6.25)
P. fellutanum	.059 (4.76)	.252 (17.84)	-	-	-	-	-	-	-	.092 (6.66)	-	-
P. funiculosum	-	-	-	-	-	-	-	-	.192 (12.28)	-	.149 (9.25)	-
P. Javanicum	.029 (2.38)	-	.142 (12.82)	-	.053 (3.70)	-	-	-	-	-	-	-
P. vermiculatum	.059 (4.76)	-	-	-	-	-	.080 (16.66)	-	.247 (15.78)	-	.239 (14.81)	-
Trichoderma koningii	-	-	-	-	-	-	-	-	.109 (7.04)	-	-	.118 (8.33)
Trichoderma viride	-	-	.198 (19.94)	.145 (12.61)	-	-	-	-	.192 (12.28)	.092 (6.66)	-	.237 (16.68)
White sterile	.296 (23.78)	.568 (33.33)	.312 (28.80)	.232 (16.66)	.348 (40.67)	.080 (14.28)	.080 (16.66)	.384 (30.75)	-	.231 (16.66)	.119 (7.40)	.327 (22.91).
Yellow sterile	-	-	-	.087 (6.25)	.053 (3.70)	-	.080 (16.66)	.295 (23.78)	-	-	-	-

Table - 2.9 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 5 year plantation at 10-20 cm depth during the sampling period 1985-1986. values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	.058(4.76)	.030(1.75)	-	-	-	.085(5.88)	-	-	-
Alternaria alternata	-	-	-	-	-	-	-	-	-	-	-	.030(2.77)
Aspergillus flavus	-	-	-	.058(4.76)	-	-	-	-	-	-	-	-
Aspergillus nedulans	-	-	-	-	-	-	-	-	-	-	.242(16.68)	-
Aspergillus niger	-	-	-	-	-	-	.194(17.94)	-	-	.086(6.33)	-	.061(5.55)
Cladosporium herbarum	-	-	-	.058(4.76)	-	-	-	-	-	-	-	-
Cunninghamella echinulata	-	-	-	.058(4.76)	-	-	-	-	-	-	-	-
Fusarium moniliforme	-	.215(11.96)	.467(25.00)	.146(8.90)	.394(20.78)	.229(20.51)	.112(10.25)	.330(28.57)	.170(11.76)	.229(22.22)	.242(16.68)	.185(16.66)
F. solani	-	.092(4.55)	-	.058(4.76)	.272(15.78)	.057(6.12)	.139(12.82)	.165(14.89)	.255(17.64)	.057(5.55)	-	.061(5.55)
Gongronella butleri	-	-	-	.117(8.66)	-	-	-	-	.056(3.92)	-	-	.061(5.55)
Humicola fuscoatra	-	-	-	-	-	-	-	-	-	.114(11.16)	-	-
Mucor hiemalis	.365(20.05)	-	.031(1.66)	-	-	.057(6.12)	-	-	.056(3.92)	.229(22.22)	-	.092(8.33)
M. plumbeus	-	-	-	.058(4.76)	-	-	-	-	-	-	-	-
M. racemosus	.213(11.28)	-	-	.058(4.76)	-	-	-	-	-	-	-	.030(2.77)
Myeogone alba	-	-	-	.029(3.38)	-	-	-	-	-	-	-	-
Paecilomyces lilliacinum	-	-	-	.087(7.14)	.030(1.75)	-	-	.055(8.76)	-	-	.212(16.52)	-
Penicillium chrysogenum	.395(20.80)	.339(29.62)	.062(3.33)	.058(4.76)	-	.171(16.38)	.222(20.51)	.137(13.90)	.113(7.84)	.057(5.55)	.182(13.76)	.123(11.18)
P. fellutanum	-	.153(8.25)	.093(5.50)	.117(8.66)	.181(10.52)	-	.055(5.12)	.082(8.14)	.056(3.92)	-	-	-
P. funiculosum	-	-	-	.087(7.14)	-	-	.055(5.12)	-	-	.057(5.55)	.546(36.29)	-
P. javanicum	-	-	-	-	-	-	-	-	-	.086(8.33)	-	-
P. vermiculatum	.334(18.29)	.276(16.14)	.405(21.66)	.087(7.14)	.272(15.78)	-	.027(2.56)	-	-	.028(2.77)	-	.030(2.77)
Trichoderma koningii	-	-	-	-	-	-	-	-	.312(29.56)	-	-	.061(5.55)
T. lignorum	-	-	.311(16.69)	.058(4.76)	-	.028(3.56)	-	-	-	-	-	-
T. viride	-	.184(10.11)	-	.029(2.38)	.181(10.52)	.143(13.82)	-	.220(19.04)	.085(5.89)	.028(2.77)	-	.216(19.44)
White sterile	.395(20.80)	.338(20.37)	.249(13.33)	-	.121(7.01)	.257(23.24)	.222(20.58)	.082(8.14)	.113(7.84)	-	-	-
Yellow sterile	.152(7.77)	-	.249(13.33)	.058(4.76)	.303(16.11)	.114(10.25)	.055(5.12)	.055(8.76)	-	.057(5.55)	-	.154(13.88)

Table 2.10 Monthly variation in fungal population (per gram dry soil x 10^3) in the soil of 5 year plantation at 10-20cm depth during the sampling period 1986-1987. Values in parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.113(11.11)	-	-	-
Alternaria alternata	-	-	-	-	-	-	-	-	-	-	-	.030(3.03)
Aspergillus nedulans	-	-	-	-	.080(9.09)	-	-	-	-	.182(5.38)	-	-
Aspergillus niger	-	-	-	-	-	-	.056(8.33)	-	-	-	-	.030(3.03)
Fusarium moniliforme	-	.220(14.58)	.207(21.21)	.091(12.50)	.080(9.09)	.166(20.00)	.140(20.83)	.206(25.92)	.085(8.33)	.030(10.00)	.121(10.30)	.185(18.18)
F. solani	-	-	.118(12.12)	-	.026(3.03)	.083(15.00)	.056(8.33)	.236(18.51)	.113(11.11)	.061(7.78)	.060(5.12)	.185(18.18)
Gongronella butleri	-	-	-	-	-	-	-	-	.113(11.11)	-	-	.061(6.06)
Mucor hiemalis	.237(26.66)	-	.088(9.09)	-	.026(3.03)	.207(25.00)	-	-	-	-	-	.092(9.09)
M. plumbeus	-	-	-	-	-	-	-	-	-	.030(10.00)	.060(5.12)	-
M. racemosus	-	-	-	-	-	-	-	-	-	-	-	.061(6.06)
Paecilomyces lilacinum	-	-	.029(3.03)	-	-	-	-	-	-	-	.182(15.38)	-
Penicillium chrysogenum	.177(23.32)	.252(16.66)	.207(21.21)	.395(54.18)	.161(18.18)	.166(20.00)	.084(12.52)	.236(18.51)	.085(8.33)	.123(13.33)	.273(23.07)	.092(9.09)
P. fellutanum	-	-	-	-	.053(6.06)	-	-	-	.056(5.55)	-	-	-
P. funiculosum	-	-	-	-	-	-	.056(8.33)	-	-	.123(13.33)	.242(20.51)	-
P. liliacinum	-	-	-	-	-	-	-	-	.028(2.77)	-	-	-
P. vermiculatum	.059(6.66)	-	-	-	.134(15.15)	-	-	-	.028(2.77)	.123(13.33)	.060(5.12)	.030(3.03)
Trichoderma koningii	-	-	-	-	-	-	-	-	.198(22.79)	.061(7.78)	-	.030(3.03)
T. viride	-	.252(16.66)	-	-	.053(6.06)	-	-	-	.141(13.88)	-	-	.185(18.18)
White sterile	.296(33.9)	.852(52.10)	.296(30.31)	.121(16.66)	.134(15.15)	.116(20.00)	.140(20.83)	.177(21.08)	.028(2.27)	.061(7.78)	-	.030(3.03)
Yellow sterile	.088(10.00)	-	.029(3.03)	.121(16.66)	.134(15.15)	-	.140(20.83)	.177(21.08)	-	.154(16.66)	-	-

Table 2.11 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 5 year plantation at 20-30cm depth during the sampling period 1985-1986. Values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	.059(4.44)	.091(13.66)	-	-	-	-	.057(6.06)	-	-
Aspergillus nedulans	-	-	.090(5.88)	.059(4.44)	-	-	-	-	-	-	-	-
A. niger	-	-	-	.147(11.11)	-	-	-	-	-	.057(6.06)	-	-
Fusarium moniliforme	-	.184(18.18)	.242(14.85)	.177(20.33)	.182(11.11)	.345(28.57)	.094(6.66)	.336(35.36)	.315(22.91)	.344(36.36)	.215(15.15)	.243(24.24)
F. solani	-	.030(3.02)	.121(7.84)	-	.334(12.37)	-	.056(4.44)	.168(18.18)	-	-	-	.060(6.06)
Gengronella butleri	-	-	-	-	-	-	-	-	.057(4.16)	-	.123(8.88)	.060(6.06)
Humicola fuscoatra	-	-	-	-	-	-	-	-	.057(4.16)	-	-	-
Mucor hiemalis	.151(12.82)	-	.181(11.76)	.059(4.44)	.060(3.70)	-	-	-	-	.172(18.18)	-	.060(6.06)
Mucor plumbeus	.090(9.69)	-	-	-	-	-	.084(6.66)	-	-	-	-	-
Mucor racemosus	.121(10.35)	-	-	-	-	-	.140(11.11)	-	-	-	-	-
Paeciliomyces lilliacinum	-	-	-	.147(11.11)	.030(1.85)	-	.084(6.66)	-	.114(8.33)	-	.092(6.66)	-
Penicillium chrysogenum	.181(15.38)	.277(27.27)	.960(3.92)	-	-	.172(14.28)	.253(20.00)	.056(6.06)	.095(5.25)	.057(6.06)	.276(21.66)	-
P. claviforme	-	-	-	-	-	-	-	-	-	.057(6.06)	-	-
P. fellutanum	-	.184(18.18)	.030(5.88)	.118(9.60)	.091(13.49)	.028(2.37)	.112(8.88)	.028(3.03)	.114(8.33)	-	.092(6.66)	-
P. funiculosum	.211(17.94)	-	-	-	-	-	-	-	.029(5.29)	.029(2.01)	.369(26.66)	.091(9.09)
P. javanicum	.030(2.56)	.123(12.12)	-	-	-	-	-	-	-	.086(11.15)	.215(15.15)	-
P. liliacinum	-	-	-	-	-	-	-	-	.229(16.66)	-	-	-
P. vermiculatum	.211(17.94)	.061(6.08)	.121(7.84)	.206(15.15)	.182(11.11)	-	.140(11.11)	.140(15.15)	.057(4.16)	.057(6.06)	-	-
Trichoderma koningii	-	-	-	-	-	-	-	-	.258(18.75)	-	-	.030(3.03)
T. lignorum	-	-	-	.088(6.66)	-	-	-	.028(3.03)	-	-	-	-
T. viride	-	-	-	.059(4.44)	.121(7.40)	.230(19.08)	-	.084(9.09)	-	.057(6.06)	-	.243(24.24)
White sterile	.151(12.82)	.154(15.15)	.423(27.45)	.029(2.22)	.303(10.50)	.259(21.42)	.168(15.60)	.028(3.03)	-	-	.123(8.88)	.212(21.22)
Yellow sterile	-	-	.302(14.58)	.088(6.66)	.242(14.81)	.057(14.28)	.112(8.88)	.056(6.06)	-	-	-	-

Table 2.12 Monthly variation in fungal population (per gram dry soil x 10^3) in the soil of 5 year plantation during the sampling period 1986-1987. Values in parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.028(3.03)	-	-	-
Fusarium moniliforme	-	.062(7.40)	.254(33.33)	.205(29.16)	.167(22.26)	.339(30.76)	.140(18.54)	.147(20.83)	.086(9.09)	.235(15.00)	.153(13.88)	.182(20.00)
Fusarium solani	-	-	-	-	.111(22.22)	.127(11.53)	-	-	.028(3.03)	.094(10.00)	-	.030(3.33)
Gongronella butleri	-	-	-	.087(12.50)	-	-	-	-	.086(9.09)	-	.123(11.11)	.030(3.03)
Humicola fuscoatra	-	-	-	-	-	-	-	-	.114(12.13)	-	-	-
Mucor hiemalis	.148(22.77)	-	-	-	-	.212(19.29)	-	-	-	-	-	.060(6.66)
M. plumbeus	-	-	-	-	-	.127(11.53)	-	-	-	-	-	-
M. racemosus	-	-	-	-	-	.169 (16.38)	.028(3.70)	-	-	-	-	-
Paecilomyces liliacinum	-	-	.042(5.55)	-	-	-	.084(11.11)	-	.029(3.03)	-	.153(13.88)	-
Penicillium chrysogenum	.148(22.87)	.434(51.85)	.254(33.33)	.058(8.33)	.111(22.22)	-	.028(3.70)	.177(25.00)	.143(15.15)	.188(20.00)	.246(22.22)	-
P. fellutanum	-	-	-	-	.027(5.55)	-	.028(3.70)	.059(8.33)	.057(6.06)	-	.123(11.11)	-
P. funiculosum	.059(11.11)	-	.042(5.55)	-	-	-	.084(11.11)	.059(8.33)	.029(3.03)	.198(20.00)	.123(11.11)	.060(6.66)
P. javanicum	-	-	-	-	-	-	-	-	-	-	.184(16.69)	-
P. liliacinum	-	-	-	-	-	-	-	-	.143(15.15)	-	-	-
P. vermiculatum	.029(5.55)	-	-	-	-	-	.028(3.70)	-	.057(6.06)	-	-	-
Trichoderma koningii	-	-	.042(5.55)	-	-	-	-	-	.143(15.15)	-	-	.060(6.66)
T. viride	-	-	.042(5.55)	-	-	-	-	-	-	-	-	.273(36.07)
White sterile	.089(15.03)	.248(29.64)	.084(11.14)	.234(33.33)	.111(22.22)	.127(11.53)	.253(33.33)	.147(20.83)	-	.094(10.00)	-	.151(16.66)
Yellow sterile	.148(22.77)	.093(11.11)	-	.117(16.68)	.027(5.55)	-	.084(11.11)	.118(16.68)	-	.235(25.00)	-	-

Table 2.13 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 10 year plantation at 0-10cm depth during the sampling period 1985-1986. Values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.091(3.70)	.219(20.51)	-	-
Aspergillus niger	-	.374(14.81)	-	-	-	-	-	-	-	-	-	-
Cladosporium herbarum	-	-	-	-	-	-	-	.082(4.34)	-	-	-	-
Fusarium moniliforme	.250(9.52)	.156(6.93)	.628(44.89)	.548(24.25)	.359(17.18)	.381(33.33)	.170(16.16)	.302(15.94)	.190(8.64)	.327(30.76)	.384(24.49)	.205(13.78)
F. solani	.187(7.18)	.187(7.40)	.187(7.69)	.355(18.18)	.359(17.18)	.029(2.56)	.056(5.61)	.110(5.79)	.054(2.46)	-	-	-
Gongronella butleri	-	.374(14.91)	-	.121(6.06)	-	-	-	-	-	.054(5.12)	-	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.815(36.00)	.054(5.12)	-	-
Mucor hiemalis	-	-	-	-	-	.029(2.56)	-	-	-	.218(20.51)	-	.053(3.92)
M. plumbeus	-	-	-	.091(4.54)	-	-	-	.059(2.89)	-	-	-	-
M. racemosus	-	-	-	.060(3.03)	.089(4.54)	.176(15.38)	-	-	-	-	-	.053(3.92)
Paecilomyces liliacinum	-	.405(16.04)	-	-	-	-	-	-	.462(20.98)	-	-	-
Penicillium chrysogenum	.375(14.28)	.218(8.64)	-	.060(3.03)	.089(4.54)	.059(5.12)	.284(27.75)	.137(7.24)	.091(3.70)	.027(5.56)	.324(22.58)	.117(17.84)
P. claviforme	.343(13.09)	-	-	-	-	-	-	-	-	-	-	-
P. fellutanum	.156(5.95)	-	-	.182(9.09)	.239(12.12)	-	.113(11.11)	-	-	-	-	.147(9.80)
P. funiculosum	-	-	-	.060(3.03)	-	-	-	-	-	-	-	.058(3.92)
P. javanicum	.125(4.76)	-	-	-	-	-	-	-	-	-	-	-
P. liliacinum	-	-	-	-	-	-	-	-	.217(9.72)	-	-	-
P. vermiculatum	.250(9.52)	-	.281(11.53)	.121(6.06)	.359(17.18)	-	.113(11.11)	.330(27.39)	-	-	-	.029(5.88)
Trichoderma koningii	-	-	-	-	-	-	-	-	.162(7.40)	-	-	-
T. lignorum	-	--	-	.243(12.12)	.119(6.06)	.088(7.69)	-	.165(8.69)	-	-	-	-
T. viride	-	.311(15.33)	.875(35.89)	.213(10.60)	.209(10.60)	.146(12.82)	-	.247(13.24)	.162(7.40)	.109(12.32)	.354(23.52)	.147(9.80)
White sterile	.500(19.04)	.405(16.04)	-	-	.149(7.57)	.234(20.54)	.142(13.88)	.220(11.59)	-	-	.443(29.41)	.293(19.58)
Yellow sterile	.437(16.66)	-	-	-	.059(3.03)	-	.142(13.88)	.055(2.89)	-	-	-	.323(21.56)

Table 2.14 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 10 year plantation at 0-10 cm depth during the sampling period 1986-1987. Values in parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.084(3.33)	-	-	-
Aspergillus niger	-	.336(24.44)	-	-	-	-	-	-	-	.043(2.94)	-	-
Fusarium moniliforme	.267(17.64)	.183(13.33)	.264(21.42)	.180(18.18)	.217(19.04)	.040(5.55)	.085(14.28)	.261(23.07)	.135(8.33)	.115(7.94)	.236(14.06)	.176(13.33)
F. soleni	-	.122(8.88)	.323(27.48)	-	.163(14.29)	.040(5.53)	.085(14.28)	.058(5.12)	.135(8.33)	.043(2.94)	-	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.190(11.66)	-	-	-
Mucor hiemalis	-	-	-	-	-	.081(15.77)	-	-	-	-	-	.088(6.66)
Mucor plumbeus	-	-	-	-	-	.190(25.92)	-	-	-	-	-	-
M. racemosus	-	-	-	-	.108(9.52)	-	-	-	-	.096(5.98)	-	.058(4.47)
Paecilomyces lilliacinum	-	.336(24.44)	-	-	-	-	-	-	.190(11.66)	-	-	-
Penicillium chrysogenum	.178(11.76)	-	.234(17.77)	.301(30.27)	.163(14.28)	-	.085(14.28)	-	.271(16.65)	.260(17.64)	.295(17.57)	.264(20.00)
P. claviforme	.119(7.84)	-	-	.030(3.03)	-	-	-	-	-	-	-	-
P. fellutanum	-	-	-	.060(3.92)	-	-	.028(4.80)	-	-	-	.354(21.05)	-
P. javanicum	.119(7.84)	-	-	-	.081(7.14)	-	-	-	-	-	-	-
P. liliacinum	-	-	-	-	-	-	-	-	.163(11.72)	-	-	-
P. vermiculatum	-	-	-	-	-	.190(25.92)	.085(14.28)	-	.190(11.66)	.260(17.64)	.206(12.29)	.099(6.66)
Trichoderma koningii	-	-	-	-	-	-	-	-	.135(8.33)	-	-	-
T. viride	-	.153(11.14)	-	.120(12.12)	.190(16.66)	.054(7.40)	-	-	.135(8.33)	-	.265(15.78)	.147(11.11)
White sterile	.625(33.99)	.245(17.77)	.440(33.33)	.180(18.18)	-	.108(14.81)	.114(19.04)	.435(38.48)	-	.433(27.48)	.324(19.29)	.235(17.77)
Yellow sterile	.327(21.56)	-	-	.120(14.30)	.136(19.08)	-	.114(19.04)	.377(33.33)	-	.260(17.64)	-	.264(20.00)

Table 2.15 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 10 year plantation at 10-20cm depth during the sampling period 1985-1986. Values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.216(10.60)	-	.059(5.55)	-
Alternaria alternata	-	-	-	-	-	-	-	-	-	-	.059(5.55)	-
Aspergillus flavus	-	-	-	.098(1.51)	-	.115(8.88)	.249(28.75)	-	-	-	-	-
Aspergillus nedulans	-	-	-	-	-	.028(2.22)	-	-	-	-	-	-
A. niger	-	.316(16.65)	-	-	-	.057(4.44)	-	-	-	.085(3.33)	-	-
Cladosporium herbarum	-	-	-	-	-	-	-	.082(1.75)	-	-	-	-
Fusarium moniliforme	.252(12.12)	.190(10.00)	.325(47.84)	.266(13.63)	.207(10.60)	.173(13.33)	.138(10.41)	.247(15.78)	.092(4.54)	.293(33.30)	.298(28.48)	.239(20.51)
F. solani	.157(7.57)	.221(11.66)	-	.177(9.09)	.207(10.60)	.144(11.11)	.111(8.36)	.164(10.52)	.030(1.51)	-	-	.149(14.82)
Gongronella butleri	-	.316(16.65)	-	.207(10.60)	-	.144(11.11)	-	-	-	-	.059(5.55)	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.537(27.31)	.056(6.66)	-	-
Mucor hiemalis	-	-	-	.295(15.13)	.059(3.03)	-	-	-	-	.198(22.33)	-	-
M. plumbeus	-	-	-	-	-	-	-	.219(14.03)	-	-	-	.029(3.72)
M. racemosus	-	-	-	-	-	-	-	-	-	-	.029(6.77)	.089(7.69)
Paecilomyces lilliacinum	.126(6.06)	.190(10.00)	-	-	-	-	-	-	.247(12.12)	-	-	-
P. chrysogenum	.294(13.63)	.126(6.66)	-	.088(1.51)	.235(15.13)	.259(18.92)	.166(12.50)	.247(15.78)	.123(6.06)	.056(6.66)	.089(18.33)	.119(10.25)
P. fellutanum	.252(12.12)	-	.272(14.28)	-	.295(15.13)	-	.194(14.58)	.274(17.52)	-	.056(6.66)	-	-
P. funiculosum	.315(15.13)	-	-	-	-	-	-	-	-	-	.119(11.11)	-
P. javanicum	-	-	-	-	-	-	-	-	-	-	.119(11.11)	-
P. liliacinum	-	-	-	-	-	-	-	-	.278(13.63)	-	-	-
P. vermiculatum	.189(9.09)	-	-	-	.266(13.63)	-	.138(10.41)	.082(1.75)	.309(15.13)	.028(3.33)	-	-
Trichoderma koningii	-	-	-	-	-	-	-	-	.185(9.09)	-	-	.059(5.12)
T. lignorum	-	-	.181(9.52)	.118(6.06)	.147(7.57)	.057(4.44)	-	-	-	-	-	-
T. viride	-	.348(18.38)	.424(17.95)	.207(10.16)	.177(9.09)	.288(12.22)	-	.192(19.37)	-	.085(17.73)	-	.149(14.82)
White sterile	.284(13.63)	.190(10.00)	-	.473(22.78)	-	.028(2.22)	.194(14.58)	-	-	-	.059(5.55)	.179(15.38)
Yellow sterile	.221(10.65)	-	.212(11.11)	.177(9.09)	.325(15.22)	.144(11.11)	.138(10.41)	.054(3.50)	-	-	--	.089(7.69)

Table 12.16 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 10 year plantation at 10-20 cm depth during the sampling period 1986-1987. Values in parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan.	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.185(11.76)	-	.148(11.90)	-
Alternaria alternata	-	-	-	-	-	-	-	-	-	-	.148(11.90)	-
Aspergillus niger	-	.060(5.55)	-	-	.026(3.70)	-	.027(3.70)	-	-	.176(18.18)	-	-
Fusarium moniliforme	.357(26.66)	.182(16.66)	.236(17.77)	.062(6.66)	.159(22.22)	.198(25.00)	.110(14.81)	.169(18.18)	.154(9.80)	.117(12.12)	.148(11.90)	.176(15.38)
F. solani	.089(6.66)	.060(5.55)	.029(2.69)	.062(6.66)	.132(18.51)	.039(5.00)	.137(18.31)	.084(9.09)	.092(5.88)	.029(3.02)	-	.176(15.38)
Gongronella butleri	-	.060(5.55)	-	.062(6.66)	-	-	-	-	-	-	.208(20.05)	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.216(13.72)	-	-	-
Mucor hiemalis	-	-	-	-	-	-	-	-	-	-	-	-
M. plumbeus	-	-	-	-	.132(18.51)	.198(25.00)	-	-	-	-	-	.089(7.69)
M. racemosus	-	-	-	-	-	-	-	-	-	-	.059(6.06)	.089(7.69)
Paecilomyces liliacinum	.089(6.66)	.091(8.33)	-	-	-	-	-	-	.185(11.76)	-	-	-
Penicillium chrysogenum	.089(6.66)	.303(22.26)	-	.062(6.66)	.079(11.11)	-	.137(18.51)	.084(9.09)	.340(19.64)	.117(12.12)	.208(20.05)	.059(5.12)
P. fellutanum	.059(4.49)	-	-	-	-	-	.027(3.70)	.056(6.06)	-	.117(12.12)	-	-
P. funiculosum	.178(13.33)	.121(11.11)	-	-	-	-	-	-	-	-	.089(9.09)	.119(10.25)
P. javanicum	-	-	-	.124(13.33)	.026(3.70)	-	-	-	-	-	.029(3.03)	-
P. liliacinum	-	-	-	-	-	.079(10.00)	-	-	.061(3.92)	-	-	-
P. vermiculatum	.089(6.66)	-	-	-	-	-	.055(7.40)	.056(6.06)	.061(3.92)	.117(12.12)	-	.089(7.69)
Trichoderma koningii	-	-	-	-	-	-	-	-	.185(11.76)	-	-	.059(5.12)
T. viride	-	.060(5.55)	.027(15.55)	.062(6.66)	.053(7.40)	.198(25.00)	-	-	.123(7.84)	.058(6.06)	-	.149(12.87)
White sterile	.028(15.55)	.212(19.44)	.591(48.44)	.186(20.04)	.106(14.86)	.079(10.00)	.082(11.14)	.169(18.18)	-	.146(18.20)	.059(6.06)	.119(10.25)
Yellow sterile	.178(13.33)	-	.266(15.55)	.218(33.33)	-	-	.165(22.22)	.311(33.34)	-	.058(6.06)	-	.089(2.56)

Table :2.17 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 10 year plantation at 20-30cm depth during the sampling period 1985-1986. Values in the parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.157(8.77)	-	-	-
Aspergillus flavus	-	-	-	-	-	.057(3.70)	-	-	-	-	-	-
A. nedulans	-	-	-	-	-	-	-	-	-	-	.058(3.33)	-
A. niger	-	-	-	-	.030(2.77)	.086(5.55)	-	-	-	-	-	-
Curvularia maculans	-	-	-	-	-	-	-	.027(2.56)	-	.141(18.51)	-	-
Fusarium moniliforme	.221(12.96)	.190(11.76)	.305(25.61)	.210(19.48)	.120(10.11)	.202(13.96)	.168(11.11)	.165(15.38)	.220(12.28)	.226(26.62)	.264(39.50)	.179(18.18)
F. solani	.126(7.47)	.158(9.80)	-	.090(8.33)	.241(21.22)	.086(5.55)	.253(16.66)	.055(5.12)	-	-	-	.089(9.09)
Gongronella butleri	-	-	-	-	-	.144(9.25)	-	-	-	-	-	-
Humicola fuscoatra	-	-	-	-	-	-	-	-	.094(5.26)	-	-	-
Monilia sp.	-	-	.030(2.56)	-	-	-	-	-	-	-	-	-
Mucor hiemalis	-	-	-	-	-	-	-	-	-	.141(18.51)	-	-
M. plumbeus	-	-	-	-	-	-	-	-	-	-	.029(4.16)	-
M. racemosus	-	-	-	-	-	.144(9.25)	-	-	.031(1.75)	-	-	-
Paecilomyces lilliacinum	.063(3.70)	.158(9.80)	-	.060(5.55)	-	-	-	-	.378(21.05)	-	-	-
Penicillium chrysogenum	.316(18.50)	.380(23.52)	-	-	-	.202(13.96)	.309(20.37)	.192(17.94)	.126(14.60)	.056(10.44)	.147(25.83)	.119(12.12)
P. fellutanum	.158(9.25)	.253(15.68)	.183(15.38)	.060(5.55)	.060(5.55)	.057(3.70)	.140(9.28)	-	.094(5.26)	-	-	-
P. funiculosum	.063(3.70)	-	.061(5.12)	.240(22.22)	-	-	.168(11.11)	-	.063(3.50)	-	.058(8.68)	-
P. javanicum	.063(3.70)	.095(5.88)	-	-	-	-	-	-	-	-	-	-
P. vermiculatum	.316(18.50)	.095(5.88)	-	.090(8.33)	.120(10.11)	.086(5.55)	.225(14.81)	.220(20.56)	.063(3.50)	-	-	-
Trichoderma koningii	-	-	-	-	-	-	-	-	.252(24.03)	-	-	-
Trichoderma lignorum	-	-	.061(5.12)	.030(2.77)	-	.028(1.85)	-	.027(2.56)	-	-	-	-
T. viride	-	-	-	.060(5.55)	.241(21.22)	.231(15.58)	-	.082(7.69)	-	.169(22.22)	-	.179(18.18)
White sterile	.190(11.11)	.222(17.68)	.366(28.27)	.120(11.11)	.241(21.22)	.115(8.40)	.168(11.11)	.192(17.94)	-	-	.088(13.5)	.359(33.34)
Yellow sterile	.190(11.11)	-	.213(17.04)	.120(11.11)	.090(7.80)	.057(3.70)	.084(5.55)	.110(10.25)	-	.028(3.70)	-	.089(9.09)

Table 2.18 Monthly variation of fungal population (per gram dry soil x 10^3) in the soil of 10 year plantation at 20-30 cm depth during the sampling period 1986-1987. Values in parentheses are % relative abundance.

Fungi	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Absidia glauca	-	-	-	-	-	-	-	-	.126(8.33)	-	-	-
Aspergillus nedulans	-	-	-	-	-	-	-	-	-	-	.176(15.38)	-
A. niger	-	-	-	-	.026(3.70)	-	-	.028(3.33)	-	.219(27.29)	-	-
Fusarium moniliforme	-	.148(18.51)	.289(27.75)	.031(4.17)	.187(25.92)	.055(2.77)	.137(16.76)	.142(16.66)	.189(12.58)	.188(18.18)	.176(15.38)	.179(19.18)
F. sonali	.089(7.69)	.148(18.51)	.289(27.75)	-	.053(7.40)	-	.027(3.33)	.056(6.66)	-	.047(4.54)	-	.119(12.12)
Humicola fuscoatra	-	-	-	-	-	-	-	-	.031(2.08)	-	-	-
Mucor hiemalis	-	-	-	-	-	.055(2.77)	-	-	-	-	-	-
M. plumbeus	-	-	-	-	-	.363(31.05)	-	-	-	-	.254(23.11)	-
M. racemosus	-	-	-	-	-	.223(22.22)	-	-	.031(2.08)	-	-	-
Paecilomyces liliacinum	.089(7.69)	.029(3.70)	-	-	-	-	.027(3.33)	.028(3.33)	.126(8.33)	-	-	-
Penicillium chrysogenum	.118(10.28)	.177(22.22)	.057(5.62)	.095(12.50)	.267(37.00)	.223(22.22)	.110(13.33)	.312(36.66)	.189(12.50)	-	.176(15.38)	.179(18.18)
P. fellutanum	.089(7.69)	-	-	-	-	-	.027(3.33)	-	.126(8.33)	-	-	-
P. funiculosum	.089(7.69)	.059(7.40)	-	-	-	-	.110(13.33)	-	.189(12.50)	-	.117(10.25)	-
P. liliacinum	-	-	-	-	-	-	-	-	.157(10.41)	-	-	-
P. vermiculatum	.089(7.69)	-	-	-	-	.055(2.77)	.055(6.66)	-	.063(3.79)	-	.117(10.25)	.059(6.06)
Trichoderma koningii	-	-	-	-	-	-	-	-	.189(12.50)	-	-	-
T. viride	-	-	-	.285(37.50)	-	-	-	-	-	.094(9.09)	-	.179(18.18)
White sterile	.237(20.51)	.325(29.66)	.405(38.88)	.253(33.33)	.160(22.22)	.055(2.77)	.193(26.66)	.142(16.66)	.157(10.41)	.235(22.72)	.117(10.25)	.149(15.15)
Yellow sterile	.356(30.76)	-	-	.095(12.50)	.026(3.76)	.055(2.77)	.110(13.33)	.056(6.66)	-	.188(18.18)	-	.119(12.12)

tions did not differ much. Similarly, depth-wise distribution of fungal species also did not show marked difference. Majority of the fungal species were common to all the depths (Tables 2.1-2.18). A total number of 33 fungal species were isolated from all the three plantation soils. These isolates include two sterile forms also (Tables 2.1-2.18).

Surface soil (0-10 cm) of 1 year plantation harboured a total number of 29 fungal species (Tables 2.1-2.2). The species were Absidia glauca; Aspergillus flavus; A. nedulans; Fusarium moniliforme; F. solani; Gongronella butleri; Humicola fuscoatra; Mortierella ramanniana; Mucor hiemalis; M. plumbeus; M. racemosus; Mycogone alba; Paecilomyces liliacinum; P. chrysogenum; P. claviforme; P. fellutanum; P. fumiculosum; P. javanicum; P. liliacinum; P. vermiculatum; Trichoderma koningii; T. lignorum; T. viride; Verticillium chlamydrosporum; white sterile and yellow sterile. All the 28 species isolated from 10-20 cm depth soil were common with the 0-10 cm depth soil (Tables 2.3,2.4). A total number of 25 fungal species were recorded from the 20-30 cm depth soil (Tables 2.5,2.6). Aspergillus versicular; Cladosporium herbarum and Curvularia lunata were isolated only from the 20-30 cm depth soil while other species were common to all the depths.

Surface soil (0-10 cm) of 5 year plantation exhi-

bited a total number of 22 fungal species namely; Absidia glauca; Aspergillus flavus; Curvularia maculans; Fusarium moniliforme; F. solani; Gongronella butleri; Humicola fuscoatra· Mucor hiemalis; M. plumbeus; M. racemosus; Paecilomyces liliacinum; P. chrysogenum; P. fellutanum; P. funiculosum; P. javanicum; P. liliacinum· P. vermiculatum; Trichoderma koningii; T. lignorum; T. viride; white sterile and yellow sterile (Tables 2.7,2.8). 10-20 cm soil showed a total number of 27 fungal species (Tables 2.9,2.10). 22 fungal species which were recorded from the 0-10 cm soil were also recorded from the 10-20 cm soil. 5 fungal species Alternaria alternata; Aspergillus nedulans; A. niger; Cladosporium herbarum and Cunninghamella echinulata appeared in 10-20 cm soil (Tables 2.9,2.10). Similarly (23) fungal species were recorded from the 20-30 cm soil. Penicillium claviforme which was not recorded from the 0-10 cm and 10-20 cm soil depth was isolated from 20-30 cm soil depth (Tables 2.11,2.12).

From the 0-10 cm soil of the 10 year plantation 23 fungal species viz· Absidia glauca· Alternaria alternata; Aspergillus niger; Cladosporium herbarum; Fusarium moniliforme; F. solani; Gongronella butleri· Humicola fuscoatra; Mucor hiemalis; M. plumbeus· M. racemosus; Paecilomyces liliacinum; Penicillium chrysogenum· P. claviforme; P. fellutanum; P. funiculosum· P. javanicum· P. liliacinum; P. vermiculatum; Trichoderma koningii; T. lignorum; T.viride;

white sterile and yellow sterile were recorded (Tables 2.13, 2.14). 10-20 cm soil depth harboured 25 fungal species (Tables 2.15,2.16). Similar fungal flora was also recorded from the 10-20 cm soil as it was recorded from the 0-10 cm soil depth. The main difference between the fungal flora of the two depths was the absence of Penicillium claviforme in 10-20 cm depth soil and presence of two new fungal species namely; Aspergillus flavus and A. nedulans in 0-10 cm soil depth (Tables 2.15,2.16). 26 fungal species were recorded from the 20-30 cm soil (Tables 2.17,2.18). The fungal flora of the 20-30 cm depth soil was found quite similar to that of the 0-10 cm and 10-20 cm soils except the absence of Cladosporium herbarum and the appearance of two new fungal species viz., Curvularia maculans and Monilia sp.

Out of the total 33 fungal species 31 species were recorded from the surface (0-10 cm) soil of the plantations studied.Only two species, Aspergillus versicular and Curvularia lunata were not recorded from the surface soil (Tables 2.1-2.2; 2.7-2.8; 2.13-2.14). Similarly 31 fungal species were recorded from the 10-20 cm depth soil (Tables 2.3-2.4; 2.9-2.10· 2.15-2.16). While on the other hand out of 33 fungal species a total of 30 species were isolated from the 20-30 cm layer of soil of all the plantations (Tables 2.5-2.6; 2.11-2.12; 2.17-2.18). Mostly 20-30 cm

depth soil also exhibited similar type of fungal species as in 0-10 cm and 10-20 cm depth soils except that Alternaria alternata· Cunninghamella echinulata; Mortierella ramanniana and Mycogone alba were not recorded from this depth (Tables 2.5-2.6; 2.11-2.12· 2.17-2.18). Aspergillus versicular; Curvularia lunata and Monilia sp. appeared in 20-30 cm depth soils which were not recorded from the 0-10 cm and 10-20 cm depths.

Fusarium moniliforme; F. solani; Penicillium chrysogenum; P. claviforme; P. fellutanum; P. funiculosum; P. javanicum; P. liliacinum; P. vermiculatum; Trichoderma lignorum; T. viride; white sterile and yellow sterile showed their common occurrence throughout the study period while on the other hand Absidia glauca; Alternaria alternata; Aspergillus flavus; A. niger; A. nedulans; Cladosporium herbarum; Cunninghamella echinulata; Curvularia maculans; Gongronella butleri; Humicola fuscoatra; Mortierella ramanniana; Mucor racemosus; M. plumbeus· M. hiemalis; Mycogone alba; Paecilomyces liliacinum; Trichoderma koningi and Verticillium chlamydosporum occurred sporadically in all the plantation soils (Tables 2.1-2.18).

From the tables 2.1-2.18, it is clear that 1 year plantation soils exhibited highest number (31)of fungal isolates which was followed by 5 year (29) and 10 years (28) plantation soils. Alternaria alternata and Monilia sp. were

not recovered from 1 year plantation soils (Tables 2.1-2.6). Similarly, Aspergillus versicular; Curvularia lunata; Monilia sp.; Mortierella ramanniana and Verticillium chlamydosporum were not isolated in 5 year plantation soil (Tables 2.7-2.12). Cunninghamella echinulata; Mycogone alba were not recorded from the 10 year plantation soils (Tables 2.13 - 2.18).

Enzyme activities :

Dehydrogenase :

Monthly variation in dehydrogenase activity is depicted in fig.2.3. The activity was generally higher in surface soils of all the three plantations and it decreased with increasing depth (Fig.2.3). Maximum dehydrogenase activity was recorded in the month of May from surface soils of all plantations. During most of the period the dehydrogenase activity varied within a narrow range and almost similar trend of variations was noted in the three plantations. Dehydrogenase activity did not differ much with plantation age. A positive correlation was noted among dehydrogenase activity and soil moisture, temperature, organic carbon, potassium, total nitrogen, phosphatase activity and fungal population. It correlated negatively with the soil pH and CO_2 evolution (Tables 2.19-2.21).

Urease activity :

Higher urease activity was generally recorded in

surface soils of all the plantations (Fig.2.4). No significant difference was noted in the urease activity along depths in all the plantations. Maximum urease activity was recorded in the month of April or May which dropped to a low level during forthcoming months. Almost similar trend of monthly variation was observed in all the depths as well as in all the plantations studied (Fig.2.4). Higher urease activity was recorded from the 5 year plantation soils too followed by 10 year and 1 year plantation soils respectively (Fig.24). Urease activity correlated positively with soil moisture, temperature, organic carbon, total nitrogen, exchangeable potassium, dehydrogenase activity, phosphatase activity and fungal and bacterial population(Tables 2.19-2.21).

Phosphatase activity :

Data on phosphatase activity are presented in fig. 2.5. Generally, soil from oldest plantation had the highest levels of activity followed in descending order by those from 5 year old and 1 year old plantations. Phosphatase activity was maximum in the month of March/April in all the three plantations. Phosphatase activity did not differ significantly along with depth. Generally, similar trend of monthly variation in phosphatase activity was noted in case of all depths and plantations too. Phosphatase activity was higher during first year as compared to the second year.

Fig. 2.1 Monthly variation in fungal population of different plantation soils.

Fig. 2.1

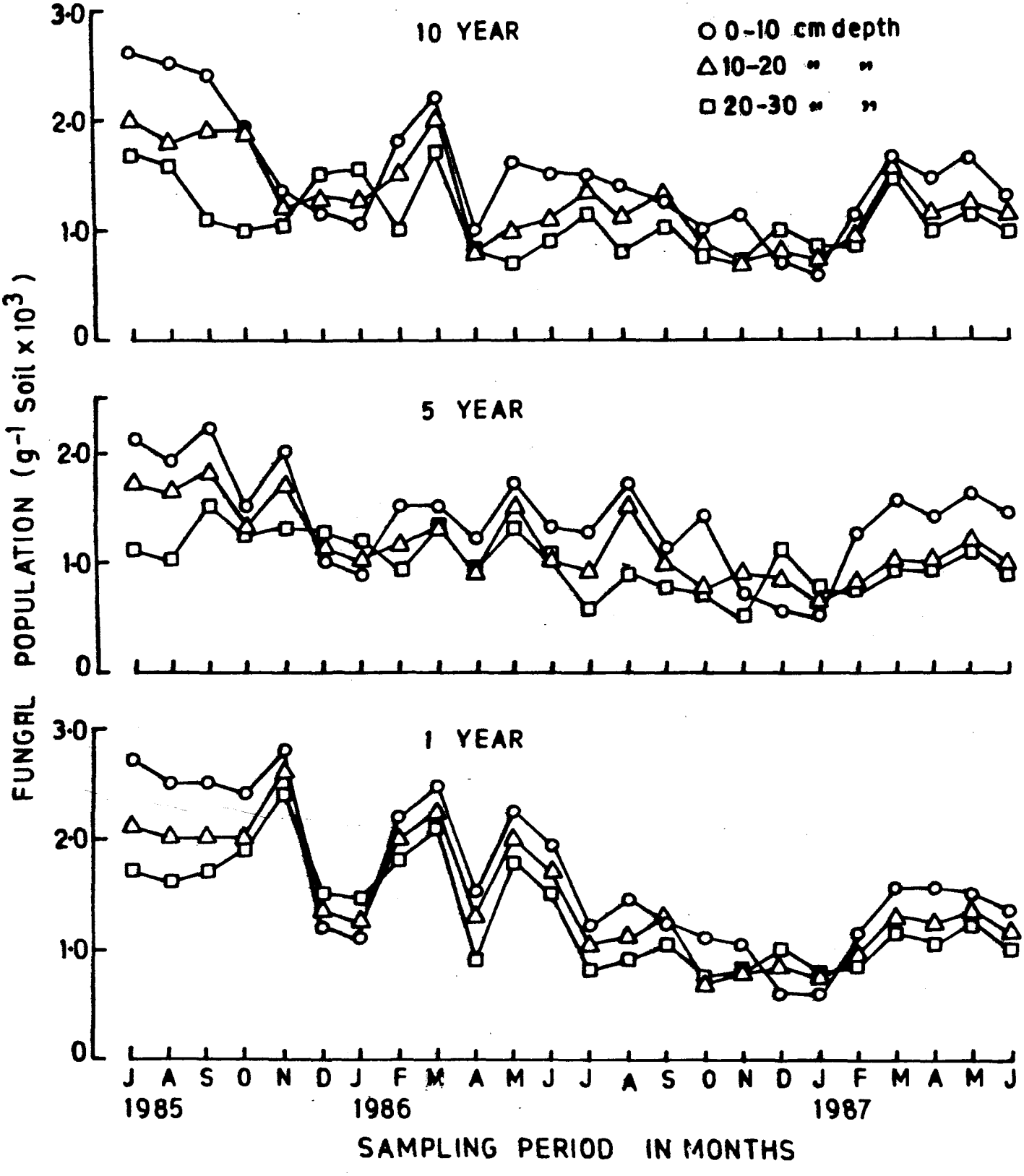

10 YEAR
○ 0-10 cm depth
△ 10-20 " "
□ 20-30 " "
5 YEAR
1 YEAR
FUNGAL POPULATION (g⁻¹ Soil x 10³)
3·0
2·0
1·0
0
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 2.2 Monthly variation in bacterial population of different plantation soils.

Fig. 2.2

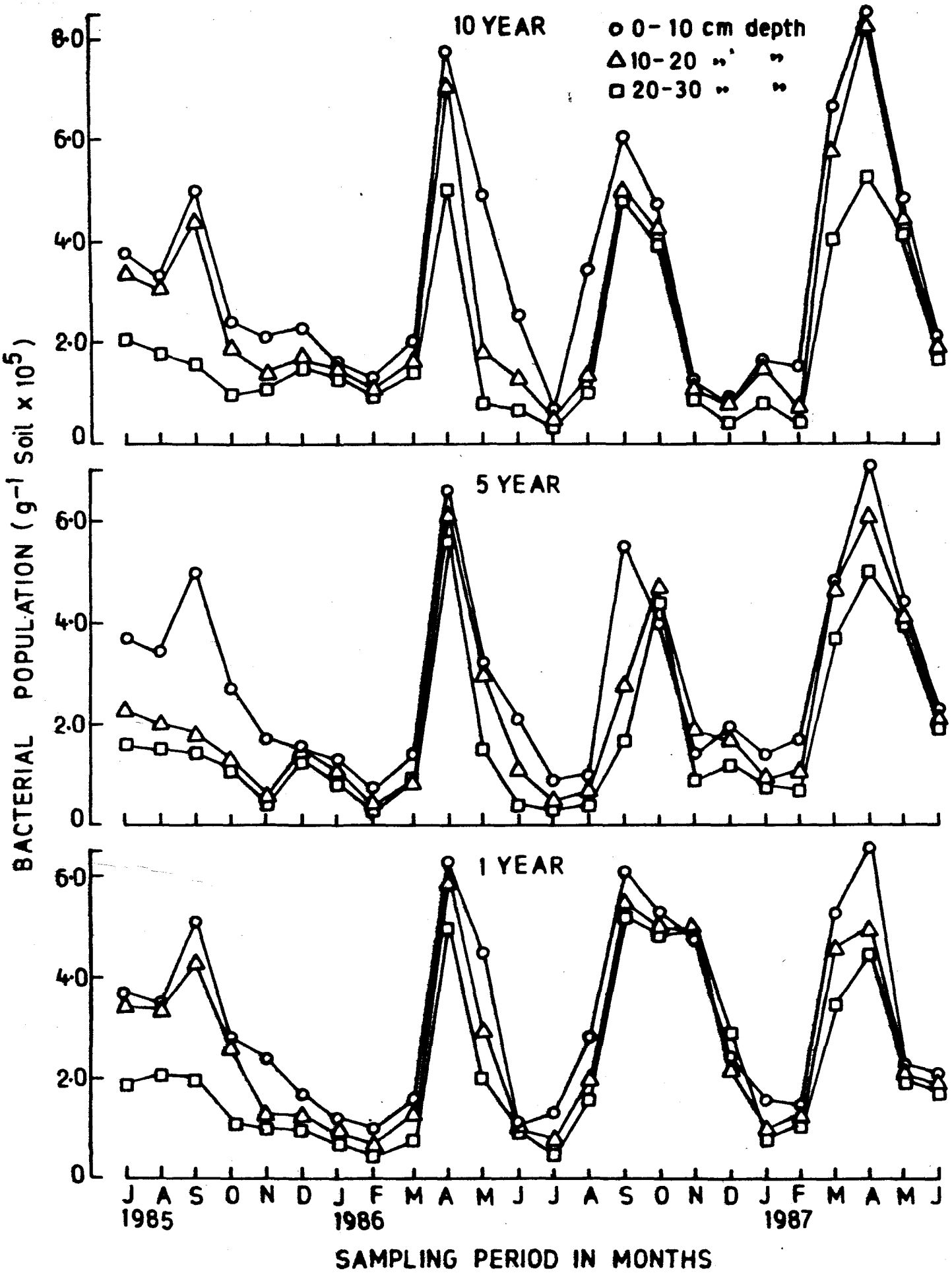

10 YEAR
o 0-10 cm depth
Δ 10-20 " "
□ 20-30 " "
5 YEAR
1 YEAR
BACTERIAL POPULATION (g⁻¹ Soil x 10⁵)
8·0
6·0
4·0
2·0
0
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 2.3 Monthly variation in dehydrogenase activity of different plantation soils.

Fig. 2.3

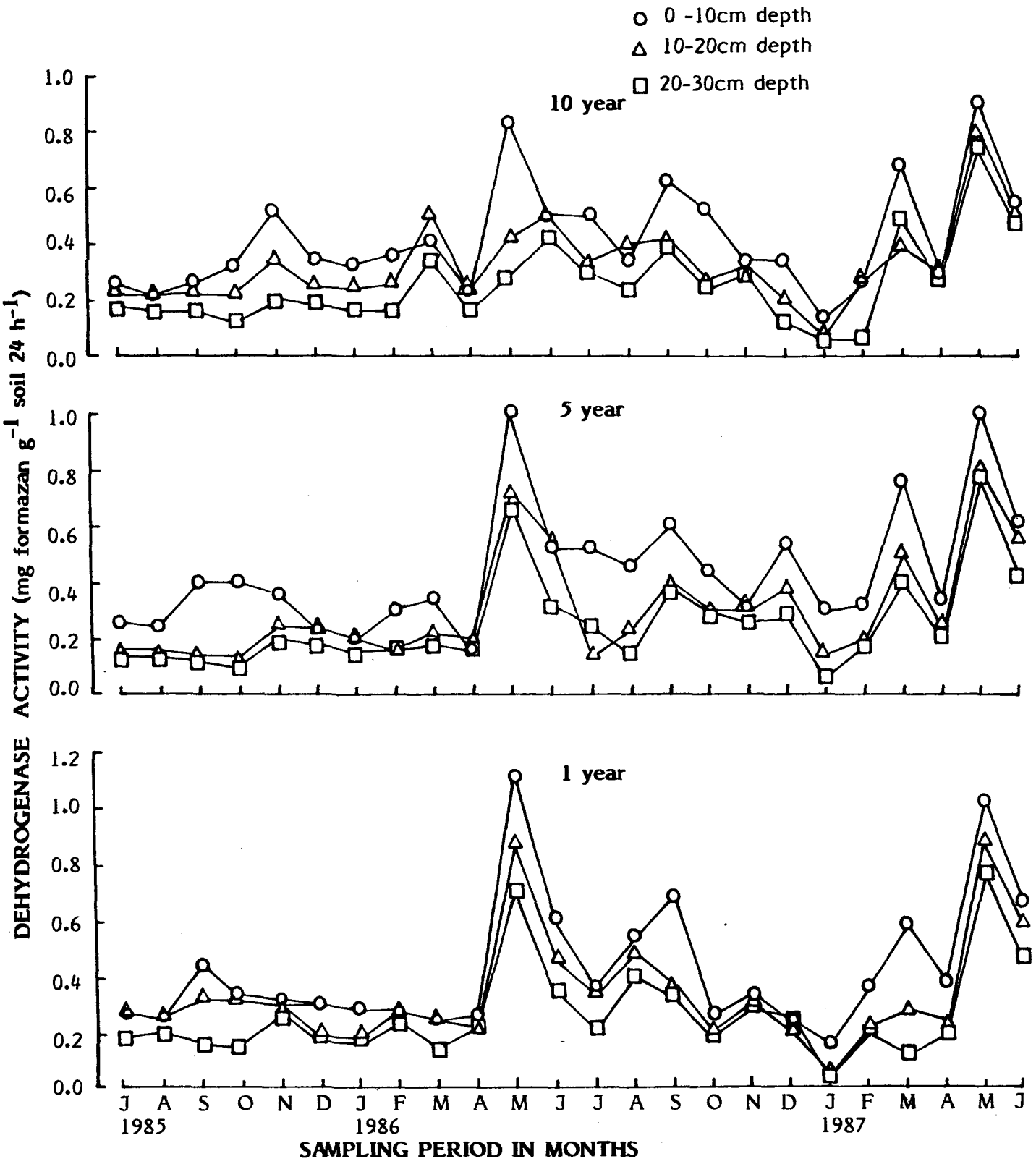

0 -10cm depth
10-20cm depth
20-30cm depth
10 year
5 year
1 year
DEHYDROGENASE ACTIVITY (mg formazan g^{-1} soil 24 h^{-1})
1.0
0.8
0.6
0.4
0.2
0.0
1.2
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 2.4 Monthly variation in urease activity of different plantation soils.

Fig. 2.4

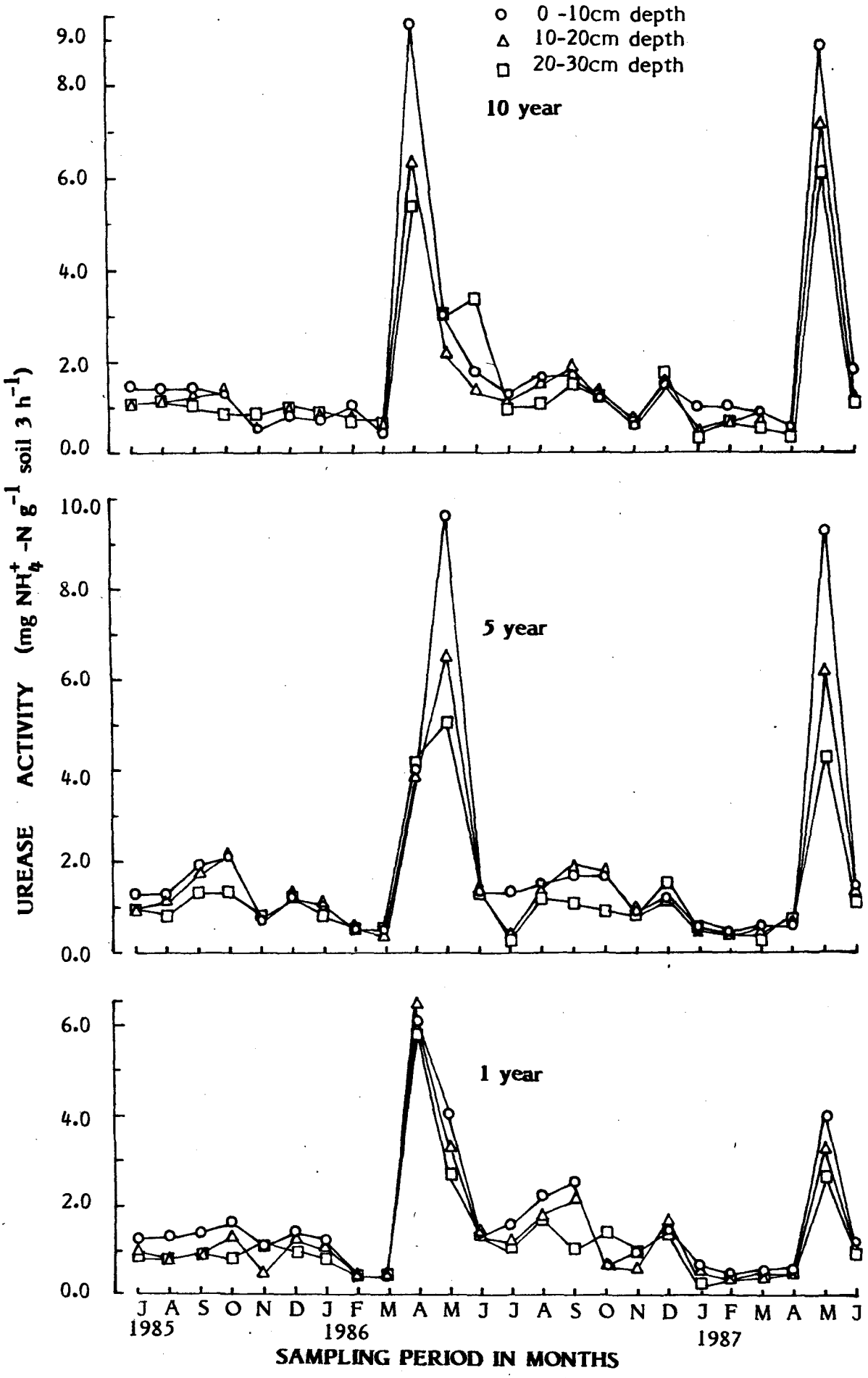

0 -10cm depth
10-20cm depth
20-30cm depth
10 year
5 year
1 year
UREASE ACTIVITY (mg NH_4^+ -N g^{-1} soil 3 h^{-1})
9.0
8.0
6.0
4.0
2.0
0.0
10.0
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 2.5. Monthly variation in phosphatase activity of different plantation soils.

Fig. 2.5

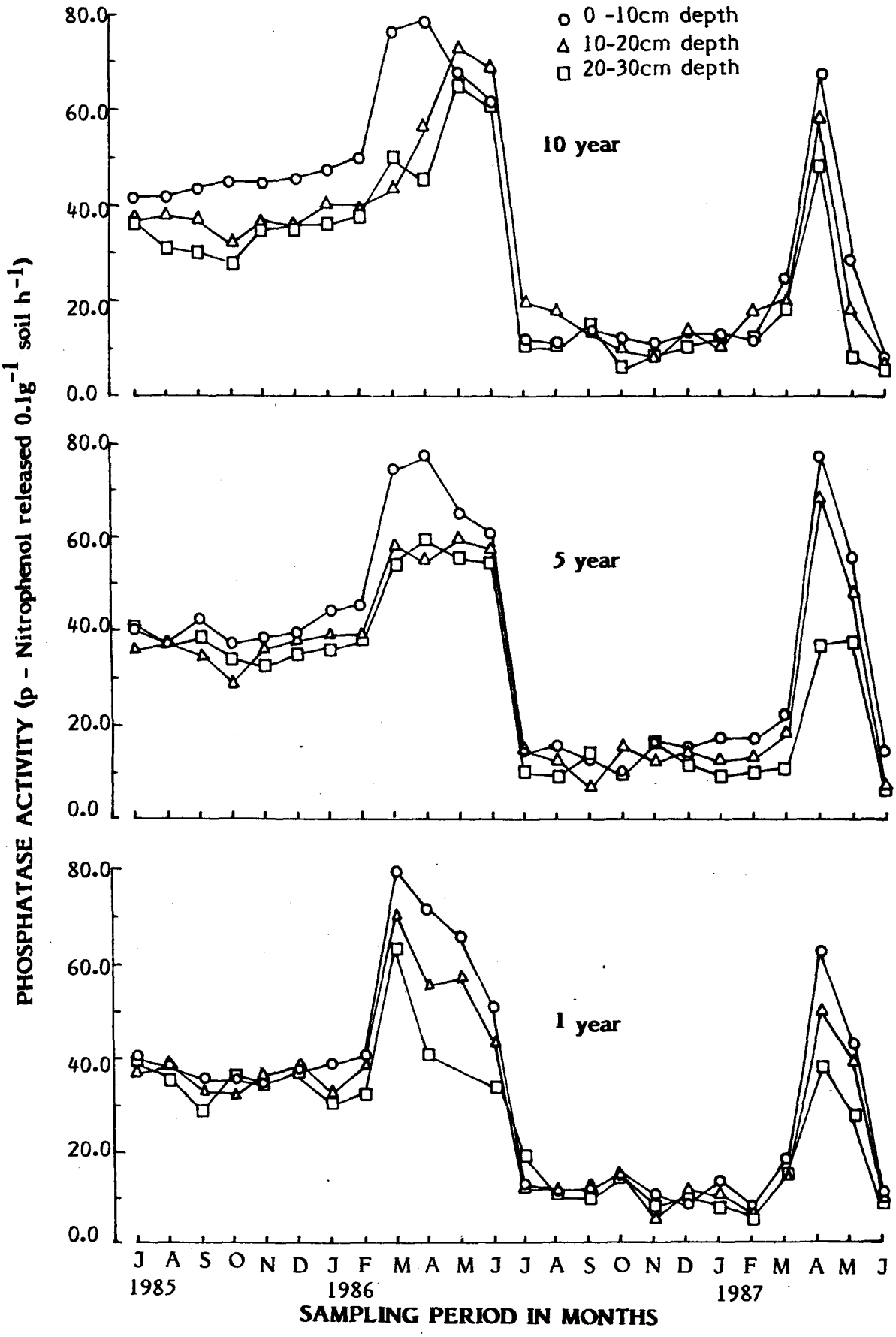
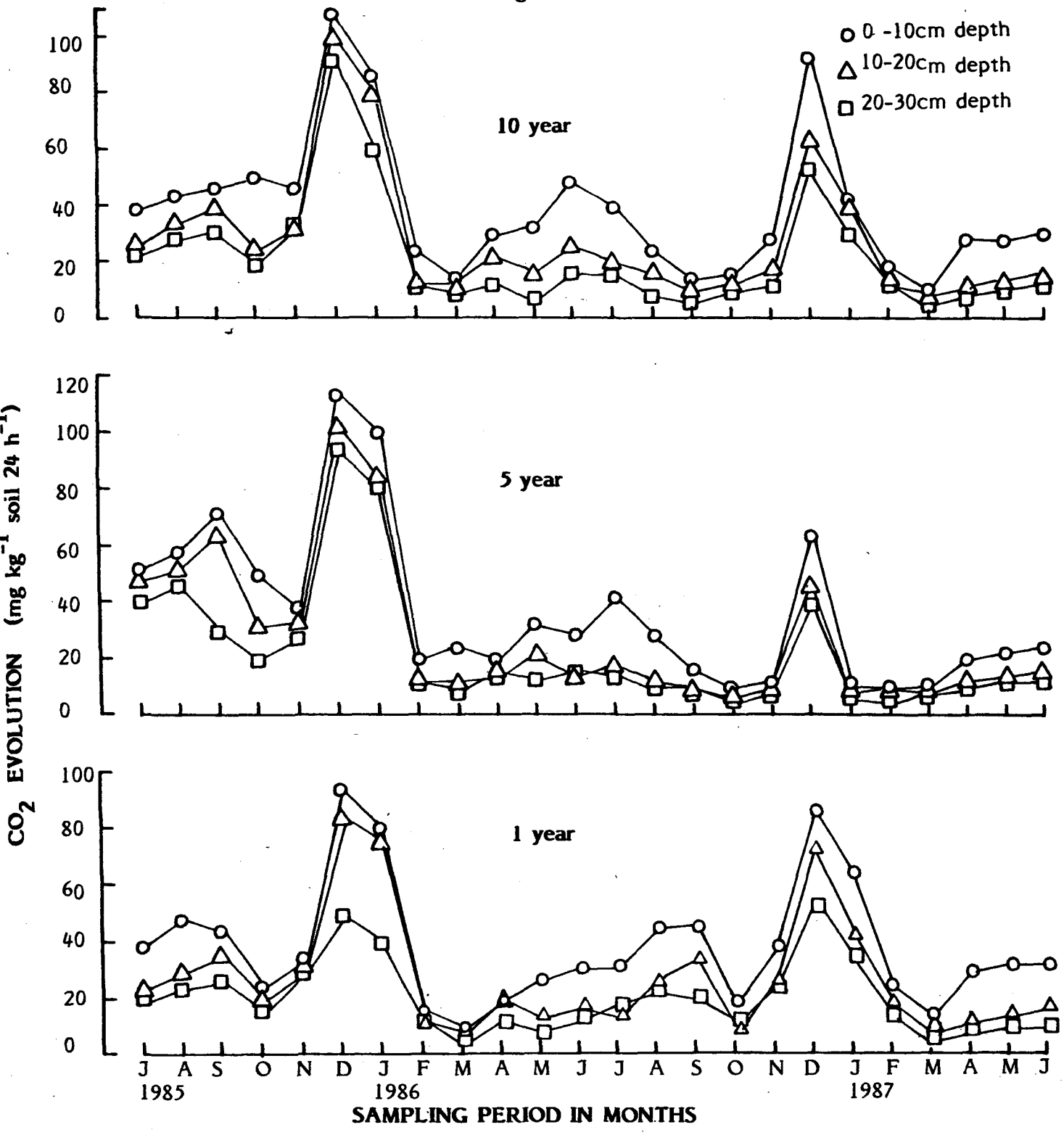

o 0 -10cm depth
Δ 10-20cm depth
□ 20-30cm depth
10 year
5 year
1 year
80.0
60.0
40.0
20.0
0.0
PHOSPHATASE ACTIVITY (p - Nitrophenol released 0.1g^{-1} soil h^{-1})
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

Fig. 2.6 Monthly variation in CO_2 evolution of different plantation soils.

Fig. 2.6


0 -10cm depth
10-20cm depth
20-30cm depth
10 year
5 year
1 year
CO_2 EVOLUTION (mg kg^{-1} soil 24 h^{-1})
0
20
40
60
80
100
120
J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
SAMPLING PERIOD IN MONTHS

However, the spring maximum was more pronounced during the second year (Fig.2.5). Phosphatase activity correlated positively with soil temperature, organic carbon, total nitrogen, exchangeable potassium, dehydrogenase activity, urease activity and bacterial population. A negative correlation was also noted between phosphatase activity and soil pH and CO_2 evolution (Tables 2.19-2.21).

CO_2 evolution :

CO_2 evolution was found highest in the surface soils of all plantations. It decreased with increasing depths (Fig.2.6). Maximum CO_2 evolution was noted from soil of all the plantations during the month of December. Thereafter, CO_2 evolution decreased in all the plantation studied. CO_2 evolution remained low till the forthcoming winters. During winter it attained a peak followed by a sudden drop and a slight increase in the month of March/April. Thereafter, CO_2 evolution remained at a low level. It was found to be correlated negatively with soil temperature, moisture, organic carbon, total nitrogen, exchangeable potassium, available phosphorus, dehydrogenase activity, phosphatase activity and fungal population (Tables 2.19-2.21).

DISCUSSION

Temporal and depth-wise distribution of fungi :

Reversal in depth-wise distribution of fungal popu-

lation during winters (December and January) in all the plantation soils appears to be due to the effect of low temperature during this period (Fig.1.1). The effect of low temperature was more pronounced in surface soils and probably, due to insulation, fungi of deeper soils were less affected resulting into higher populations in deeper soils. Dwivedi (1965); Balasubramaniam et al. (1972); Mishra and Kanaujia (1972); Tyagi (1973) and Behera and Mukerji (1985) also found that surface soils harboured higher population of fungi than the deeper layers. Results of the present study are also in conformity with the observations of above authors except during the winters. Could be the above studies were conducted at lower altitudes where winter temperature did not drop beyond the tolerance limit of the fungi. Seasonal variation of fungal population may be attributed to the change in soil organic matter content, moisture content, temperature and pH (Dwivedi, 1966; Mishra, 1966; Prakash and Khan, 1971; Morrall, 1974; Wong, 1975; Dunn et al. 1985; Dkhar and Mishra, 1987; Tiwari et al. 1987 b)

Temporal and depth-wise distribution in bacterial population :

A bimodal bacterial population was recorded during the study period. One peak was in September and another in April. During winter months the bacterial population depleted to a minimum (Fig.2.2). Higher bacterial population was

always noted from the surface soil which may be due to higher organic carbon content and favourable moisture level (Figs. 1.4,1.2). Similar observations were also made by Tate and Terry (1980); Kauri (1982); Baldensperger (1981); Deka (1981); Baruah (1983) and Dkhar (1983). In September the higher moisture level in surface soil might be responsible for the increased bacterial population. The drop in winter may be attributed to low temperature (Fig.1.1) and/or depletion of the available soluble organic nutrients. During April the higher bacterial population may be due to onset of rains resulting into increased moisture which may transfer the soluble organic matter from decomposing plant litters (Fig.I) as most of the litter are added to the soils during this period. Rise in temperature may also be responsible for the increased bacterial population during this period (Fig.1.1). Higher bacterial population in 10 year plantation soil might be attributed to higher organic carbon, moisture and temperature of the soil (Figs. 1.4,1.2,1.1).

Distribution of fungal species in the soils of different plantations :

It is widely accepted that each type of vegetational community harbours a characteristic soil mycofloral population (Pugh, 1962; Wohlrab et al. 1963). In the present investigation almost similar fungal flora was recorded from all the three plantation soils which may be attributable to the similarity in type of vegetatal cover. Variations

in the soil moisture, temperature and pH may be accounted for the slight variation in fungal spectrum of all the plantation soils (Mishra and Kanaujia, 1972). From each of the studied plantation soils only a few dominant fungal species were recorded. Bissett and Parkinson (1979) also found the similar results and pointed out that from a given community only a few species were quite dominant.

In the present study most of the fungal species were not confined to a particular horizon. Only a very few species were restricted to a specific depth or plantation. Distribution of most of the fungal species to all depths might also be due to activities of soil animals (earthworms) because their feeding and burrowing activity homogenize the species composition along all the depths.

Dehydrogenase activity :

Higher dehydrogenase activity was found in surface soils which might be due to higher bacterial population and/or higher amount of organic carbon (Dash et al. 1981; Rao and Ghai, 1985). But contrary to the above, Das and Mishra (1986) did not find the correlation between dehydrogenase activity and organic matter and microbial population. Maximum dehydrogenase activity during the month of April may be due to higher bacterial number and increased moisture level as also observed by Ross (1970); Dkhar and Mishra (1983); Baruah and Mishra (1984) and Tiwari et al. (1987 b).

Results of the present study indicate that dehydrogenase activity is related to the soil temperature, moisture and organic carbon contents of soil. Fungal and bacterial populations were not found to correlate with dehydrogenase.

If a certain level of enzyme concentration is available in soil the level of enzyme does not become limiting to the activity. In such cases the activity will not change with the variations in the population of fungi and bacteria. It may, therefore, be inferred that the concomitant drop in dehydrogenase may be expected only in cases where the microbial population drops beyond a certain minimum. Therefore, on the basis of indirect evidences, it may be speculated that a high level of dehydrogenase enzyme was present in the soils.

Urease activity :

Higher urease activity during the months of April/May in surface soil of all the plantations may be due to higher organic carbon content, bacterial population and favourable moisture (Dalal, 1975; Speir, 1977; Tabatabai,1977; Beri et al. 1978; Dkhar and Mishra, 1983; Gonzalez and Fuente, 1984; O'Toole et al. 1985; Tiwari et al. 1987 b). Results of the present study indicate that urease activity is largely governed by the soil temperature, moisture, organic carbon and bacterial numbers (Tables 2.19-2.21).

Sahrawat (1984) noted that urease activity increased with the increasing temperature. Skujins (1976), Beri and Brar (1978); Dkhar and Mishra (1983); Sahrawat (1983) and Rao and Ghai (1985) found that the activity was principally associated with the organic carbon content of the soil.

Phosphatase activity :

Increased phosphatase activity during spring (March - April)may be attributed to higher temperature and higher bacterial numbers (Nannipieri et al. 1979; Appiah and Thomas, 1982; Chhonkar and Tarafdar, 1984). Possibly it is the temperature which regulate both; the bacterial number as well as the rate of enzyme activity. Soil moisture, pH, organic matter, phosphorus content (Harrison, 1983) and bacterial population (Chhonkar and Tarafdar, 1984) were found to be important factors affecting the phosphatase activity. However, in the present study phosphorus content and soil pH did not have any influence on the phosphatase activity. During the present investigation phosphatase activity was found to be regulated by the organic carbon content and soil temperature. Bacterial population was found to be positively correlated ($r=0.503$, $P=0.05$) with the activity in 1 year and 10 year plantations ($r=0.717$, $P\neq0.001$). However, the correlation was not significant in the 5 year old plantation (Tables 2.20).

CO_2 evolution :

CO_2 evolution in soils is mainly influenced by microbial population, root biomass, plant cover, soil invertebrates population, soil moisture, temperature, pH and nutrient status of the soil (Stotzky, 1960; Tesarova and Gloser, 1976; Singh and Gupta, 1977; Siddiqui and Singh, 1981; Mishra and Dash, 1982; Orchard and Cook, 1983; Viskowa, 1983; Singh, 1984; Mathur and Gaur, 1986; Das and Mishra, 1986; Ceulemans, 1987; Dkhar and Mishra, 1987 and Tiwari et al. 1987 b). The higher CO_2 evolution in the present investigation was recorded during the month of December (Fig.2.6). While Siddiqui and Singh (1981) and Singh (1984) reported the minimum CO_2 evolution during the same period. During winter the microbial activity is expected to drop and as most CO_2 comes from microbial respiration(Smith and Brown, 1932) a drop in CO_2 evolution is also expected. But contrary to the above, the CO_2 evolution was higher during this period. Although it is difficult to understand what factor actually was responsible for the increased CO_2 evolution during winter. However, one possible explanation may be that during winter months the moisture level dropped may (Fig. 1.2) which increased the aeration of soil favouring the gaseous exchange. While during other periods the soils contained higher moisture levels which did not allow the CO_2 to escape and may be a part of CO_2 produced during this period was absorbed by the soil water. CO_2 accumulated in

in the soil water may also evolve during dry winters. During high moisture conditions the microbial populations might be predominantly composed of anaerobes or facultative aerobes which might have contributed to a low CO_2 output. During winters bacterial and fungal populations estimated by plate count method were minimum. A part of the carbon-dioxide evolved during winters might have come from the dead or decaying microbes.

Decrease in CO_2 evolution with increase in depth (Fig.2.6) is in general conformity with the observations of earlier workers (Baruah, 1983; Dkhar, 1983; Tiwari et al. 1987 c). From the present study it appears that CO_2 evolution was not related with the fungal and bacterial populations estimated with the plate culture procedures as CO_2 evolution was maximum during the periods when microbial population was minimum (Fig.2.1,2.2).

Decrease in microbial activity with increasing depth suggested that the activity was inhibited by unfavourable environmental conditions prevailing in the deeper region of the soil (Duxbury and Tate, 1981). Lower microbial population and nutrient status in the soils of deeper layers may also be responsible for decreased microbial activities in the deeper soils. Correlation coefficient (r) among various parameters was calculated separately for each plantation soil and in a number of cases different r values were found for the three plantations (Table 2.19-2.21). It

Table 2.19 Correlation coefficient values (r) for various parameters in 1 year plantation soil.

	Fungal population	Bacterial population	Dehydrogenase activity	Urease activity	Phosphatase activity	Co_2 evolution
Soil temperature	NS	.482*	.513*	.604**	.679*	.621**
% Moisture	NS	NS	.662***	.637**	NS	NS
Soil pH	NS	NS	-.622**	NS	-.481*	NS
% Organic carbon	.645***	NS	.664***	.457*	.670***	-.702***
Total nitrogen	NS	NS	NS	.495*	.724***	-.547**
Available phosphorus	.680***	.487*	NS	NS	NS	-.607**
Exchangeable potassium	.477*	NS	.491*	NS	.484*	-.605**
Fungal population		NS	NS	NS	NS	-.645***
Bacterial population			NS	.601**	.503*	NS
Dehydrogenase activity				.571**	.424*	NS
Urease activity					.675***	NS
Phosphatase activity						-.466*

Values marked with *, **, *** are significant at 0.05, 0.01 and 0.001 probability levels respectively.

NS = Not significant.

Table 2.20 Correlation coefficient values (r) for various parameters in 5 year plantation soil.

	Fungal population	Bacterial population	Dehydrogenase activity	Urease activity	Phosphatase activity	Co_2 evolution
Soil temperature	.606**	.462*	.516*	.436*	.580**	-.458*
% Moisture	.613**	NS	.484*	.545**	NS	NS
Soil pH	NS	NS	NS	NS	NS	NS
% Organic carbon	.447*	NS	.623**	.453*	.665***	-.776***
Total nitrogen	.600**	NS	NS	NS	NS	-.482*
Available phosphorus	NS	NS	NS	NS	NS	NS
Exchangeable potassium	.611**	NS	.418*	.433*	.528**	.657***
Fungal population		NS	.453*	.465*	NS	NS
Bacterial population			NS	NS	.736***	NS
Dehydrogenase activity				.827***	.424*	NS
Urease activity					.587**	NS
Phosphatase activity						NS

Values marked with *, **, *** are significant at 0.05, 0.01 and 0.001 probability levels respectively.

NS = Not significant.

Table 2.21 Correlation coefficient values (r) for various parameters in 10 year plantation soil.

	Fungal population	Bacterial population	Dehydrogenase activity	Urease activity	Phosphatase activity	Co_2 evolution
Soil temperature	NS	.528*	.676***	.595**	.533**	-.511*
% Moisture	.439*	NS	.593**	.420*	NS	-.435*
Soil pH	NS	NS	-.592**	NS	NS	NS
%Organic carbon	NS	NS	.739***	.412*	.541**	-.794***
Total nitrogen	.482*	.461*	.763***	.672***	.518*	-.474*
Available phosphorus	-.645***	NS	NS	NS	NS	NS
Exchangeable potassium	NS	NS	.567**	NS	NS	NS
Fungal population		NS	NS	NS	NS	-.434*
Bacterial population			NS	.638**	.717***	NS
Dehydrogenase activity				.494*	NS	-.444*
Urease activity					.722***	NS
Phosphatase activity						NS

Values marked with *, **, *** are significant at 0.05, 0.01 and 0.001 probability levels respectively.

NS = Not significant.

may be inferred that age of plantation has a definite influence on the inter-relationship among various physico-chemical and biological characteristics of soil.

Almost similar trend of temporal and depth-wise variations in microbial population and their activities shows that most of these parameters are governed by same or similar set of environmental factors. Soil temperature, moisture, organic carbon, total nitrogen, potassium and available phosphorus content appeared to be most important factors that regulate the population of bacteria and fungi as well as activities of dehydrogenase, urease and phosphatase enzymes. Soil pH did not correlated with fungal population. Positive correlation between soil temperature and bacterial population showed that it regulates the temporal and depth-wise distribution of bacteria in the soils of pineapple plantations while moisture content did not exert any effect on the bacterial population. The seasonal pattern in microbial activity in the pineapple plantations is more like forest soils of this region (Das and Mishra, 1986) than the soil under annual crops (Baruah and Mishra, 1984). It appears that within the same climatic belt the seasonality of microbial activity differs widely depending on the types of vegetation and agricultural practice.

C H A P T E R III

MICRO IAL DECOMPOSITION OF PINEAPPLE LITTERS

INTRODUCTION

Decomposition term has been used to describe the processes by which the dead organic matter decays and resolves into simpler compounds resulting ultimately into simple inorganic compounds. The organic matter subjected to microbial decay in soil comes from several sources. Vast quantities of plant remains decompose above the surface. Subterranean portions of the plant body become food for the soil microflora.

Litter decomposition is an important factor in the nutrient cycling. Results of the several studies demonstrated that approximately 70% of the annual uptake of macronutrients (C,N,P,K,Ca and Mg) are returned via litterfall (Douvigneaud and Smet, 1970).

Decomposition of chemically complex organic part of the plant litter takes place in several steps. The soluble and some of the solid carbohydrates are degraded first and the remainder, which is made up of polymer carbohydrates and lignin decomposes later and at a slower rate (Berg and Stoaf, 1980).

Fungi along with bacteria are responsible for the universal decay processes releasing locked up nutrients from litters. In process of decomposition, fungi by the peculiarities of their physical organizations are specially

effective in attacking hard woody parts in which bacteria may not be too effective. It is believed that the fungi are considered to be the most important primary decomposer of lignified litter simply because some have the ability to degrade lignin which normally is structurally interwoven among the polymer carbohydrates (Ander and Eriksson, 1978; Krik, 1971). Nilsson (1973) was able to demonstrate through electron microscopic studies that lignolytic fungi could grow straight through the wood structures whereas those without the lignin degrading enzymes were only able to catch the surface of decomposing wood cells.

The climatic conditions and nature of soil environment were found to be the most important factors which significantly influence the rate of decomposition. A number of workers noted that higher moisture content and temperature enhance the rate of litter breakdown (Douglas and Tedrow, 1959; Witkamp, 1966; Ivarson, 1973; Brinson, 1977; Shukla et al. 1978; Christensen, 1986; Moore, 1986).

Most of the studies regarding the litter decomposition are generally, confined to the forest and agricultural crop residues (Mishra, 1979; Baruah, 1983; Dkhar, 1983; Shukla and Singh, 1984; Jansson and Berg, 1985; Christensen, 1986; Jawson and Elliott, 1986; Wessen and Berg,1986; Moore, 1986). Pineapple is one of the most important commercial cash crops of this region. A large amount of

litter is added each year to the pineapple plantation soil by the death of old leaves. Information about the pineapple litter decomposition is still lacking. Therefore, it was thought desirable to study the process of pineapple litter decomposition with an aim to understand the rate of breakdown, chemical changes in the nutrient contents and role of bacteria and fungi in the pineapple litter decomposition.

REVIEW OF LITERATURE

The decomposition of Carex paniculata L. leaf litter was studied by Pugh (1958). He recorded definite changes in fungal flora of the litter during the decomposition. He further, pointed out that the temperature and moisture content of leaf litter were the major factors that influenced the activities of microbes during the decomposition.

Similarly, Douglas and Tedrow (1959) described temperature, moisture and soil types as important factors which influenced the rate of decomposition.

The decomposition of beach leaf litter was studied by Caldwell (1963). He observed that most fungi were isolated from the earliest to the latest stage of decomposition and he did not find much change in their frequency.

Witkamp (1963) found a positive correlation between microbial population and the rate of litter breakdown. He

also noted that temperature, moisture and stage of litter decay effectively controlled the microbial population and rate of litter decomposition.

Smith (1966) studied the decomposition of three plants viz., maize, wheat and soyabean and observed that root litter of these plants decomposed more slowly than the leaf or stalk.

Linkens et.al. (1970) pointed out that the removal of forest vegetation increased the rate of decomposition which in turn enhanced the nutrient availability to the soil mycoflora.

Ivarson (1973) observed that the rate of decomposition increased with the increase in temperature.

Lousier and Parkinson (1976) noted that the nutrients which returned to the soil via tree leaf litter fall were Ca, N, K, Mg, P, Zn, Fe, Mn, Na and Cu. The total weight of these nutrients returned to the soil was 116 Kg ha^{-1}. N, Ca and K accounted for 89% and Mg and P for 9.8% of the total.

Brinson (1977) suggested that temperature and moisture were the most important factors controlling the rate of decomposition.

The biological decomposition of wheat straw was studied by Wani and Shinde (1977). They found Aspergillus sp. as the most rapid wheat straw decomposer under the laboratory conditions.

Shukla et al. (1978) studied the decomposition rates of litters and inferred that environmental factors coupled with population of microflora and microfauna were directly responsible for the breakdown of litter. They observed slow decomposition rate during summer season in comparison to the rainy season.

Fungal flora of decomposing roots of Triticum aestivum, Hordeum vulgare, Paspalum scrobiculatam, Echinochloa crusgalli and Pennisetum typhoides was studied by Mishra (1979). The results of the study revealed that the distribution pattern of the fungal species on and within the decomposing roots, besides a number of other factors, is regulated by their enzymatic activities.

Douglas et al. (1980) noted that burried straw decomposed faster than the straw placed on the soil surface. Changes in the N content of straw exposed on or above the soil surface were usually lesser than the straw burried under the soil.

The effect of relative humidity and substrate moisture content on rate of decomposition of Eucalyptus leaf litter was studied by Nagy and Macauley (1982). They pointed out that biological decomposition is not significant until relative humidity and moisture content values are above 75 and 13% respectively.

Schinner (1982) studied the litter decomposition

at various altitudes. He observed that after one year 46% of litter exposed was decomposed at an altitude of 2550m, 76% at 1920m and 86% at 1560m.

Cuenca et al. (1983) worked out the rate of coffee litter decomposition under shade. Litter bags of 0.03mm size showed slow decomposition rate than the bags with the mesh size of 0.5mm. Nitrogen and phosphorus exhibited an increase in concentrations as decomposition progressed while potassium, calcium and magnesium followed a decrease in concentration that paralleled to that of the dry weight loss.

Dkhar (1983) studied the maize (Zea mays L.) litter decomposition and noted slow rate of decomposition during early period which was followed by an increase, Maximum rate of breakdown was observed in leaf followed by stem and root.

Shukla and Singh (1984) studied the microbial degradation of Shorea robusta leaf litter for a period of one year. They found that the elements remained nearly untouched in the summer season but with the onset of rain the minerals were found to be exposed to the attack of microorganisms.

Kjoller et al. (1985) estimated the bacterial dynamics during decomposition of alder litter. They found that the numbers of aerobic, amylolytic and proteolytic bacteria were high after leaf fall and decreased towards the end of decomposition. They further, suggested that the fluctuation in the anaerobic groups or organisms were mainly influenced

by moisture.

Struwe and Kjoller (1985) enumerated the numbers of aerobic and anaerobic bacteria present on the litter at monthly interval and observed higher bacterial population ($10^{10} g^{-1}$ of dry litter) on decomposing litter.

Christensen (1986) studied the barley straw decomposition under field conditions. The results of his study demonstrated that no difference occurred in weight loss pattern of straw burried at 5, 10 and 15 cm depths. Straw exposed to soil showed an intial rapid weight loss but thereafter, the rate of loss became almost constant. Straw on the soil surface on the other hand, suffered a somewhat irregular pattern of weight loss.

Jawson and Elliott (1986) investigated the carbon and nitrogen transformations during wheat straw and root decomposition. Initially, they recorded higher total carbon in the straw than the root and more nitrogen in roots than the straw.

Moore (1986) described the effects of temperature and moisture on decomposition rates of hard wood and coniferous leaf litter. The results of his study showed that soil horizon, litter type, temperature and moisture significantly ($P=0.01$) affected the rate of decomposition.

Wessen and Berg (1986) estimated the mass loss of

barley straw which was exposed at 10 cm depth in an unfertilized field for a period of two years. More rapid mass loss was found during the first year than the second year. They further, observed that within three weeks about 30% of the N had been leached from the straw and after the first winter 50% of N was released.

O'Connell (1987) studied the Eucalyptus litter decomposition at three contrasting forest sites of south western Australia. He reported that the rates of nutrients released from the decomposing litter followed a trend Na > Cl > K > Mg > S > Ca > N > P. He further, suggested that the difference in Ca, N and P content in decomposing litter at three different sites was related to the amount of these nutrients in surface soil at each site.

Saini (1987) studied the decomposition pattern of Seshania aculeata in the field condition. The weight loss after 92 days was found to be 71%, 96% and 85% for stem leaves and roots respectively. He noted the higher decomposition rate of litters initially and slower thereafter.

MATERIALS AND METHODS

Rate of pineapple litter breakdown :

Litter bag technique suggested by Bocock et al. (1960) was adapted for the determination of the rate breakdown of litter. Leaves and roots of pineapple

collected and air dried for a period of fifteen days. Plastic bags (20x20 cm size) with a mesh size of 1.0 mm were used for the study. Each bag was filled with 10.0 of air dried litter and the open end was stitched. The bags with the leaf litter were spread randomly on the surface while the bags having root litter were burried under the soil (5.0 cm) in the pineapple plantation field on 15th December, 1985. The samplings were done at bi-monthly interval for a period of eighteen months. Five replicates bags of each type of litter were collected aseptically and were brought to the laboratory for the estimation of loss in dry weight and determination of microbial population of the litter. Out of the five bags one was used for microbial analysis and one for the determination of pH and moisture content of decomposing litter. The remaining three bags were open and from each bag, litter was carefully separated, cleaned for any soil adhering particles and was allowed to dry in a hot air oven at a temperature of 60°C until a constant dry weight was obtained. Initially, the dry weight of 10 grams air dried litter was estimated by drying the litter in a hot air oven at the temperature of 60°C for such a period until the constant dry weight was obtained to obtain corresponding oven dry weight of the air dried. The percentage weight loss was estimated on the basis of oven dry weight.

Population dynamics of microflora associated with the decomposing litters.

The aim of this study was to assess the saprophytic activity of microflora and also to evaluate the pattern of succession of microflora (fungi and bacteria) during the decomposition of litter. Mostly, the microbial population was estimated on the date of sampling. Occassionally, the bags were stored overnight in the fridge at $4^{o}C$ when the processing could not be finished on the date of collection (Ruscoe, 1971).

Enumeration of microflora :

Dilution plate method was used for the enumeration of the fungal and bacterial population associated with the decomposing litters (Waksman, 1922). 1g litter was cut into 1.0 cm small pieces using sterilized scissors and transferred into a 250 ml sterilized conical flask containing 100 ml of sterilized distilled water. Litter suspension of 1:100 dilution was prepared. The flask was thoroughly shaken for fifteen minutes to homogenizing the suspension. 10 ml of the suspension was then transferred aseptically by means of a sterilized 10 ml pipette to another 250 ml sterilized conical flask containing 90 ml of sterilized distilled water to get a suspension of 1:1000 dilution. The process was repeated once more to get a suspension of

1:10,000 dilution. For the estimation of fungi and bacteria 1:1000 and 1:10,000 dilutions were used respectively. Enumeration of fungal and bacterial population was done using rose bengal agar (Martin, 1950) and nutrient agar media (Johnson and Curl, 1972) respectively.

0.5 ml of litter suspension was transferred aseptically from 1:1000 and 1:10,000 dilutions into each of sterilized petridishes containing 15 ml of cooled solidified rose bengal agar and nutrient agar media for the estimation of fungi and bacteria respectively. The petridishes were rotated gently with hand so that the inoculum was dispersed uniformly over the surface of the agar media. Three replicates were maintained in each case. Isolation of bacteria and fungi was carried out in a "Laminar flow chamber".For the isolation of fungi and bacteria the petridishes were incubated at temperature of $25 \pm 1^{\circ}C$ for five days in BOD incubator. For bacteria the plates were incubated at $30 \pm 1^{\circ}C$ for 24 hours in bacteriological incubator.The total number of fungi and bacteria (g^{-1} dry litter) was calculated on the basis of moisture content and dilution of the litter. Qualitatively estimation of fungi was done by consulting the manuals of Gilman (1957), Subramanian(1971), Barnett and Hunter (1972) and Ellis and Ellis (1985). No attempt was made to identify the bacteria associated with litters. Chemical composition of rose bengal agar and

nutrient agar medium used for isolation of litter microflora has been given in chapter II.

pH and moisture content of litter :

pH of the decomposing litter samples during different sampling periods was determined by electric digital pH meter. The moisture content of the litter was determined by dry weight method.

Climatic conditions :

Data on atmospheric temperature, rainfall and humidity of study site are described in chapter I.

Chemical changes in the nutrient contents (N,P and K) of the decomposing litters :

Litter samples of leaf and root were powdered separately with the help of electric grinder and sieved (0.2 mm). The powder thus prepared was used for the estimations of nutrient contents of decomposing leaf and root litters. The methods described by Allen (1974) were adapted for the estimation of N,P and K.

Determination of Nitrogen :

For the determination of total nitrogen of the plant litters (leaf and root) the semi-microjeldahl method as suggested by Allen (1974) was adapted. The details of the methods are given in chapter I.

Following formula was used for the calculation of percentage nitrogen :

$$\%N = \frac{c(mg) \times \text{solution volume (ml)}}{10 \times \text{aliquot(ml)} \times \text{sample wt(g)}}$$

where C = concentration of Nitrogen in aliquot

Determination of phosphorus and potassium :

For the estimation of phosphorus and potassium wet tri-acid digestion procedure was followed as suggested by Allen (1974).

Digestion : 0.250g powder of decomposing (leaf and root) sample was placed into a 100 ml Kjeldahl flask. Thereafter, 1 ml 60% $Hclo_4$, 5 ml HNo_3 and 0.5 ml H_2So_4 were added. The flask was swirled gently to mix powder with acid solution. The mixture was digested for a period of 40 minutes till the digest become colourless. The digested mixture was cooled, diluted to 100 ml with distilled water and filtered on Whatman No.1 filter paper. The filtrate was used for the estimation.

Estimation : Phosphorus was estimated by using the molybdenum blue method as suggested by Allen (1974). Details of the method are given in chapter I. Phosphorus of the litters (root and leaf) was calculated by using the following formula :

$$\%P = \frac{C(mg) \times \text{Solution Volume (ml)}}{10 \times \text{aliquot(ml)} \times \text{Sample wt(g)}}$$

where C = Concentration of phosphorus in the aliquot.

Estimation : Potassium in the filtrate was read out with the help of flame photometer and calculated as follows :

$$\%K = \frac{C(ppm) \times \text{Solution volume(ml)}}{10^4 \times \text{Sample wt(g)}}$$

where C = ppm value of potassium read out by flame photometer.

Three replicates were maintained in each sample analysis. The values given in the tables and figures are means.

RESULTS

Moisture content and pH of the litters :

Percentage moisture content of decomposing leaf litter varied between 3.26 and 64.18% while root litter showed a range between 10.19 and 48.25% (Table 3.1). pH of leaf litter was found to range between 5.00 and 6.58. Root litter showed a range of pH between 5.07 and 7.15 (Table 3.1).Data on ambient temperature, average rainfall and relative humidity of the study area are given in chapter I.

Rate of litter breakdown :

Initially, the litters decomposed with a slow rate, An increase in the rate of litter breakdown was noted

Table 3.1 pH and % moisture content of decomposing litters of pineapple.

± = Standard deviation

Period (days)	LEAF		ROOT	
	pH	Moisture content (%)	pH	Moisture content (%)
Initial	6.28±.03	3.26±.41	7.11±.07	0.19±.11
60	6.13±.01	5.3 ±.27	7.07±.03	14.2 ±.11
120	5.31±.08	9.1±.10	5.62±.09	22.71±.09
180	5.91±.09	46.27±.02	5.61±.03	24.25±.02
240	6.31±.04	64.18±.002	5.85±.04	44.95±.005
300	6.58±.06	47.16±.02	7.15±.07	48.25±.006
360	6.41±.01	7.19±.003	6.00±.03	10.79±.02
420	5.20±.03	29.04±.02	5.49±.02	44.26±.15
480	5.17±.08	34.89±.003	5.21±.02	35.70±.003
540	5.00±.05	34.42±.05	5.07±.04	33.63±.04

during the 120-360 days period (Fig.3.1). From the fig.3.1 it is evident that during the early period leaf litter decomposed more rapidly as compared to the root litter. At the end of experiment (540 days) 86% of leaf litter was decomposed while in case of roots 76.5% of the original weight was lost from the litter bags. Using Olson's (1963) exponental decay model it was found that time required for 95% of the leaf and root litters decomposition 1911.07 and 2575.99 days respectively (Table 3.5).

Rate of litter breakdown in the case of two litter types followed almost similar trend of variation with time. Statistical analysis of data revealed that the rate of decomposition varied significantly (P=0.05) with time.

Fungal flora associated with the litters :

Initially, lower fungal population was recorded from both the litters (Fig.3.2). Thereafter, an increase in fungal population was observed upto the period of 180 days in both the litters. Fungal population dropped to a low level during the period between 240-300 days which was followed by an increase upto 480 days and a drop was recorded towards the end of the study. Generally, leaf litter showed higher fungal population in comparison to the root litter. Two peaks in fungal population were recorded one at the 180 days and another at 480 days sampling period in the case of leaf litter. While in the case of root litter

Table 3.2 Population of fungi (g^{-1} dry litter x 10^4) associated with the decomposing pineapple leaf litter at different sampling periods. Values in the parentheses are % relative abundance.

Fungal species	Initial	60	120	180	240	300	360	420	480	540
Aspergillus niger	-	-	-	.656(18.00)	-	-	-	-	.460(13.63)	.660(22.80)
Cladosporium herbarum	-	.140(6.84)	-	-	-	-	-	-	.460(13.63)	-
Fusarium moniliforme	.206(25.00)	.351(18.66)	.623(31.48)	.937(25.00)	.744(20.22)	.283(25.00)	.107(6.66)	.422(20.00)	.409(12.12)	.559(19.29)
F. solani	-	.492(27.45)	-	.562(16.00)	.558(15.40)	-	.359(22.23)	.234(11.11)	.204(6.64)	-
Gongronella butleri	-	-	-	-	-	-	-	-	-	.304(10.56)
Mucor hiemalis	-	-	.293(19.81)	-	-	-	.215(13.33)	-	-	-
Mucor plumbeus	-	-	-	-	-	-	.359(22.23)	-	-	-
Paecilomyces liliacinum	-	.492(27.45)	-	-	-	-	-	-	-	.101(3.50)
Penicillium chrysogenum	.310(37.50)	.175(9.80)	.146(7.98)	.562(16.00)	.651(18.44)	.567(50.00)	.215(13.33)	.375(17.80)	.614(18.18)	.914(31.57)
P. fellutanum	-	.035(1.96)	.220(11.11)	-	.186(5.55)	-	.107(6.66)	.187(8.88)	-	-
P. vermiculatum	-	.035(1.96)	-	-	-	-	-	-	.255(7.57)	-
Trichoderma koningii	-	-	-	-	.186(5.55)	-	-	-	-	-
T. viride	.310(37.50)	.035(1.96)	.586(29.62)	.468(12.50)	.651(18.44)	-	-	-	-	-
White sterile	-	-	-	.468(12.50)	.186(5.55)	.283(25.00)	.251(15.55)	.563(26.66)	.819(28.24)	.355(12.28)
Yellow sterile	-	.070(3.92)	-	-	.465(10.88)	-	-	.328(15.55)	-	-

Table 3.3 Population of fungi (g^{-1} dry litter x 10^4) associated with decomposing root litter of pineapple at different sampling periods. . Values in the parentheses are % relative abundance.

Fungal species	Initial	60	120	180	240	300	360	420	480	540
Aspergillus nedulans	-	-	.172(8.88)	-	-	-	-	-	-	.100(5.55)
A. niger	-	-	-	-	-	-	-	-	-	.452(25.03)
Curvularia maculans	-	-	-	-	-	.193(20.00)	-	-	-	-
Fusarium moniliforme	.100(14.29)	.388(26.37)	.388(20.00)	.396(21.45)	.423(15.55)	.289(30.00)	.261(23.33)	.538(23.07)	.466(21.42)	.401(22.22)
F. solani	.200(28.57)	.466(30.76)	-	.462(25.00)	.181(6.66)	-	-	.299(12.82)	.266(21.42)	-
Gongrenella butleri	-	-	-	-	-	-	-	-	-	.301(16.66)
Mucor hiemalis	-	-	.301(15.55)	-	-	-	.298(26.66)	-	-	.301(16.66)
M. plumbeus	-	-	.172(8.88)	-	-	-	-	-	.207(9.52)	-
Paecilomyces lilliacinum	-	-	-	-	.121(4.44)	-	-	-	-	-
Penicillium chrysogenum	.200(28.57)	-	.086(4.48)	.132(7.14)	.605(22.22)	.483(50.00)	-	.478(20.51)	.414(19.08)	.200(11.11)
P. fellutanum	-	.155(10.25)	.258(13.33)	.132(7.14)	.181(6.66)	-	-	-	-	.050(2.77)
P. funiculosum	-	.155(10.25)	-	.264(14.28)	.121(4.44)	-	-	.119(5.15)	-	-
P. javanicum	-	-	-	-	.121(4.44)	-	-	.418(17.94)	-	-
P. vermiculatum	-	-	.172(8.88)	.132(7.14)	-	-	-	-	-	-
Trichoderma koningii	-	-	-	-	.181(6.66)	-	-	-	-	-
T. viride	.200(28.57)	.077(12.12)	.388(20.00)	.330(17.85)	-	-	.336(36.68)	-	.466(21.42)	-
White sterile	-	-	-	-	.484(17.77)	-	.149(13.33)	-	.155(7.14)	-
Yellow sterile	-	.155(10.25)	-	-	.302(11.16)	-	-	.478(20.51)	-	-

the peaks were recorded at 240 days and 420 days. During the period of decomposition minimum fungal population was recorded at 300 days sampling period in both the cases (Fig.3.2). Generally, more or less similar trend of temporal variation was found in both the litters.

A total of 19 fungal species were isolated from decomposition leaf and root litters (Tables 3.2,3.3). Qualitatively fungal flora of both the litters did not differ much. Generally, most of the fungi isolated were recovered from both the cases. Aspergillus nedulans, Cladosporium herbarum, Curvularia maculans and Penicillium javanicum were of rare occurrence. While rest of the species were isolated at most sampling periods. Cladosporium herbarum was restricted to the decomposing leaf litter and Aspergillus nedulans, Curvularia maculans and Penicillium javanicum were found restricted to the root litter.

Bacterial population associated with litters :

Initially, root litter showed higher bacterial population than the leaf litter (Fig.3.3). During early period of the decomposition bacterial population increased in both cases and thereafter it depleted to a low level at 360 day sampling period. Bacterial population again increased at 420 and 480 days sampling periods which dropped to a low level at the last sampling period (Fig.3.3). Two peaks in bacterial population were noted; one at the 120/180 days

Fig.3.1 Remaining weight of the pine-apple leaf and root litters after different periods of decomposition.

Fig. 3.1

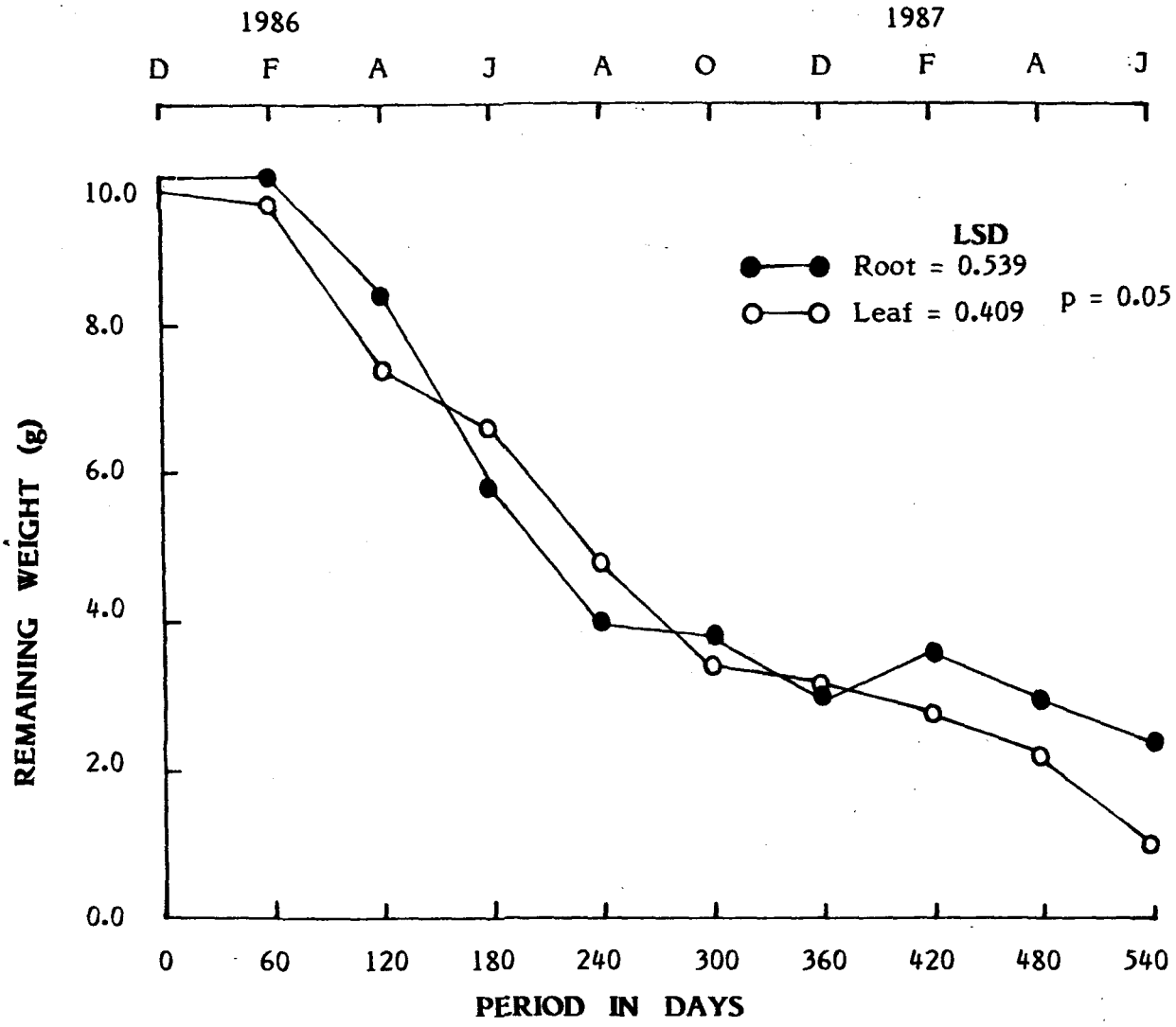

1986
1987
D
F
A
J
A
O
D
F
A
J
10.0
8.0
6.0
4.0
2.0
0.0
REMAINING WEIGHT (g)
LSD
Root = 0.539
Leaf = 0.409
p = 0.05
0
60
120
180
240
300
360
420
480
540
PERIOD IN DAYS

Fig.3.2 Fungal population associated with decomposing leaf and root litters.

Fig. 3.2

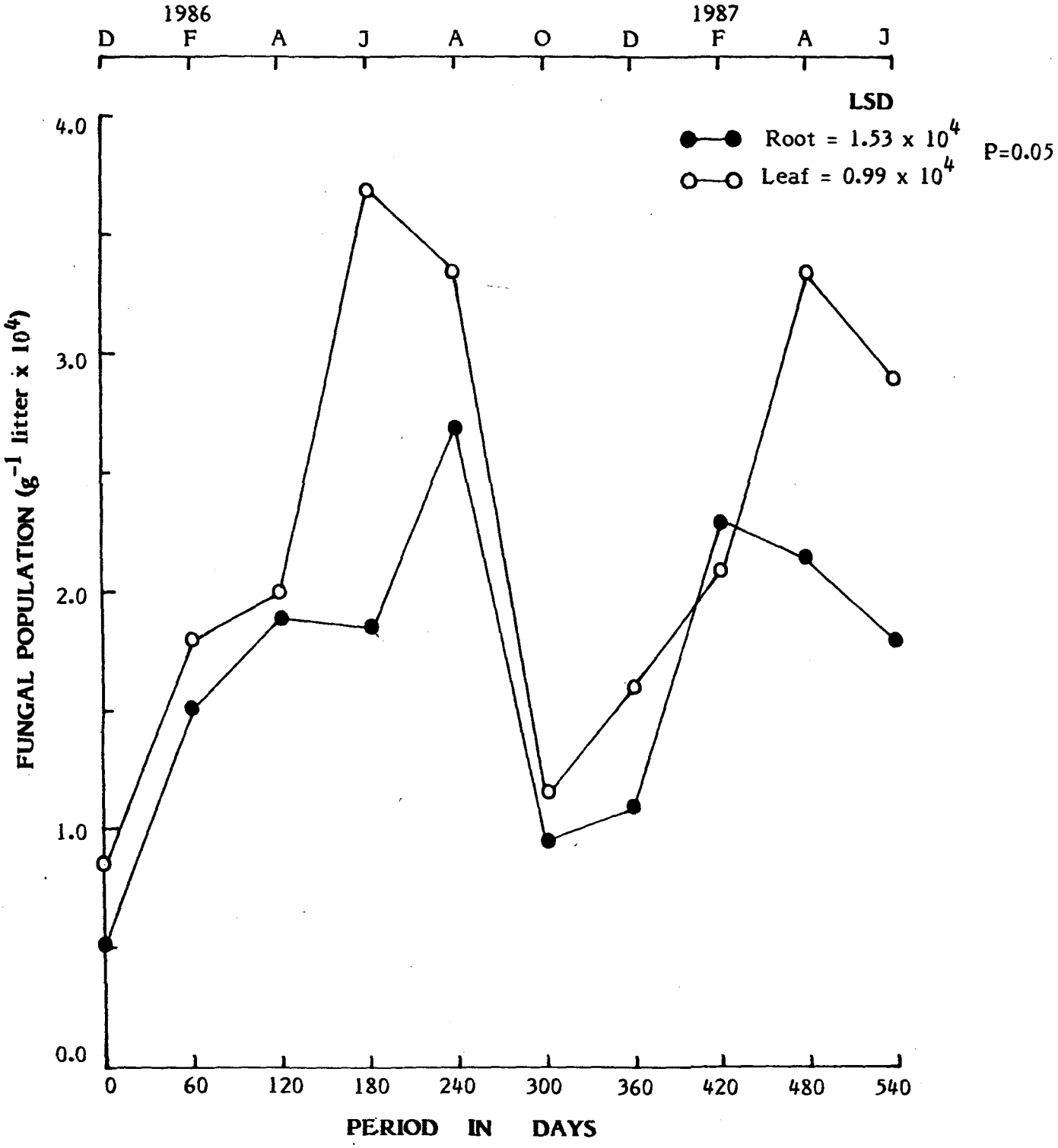
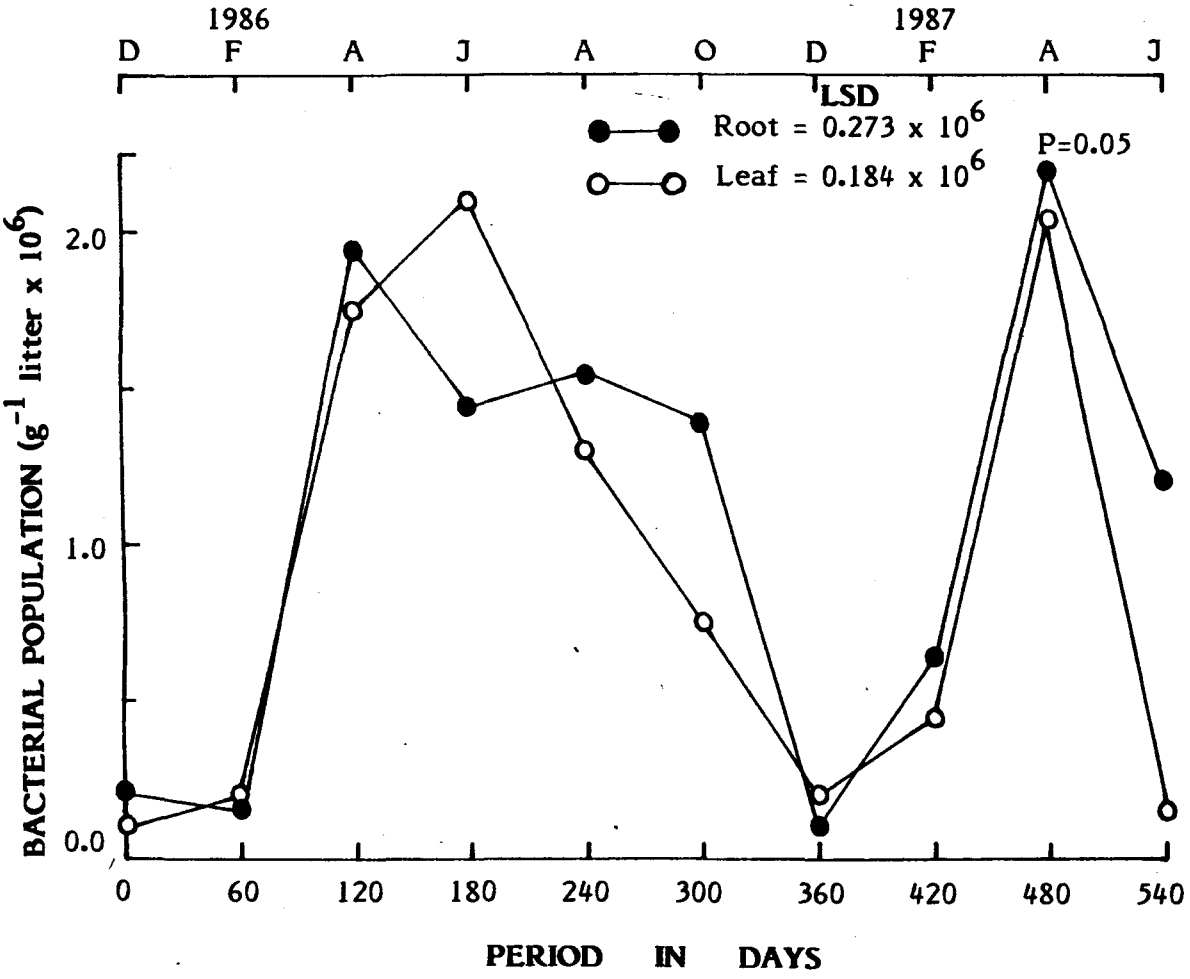

1986
1987
D
F
A
J
A
O
D
F
A
J
LSD
Root = 1.53 x 10^4
Leaf = 0.99 x 10^4
P=0.05
FUNGAL POPULATION (g^-1 litter x 10^4)
4.0
3.0
2.0
1.0
0.0
0
60
120
180
240
300
360
420
480
540
PERIOD IN DAYS

Fig.3.3 Bacterial population associated with decomposing leaf and root litters.

Fig. 3.3


1986
1987
D
F
A
J
A
O
D
F
A
J
LSD
Root = 0.273 x 10^6
Leaf = 0.184 x 10^6
P=0.05
BACTERIAL POPULATION (g^-1 litter x 10^6)
2.0
1.0
0.0
0
60
120
180
240
300
360
420
480
540
PERIOD IN DAYS

and another at the 280 days. Similar trend of temporal variation in bacterial population was recorded in both the litters.

Nitrogen :

Initially, leaf litter showed the higher nitrogen content than the root litter (Table 3.4). In the beginning of the decomposition the nitrogen content of the litters decreased which was followed by an increase. Two peaks in nitrogen content were recorded; one at 120 days and another at the 480 days in both the litters studied.

Phosphorus :

Higher phosphorus was recorded from the decomposing root litters at early stage of decomposition (Table 3.4). Drop in phosphorus was noted after the initial sampling in both cases. Increase in phosphorus was noted at 360 days.

Potassium :

During the early period of decomposition leaf litter contained more potassium than the root litter (Table 3.4). Generally, leaf litter contained higher potassium than the root litter.

DISCUSSION

The slow rate of litter breakdown during early period might be due to unfavourable moisture and temperature conditions. Rapid rate of decomposition of litters was noted between 120-300 days (rainy summer) which might

Table 3.4 N, P & K contents of decomposing pineapple (leaf and root) litters.

Period (days)	Leaf			Root		
	N%	P%	K%	N%	P%	K%
Initial	1.8	0.09	1.0	1.2	0.15	0.7
60	1.0	0.08	0.8	1.3	0.14	0.5
120	1.9	0.07	1.6	1.5	0.08	0.3
180	1.0	0.5	1.5	1.1	0.08	0.7
240	0.9	0.11	0.7	0.8	0.07	0.6
300	0.7	0.14	0.5	0.4	0.04	0.4
360	0.6	0.11	0.9	1.2	0.07	0.5
420	1.5	0.02	0.7	1.9	0.08	0.6
480	2.2	0.09	1.4	2.0	0.13	0.9
540	1.7	0.10	0.9	1.5	0.11	0.5

Table 3.5 Decay constant (K), Half life and 95% life (percentage weight remaining Vs. time in days) values for pineapple leaf and root litters decomposition under field condition.

Litter types	K (per day)	Half life (days)	95% life (days)
Leaf	.0015698	441.45	1911.07
Root	.0011646	595.07	2575.99

be attributed to the higher moisture and microbial population at the same time (Nagy and Macauley, 1982; Moore, 1986). During winter (360 - 420 days) the rate of litter breakdown decreased which may be ascribed to the lowering of temperature and low microbial population which also resulted into lower microbial activity. Shukla (1976) and Harper and Lynch (1981) also recorded slow rate of decomposition in the field conditions during low temperature conditions. The decomposition of litters in field was faster during the periods when moisture and temperature were higher (Fig.3.1).

In general, the decomposition of root litter was slower than the leaf litter. Jenkinson (1977) and Saini (1987) also reported the slower rate of root litter decomposition than the leaf litter. Similar results were also reported in case of barley (Broadbent and Nakashima, 1971) and maize root litters (Sauerbeck et al. 1972; Dkhar, 1983). Leaf litter decomposed more rapidly than the root litter which may be ascribed to the losses of polysacchrides from the leaf which are generally higher in amount in the leaves. Smith (1966) and Dkhar (1983) also reported the similar results.

Initially, population of bacteria and fungi associated with the decomposing litters was higher which may be attributed to the colonization of new substrate. Microbial population (fungi and bacteria) of leaf and root litters increased to their maximum levels at the 120 and 480 days when moisture content was higher which probably helped in

the rapid growth of the microorganisms. It is envisaged that release of soluble nutrients from the litter coupled with favourable moisture and temperature conditions played an important role in the growth of microflora on the litter. The population of bacteria and fungi after reaching at the peak declined sharply to a low level (Fig.3.2, 3.3). This drop may be due to a significantly drop in moisture content and temperature at the same period (Fig.1.2,1.1).Exhaustion of soluble nutrients from the decomposing litters at the same time may alsobbe the reason for the drop in microbial population (Baruah,1983; Dkhar,1983). Das (1980), Baruah (1983) and Dkhar (1983) also suggested the similar reason for the drop in microbial population associated with decomposing litters. Holm and Jensen (1972) reported that microbial population on decomposing litter was affected more by the changing weather condition. Higher fungal population associated with leaf litter (Fig.3.2).may also be due to the higher surface area of the leaf as it provides better chances for microbial colonization.

Qualitatively fungal flora of decomposing leaf and root litters did not differ much.Caldwell (1963) also found the similar results. Very little difference in the species composition of fungal flora of leaf and root litters (Table 3.2,3.3) suggests that most of the fungi are non-selective and they can utilizeda wide variety of substrate. Bangar et al. (1979) reported that Trichoderma viride and Penicillium

sp. were the important cellulose degrading fungi. These fungi were also isolated in the present investigation during summer season. Hayes(1979) and Anderson and Domsch (1975) also reported the similar results.

The increase in the nitrogen content during the later phase of decomposition may be attributed to the immobilization of nitrogen to the microbial biomass (Saite, 1957; Gilbert and Bocock, 1960; Iverson, 1973; Superkropp et al.1976; Das, 1980). The low nitrogen content from decomposing litters observed initially (Table 3.4) may be ascribed to the rapid breakdown of nitrogenous compounds thereby releasing nitrogen from the litter(Burges, 1967). Shukla and Singh (1984) reported that low moisture condition was not found suitable for the leaching of the nutrients from the decomposing litters. They further, suggested that during the onset of rains the litters were exposed to the attack of the microorganisms. The soluble carbohydrates protective layers of wax and cutin etc. were washed away during rainy season and this resulted into increased leaching of the minerals (N, P and K). This may be the reason for the low contents of the minerals (N, P and K) recorded from the decomposing leaf and root litters as most part of the these minerals leached into the soil during rainy season (180-300 days).

Changes in weather condition may be responsible for the temporal variation in microbial population associated with the litters (Pugh, 1958; Witkamp, 1963; Holm and Jensen, 1972). Das (1980) reported that favourable moisture,

temperature and intensive activity of soil fauna which exposed the litter surface for microbial colonization may be the reason for the gradual increase in the microbial population.

Results of the present study demonstrate that environmental conditions (moisture, temperature) and microbial population (fungi and bacteria) are the main factors which influence the rate of litters (leaf and root) decomposition. Dry season with low moisture and temperature was not suited for the litter decomposition while on the other hand rainy summer season was most suitable for the rapid rate of litter breakdown.

C H A P T E R IV

EARTHWORM POPULATIONS OF PINEAPPLE ORCHARD

INTRODUCTION

"Soil fertility"though used frequently is a poorly defined term. Brady (1974) gives a useful working definition which considers "fertility" to be the inherent capacity of soil to supply nutrients to plants in adequate amounts and in suitable proportions. Earthworms improve the nutrient supply to plants by ameleorating the physical, chemical and biological characteristics of soils. Earthworms burrow through soil and feed on organic materials, and thus they change the environment for all other soil inhabiting organisms, including plant roots. Earthworms improve plant growth by increasing incorporation of organic materials which may accelerate mineralisation, by a possible direct effect of earthworm metabolic products on plant growth and by improving aeration, water relations and penetrability in poorly structured soils (Mc Coll et al. 1982). Plant residues and dung are fragmented and mixed with soil during passage through the earthworm gut, and are incorporated into the soil profile. Thus they play an important role in the cycling of organic matter (Satchell, 1958).

Earthworms influence the supply of plant nutrients in the soil in several ways. The nutrients present in the earthworm tissues are recycled as the earthworm population dies and young earthworms grow. Nutrients cycled more rapidly through the earthworm's own metabolic processes and their

feeding activities increase the release of nutrients.

A number of physico-chemical characteristics viz; soil temperature (Hopp, 1947), moisture (Grant, 1955), pH (Cotton and Curry, 1982), organic carbon (Syers and Springeet, 1984) and organic nitrogen (Edward and Lofty, 1982) were found to be important factors which govern the earthworm population in soils. Literature has also revealed that type of covers (Slater and Hopp, 1947), tilling of soil (Lal, 1974), trampling (Piearce, 1984) and degree of disturbance (Syers and Springeet, 1984) seem to be important factors regulating the distribution and abundance of earthworms in soil.

Importance of earthworms for soil fertility has been known since Darwin (1881). But quantitative work on the mechanisms by which earthworms bring about changes in the soil is quite recent. Most of the studies were conducted in agricultural (Barley, 1961), forest (Nielson and Hole, 1964) and grassland (Cotton and Curry, 1982; Piearce, 1984). The earthworm populations under orchard crops have not received due attention. Keeping this view in mind it was thought necessary to estimate the earthworm population under pineapple orchards for possible utilization of earthworms in evolving better land management strategies.

REVIEW OF LITERATURE

Darwin (1881) first described the importance of

earthworms in soil.

Dawson (1947) and Evans (1948) reported that sludge disposal on land increased earthworm populations which resulted into an increase in infiltration and aeration of soils.

Hopp (1947) studied the effect of soil temperature on earthworms and noted that worms number increases with temperature but worm weight decreases at all temperatures departing from $35^{o}F$.

Slater and Hopp (1947) pointed out that cultivated covered land had more earthworms than cultivated bareland. They further, suggested that different type of covers affected the winter population of earthworms.

Zicsi (1958) took 25x25 cm soil blocks located at 5 m intervals on transacts parallel to the contours for the counting of earthworm numbers. He adapted hand sorting method for earthworms counting.

Raw (1959) introduced a method of using formalin solution in order to bring the deeper dwelling earthworms to the surface.

Block and Banage (1968) studied the earthworm population in Uganda soils and found a population size between $7.4/m^2$ and $101.8/m^2$.

Edward and Lofty (1972) suggested the hand picking

method for the estimation of earthworm population following randomized sampling procedures. They suggested that the quadrats should be located at a 5 m distance and noted 1.3 to 6.0 times larger population in unploughed plots as compared to ploughed plots. Effects of nitrogenous fertilizers on earthworm populations in agricultural soils was also studied by them (Edward and Lofty, 1982), where they noted a strong positive correlation (r=0.982) between amounts of inorganic nitrogen applied and populations of earthworms.

In Nigeria Lal (1974) found 20 times more earthworms population in untilled land than in tilled land.

Watanabli (1975) and Dash (1978) described that earthworms represent the major part (80%) of the soil invertebrates population.

Edward and Brown (1982) conducted an experiment in grassland plots to investigate the effect of pesticides on earthworms. They suggested that excess use of pesticides may cause the adverse effect on earthworm population.

Cotton and Curry (1982) studied the distribution and abundance of earthworms in a mineral peat soil, and noted that low pH and storage of suitable food were the main limiting factors for earthworm populations.

Piearce (1984) studied the effect of heavy trampling

on the population of earthworms and noted that trampling reduced the earthworm density and biomass. He pointed out that the surface species were most severely affected, whilst the deep burrowing species were found to be resistant.

Syers and Springeet (1984) pointed out that degree of soil disturbance and distribution of organic matter content affected the earthworm population.

Asiegbu (1984) noted that N, P and K fertilizers especially where N is used as ammonium sulphate may have adverse effect on the soil earthworms.

In a comparative study Baker (1985) found that the number of earthworms collected by formalin expulsion method was generallv equal to the numbers obtained by hand picking method.

MATERIALS AND METHODS

The study was conducted at pineapple research station Nayabunglow (Chapter I). Earthworm population was estimated at monthly intervals from the different plantation soils with an aim to investigate the seasonal variation and effect of age of the plantations on the earthworm population. Soil moisture, pH and temperature were estimated by the methods as described in chapter I. Data on average rainfall, relative humidity and ambient temperature of the study site are presented in chapter I (Fig. I).

Earthworm population was estimated by hand picking method (Edward and Lofty, 1972) following randomized sampling procedures and considering a size of 25cm cubes of soil. 20 quadrats were taken for the estimation of earthworm population in each plantation soil. Quadrats were located at 5m intervals on transects. Each quadrat was dug up by the soil digger and earthworms were sorted out carefully by hand.

Each value reported is the mean of triplicate analysis. Correlation coefficient (r) values were calculated between earthworm population and soil moisture, pH, temperature. Data were also analysed by two way analysis of variance.

RESULTS

Soil of the three plantations was sandy loam (Table 1.1). Data on soil moisture, temperature and pH are presented in Figs. 4.1, 4.2 and 4.3. Soil temperature of 1 year; 5 year and 10 year plantation ranged between 11-31^{o}C, 12-32^{o}C and 14-33^{o}C respectively. Maximum soil temperature (33^{o}C) was noted from the 10 year plantation soil on 15th January, 1987 (Fig.4.1). Moisture content of 1 year, 5 year and 10 year plantation ranged between 13.05-26.6%, 12.81-27.95% and 13.93-28.82% respectively. Highest moisture content 28.82% was recorded from the 10 year plantation soil

Fig. 4.1 Monthly variation in temperature of different plantation soils.

Fig. 4.1

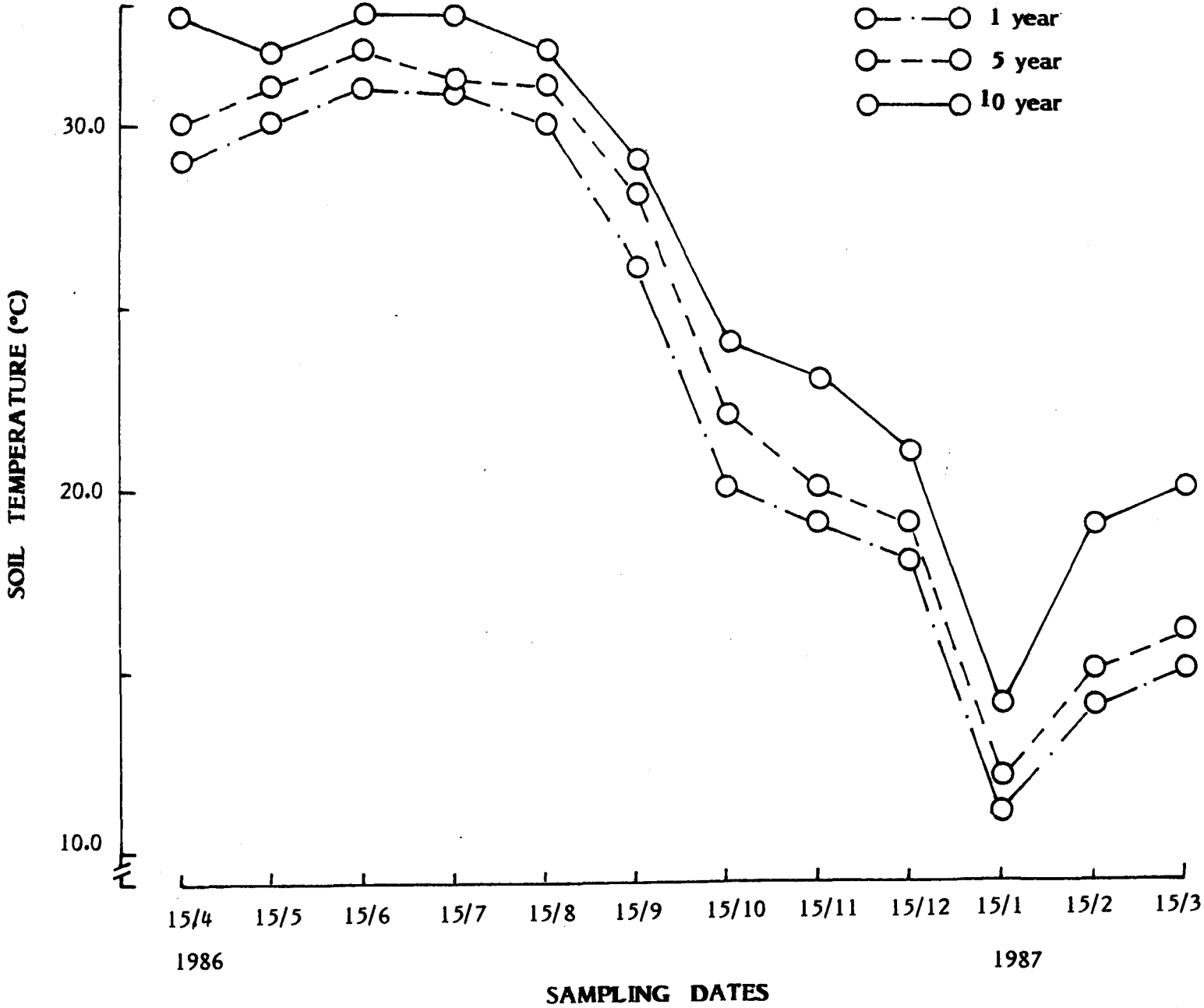

1 year
5 year
10 year
30.0
20.0
10.0
SOIL TEMPERATURE (°C)
15/4
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1
15/2
15/3
1986
1987
SAMPLING DATES

Fig.4.2 Monthly variation in moisture content of different plantation soils.

Fig. 4.2

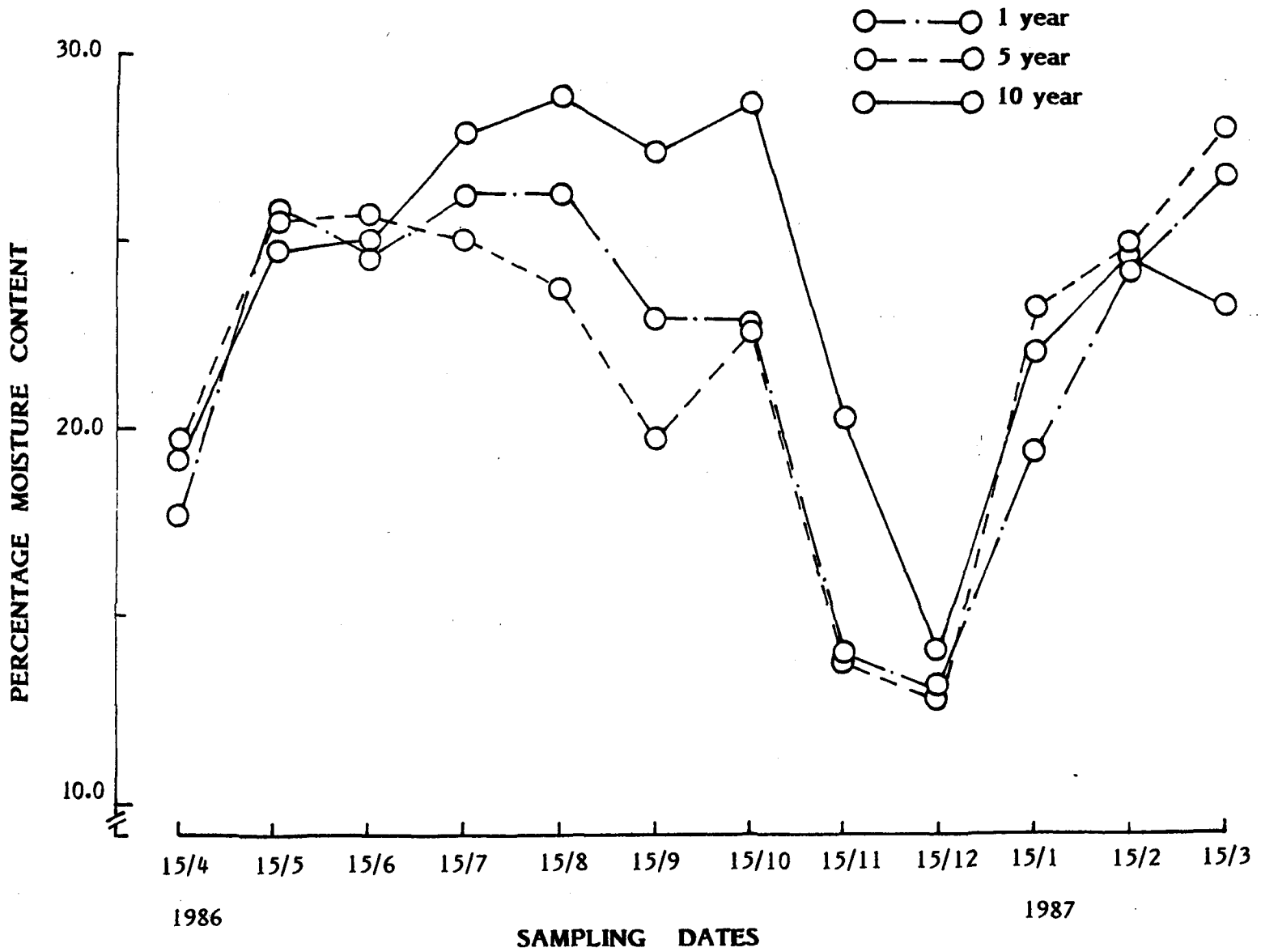
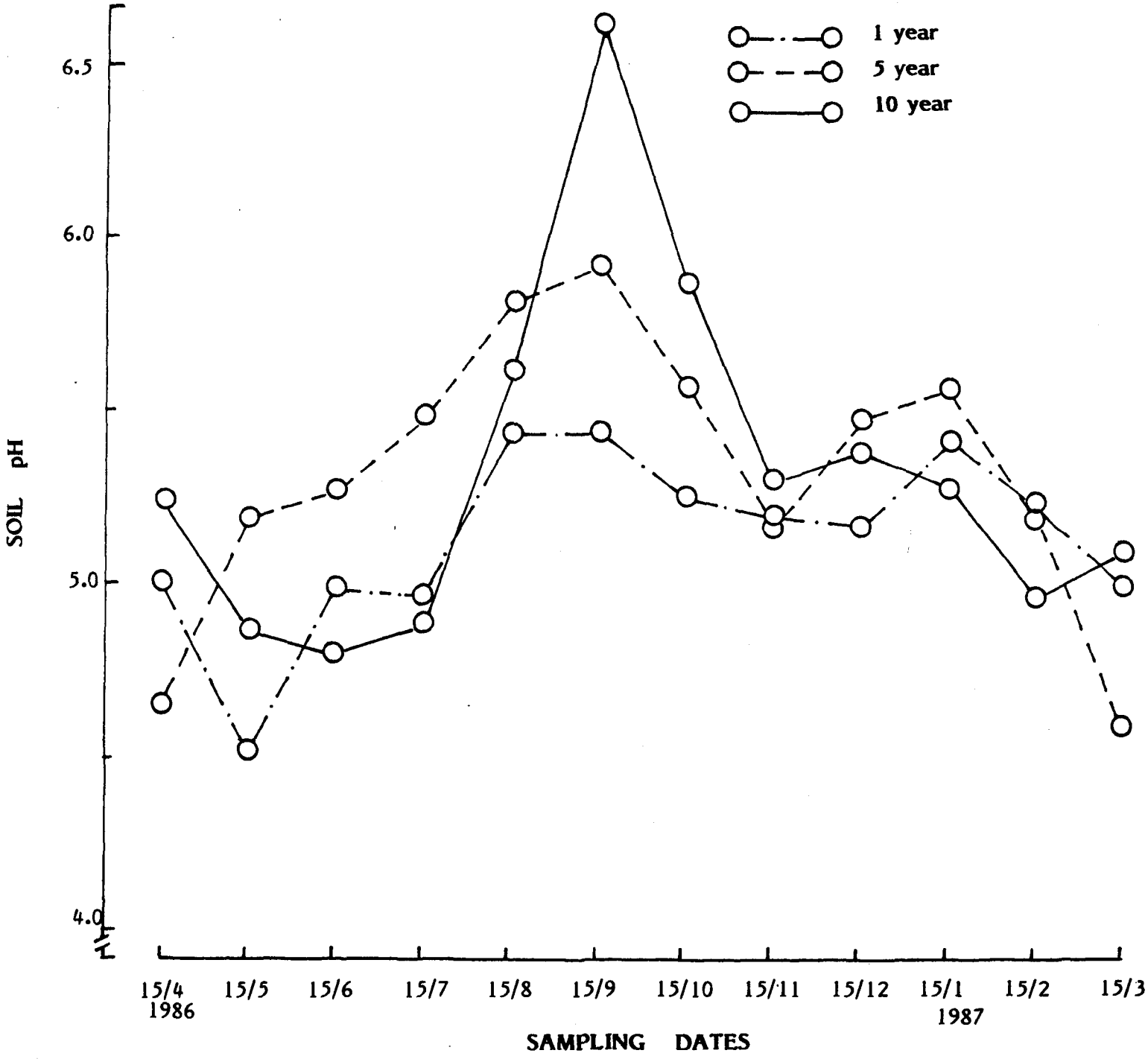

1 year
5 year
10 year
30.0
20.0
10.0
PERCENTAGE MOISTURE CONTENT
15/4
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1
15/2
15/3
1986
1987
SAMPLING DATES

Fig. 4.3 Monthly variation in pH of different plantation soils

Fig. 4.3


1 year
5 year
10 year
6.5
6.0
5.0
4.0
SOIL pH
15/4
1986
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1
1987
15/2
15/3
SAMPLING DATES

on 15th October, 1986 and lowest was recorded from the 5 year plantation on 15th December, 1986 (Fig.4.2). pH varied from 4.52 to 5.44, 4.6 to 5.92 and 4.81 to 6.62 in case of 1 year, 5 year and 10 year plantation respectively. Maximum soil pH (6.62) was noted from the 10 year plantation soil on 15th September, 1986 while minimum (4.52) was noted from the 1 year plantation soil on 15th May, 1986 (Fig.4.3).

Maximum population (7 worms/25cm soil cube) of earthworms was recorded from the 10 year plantation soil which was followed by the 5 year and 1 year plantation soils. (Fig.4.4).

All the plantation soils showed a similar trend of seasonal variation in earthworm population. The population peaked on the 15th July, 1986 in all the three plantations. Thereafter, a drop in the population was recorded and it continued upto December, 1986. No earthworm population was recorded on 15th January and 15th February, 1987. Again earthworm population was recorded on 15th March, 1987 from 5 and 10 years plantation soils while the worms were not isolated from the 1 year plantation soil on this date.

A positive correlation($r=0.542$, $P=0.05$; $r=0.661$, $P=0.05$) was observed between earthworm population and soil temperature of 5 year and 10 year plantations. However, no correlation was noted in case of 1 year plantation. Moisture content of the soil of 1 year and 10 year plantations

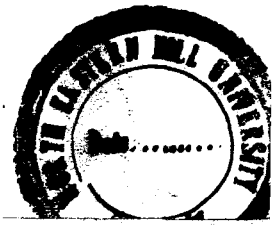
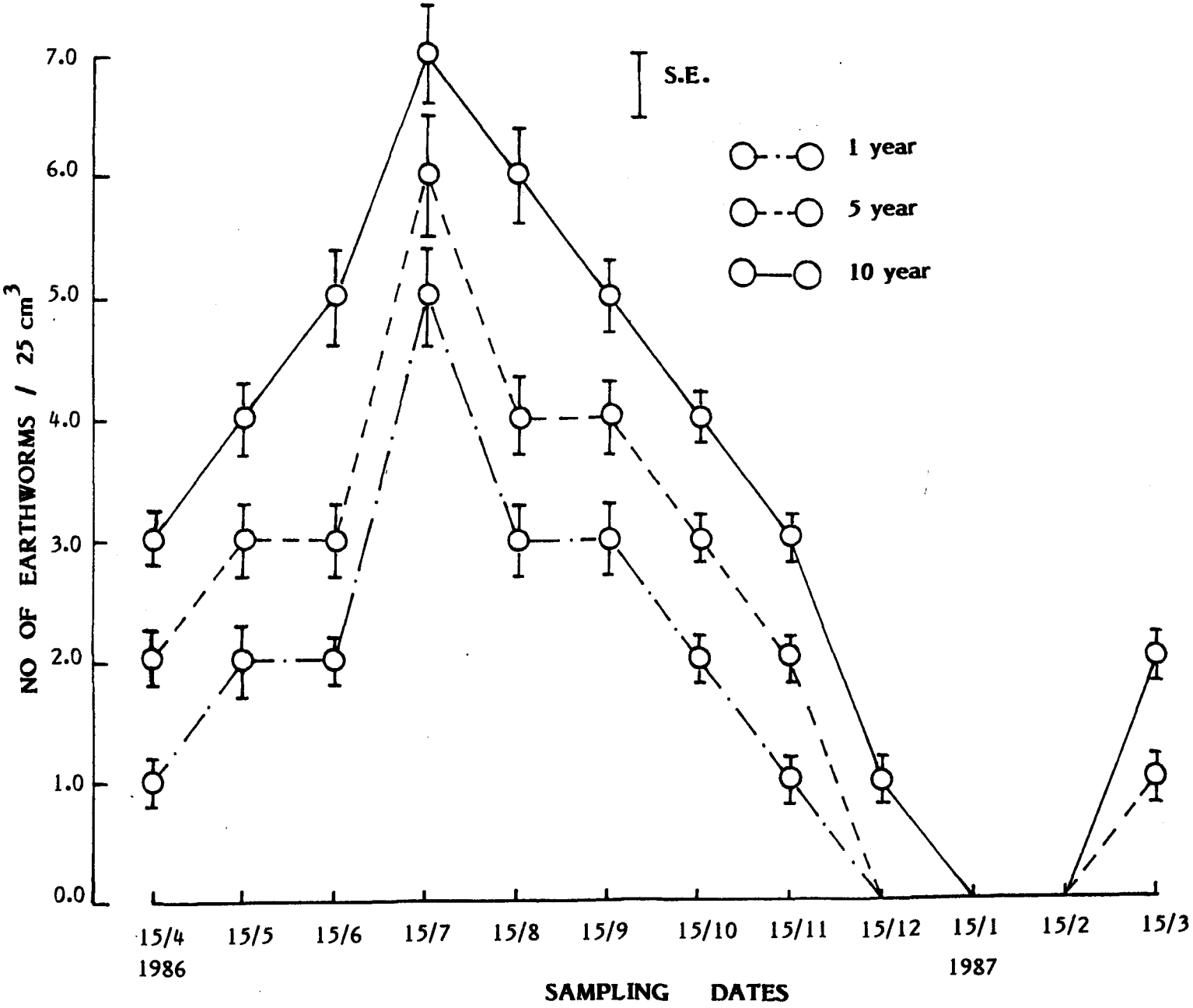


Fig.4.4 Monthly variation in earthworm population of different plantation soils.

Fig. 4.4


7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
NO OF EARTHWORMS / 25 cm3
S.E.
1 year
5 year
10 year
15/4
1986
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1
1987
15/2
15/3
SAMPLING DATES

was found to be positively correlated (r=0.517, P=0.05; r=0.786, P=0.01) with earthworm population. 5 year plantation soil did not show any such correlation. Earthworm population was positively correlated (r=0.669, P=0.05) with the pH in 5 year plantation soil and negatively (r=-0.846, P=0.01) with that of the pH of 1 year plantation. No correlation was observed between earthworm population and soil pH of the 10 year plantation.

DISCUSSION

During the present study earthworm population was recorded during rainy summer season of the year (April to November). With the onset of dry-winter the population receded and during the coldest months when the soil moisture was also minimum the earthworms could not be isolated. Gates (1961) also recorded the earthworm activity, in the humid subtropical climate of India, from May to October. Earthworm population during these periods might be due to suitable soil temperature, and moisture. Similarly, Hopp (1947) and Cotton and Curry (1982) noted the soil temperature and moisture, important factors regulating the earthworm population in soil.

On the sampling date 15th January, 1987 and 15th February, 1987, no earthworm population was recorded. It may be due to the unfavourable conditions to the worms and

Table 4.1 Correlation coefficient (r) values between soil moisture, temperature, pH and earthworm population.

	1 year	5 year	10 year
1. Soil temperature	NS	+ 0.542*	+ 0.661*
2. Soil moisture	+ 0.570*	NS	+ 0.786**
3. Soil pH	-0.846**	+ 0.669*	NS

**, Significant at 0.01 and * significant at 0.05 probability levels.

Table 4.2 Analysis of variance between plantation types and sampling dates.

Source of variation	Sum of squares	df (degree of freedom)	Mean Sq. or variance ratio	Variance ratio or F	Significance
Between plantations types	9.72	2	4.86	8.23	0.01
Between sampling dates	41.43	11	3.76	6.37	0.01
Remainder or Error	13.07	22	0.59	-	-
Total	64.22	35	0.59	-	-

they might have gone under diapause or may have become quiescent (Evans and Guild, 1947; Murchie, 1954; Hartenstein et al.1979). Syers et al. (1979) also found the lower earthworm population during colder periods.

Peak in earthworm population during July 1986 in all the soils may be attributed to higher soil temperature. Sufficient amount of food to the earthworms may be also one reason for the higher earthworm population during the same period. Drop in earthworm population might be due to lowering of soil temperature, less moisture content and slow decomposition process which probably resulted into exhaustion of easily available food to the earthworms (Cotton and Curry, 1982). Increase in earthworm population during 15th March, 1987 might be due to increase in soil temperature (Fig.4.4).

Standen et al. (1982) and Cotton and Curry (1982) reported that soil temperature, moisture, pH, shade, quantity of litter, available food and rate of litter decomposition were the important factors which influenced the earthworm populations. Organic matter content was also found to be one of the important factors which influenced the earthworm population (Syers and Springeet, 1984).

Higher earthworm population in 10 year plantation soil may be attributed to higher soil temperature, moisture content, pH and organic matter content (Fig.1.1,1.2,1.3 and 1.4) in the soils of the 10 year plantation. Large

amount of litter production, less degree of disturbance, may also be one reason for the higher earthworm population in 10 year plantation. Low population in 1 year plantation soil might be due to low soil temperature, moisture and production of less amount of plant litter resulting into a less amount of easily available food to the earthworms. Degree of disturbance during the time of transplantation has also be reported to be the reason for low counts of the earthworm (Syers and Springeet, 1984).

From the results it could be inferred that the temperature and moisture were the most important factors responsible for the seasonal variation in the earthworm population. While low temperature was the most important factor responsible for the absence of the earthworms during the winters. The peak during July was largely due to moisture. The variations between the plantations were largely due to the variations in organic carbon content.

Variations in earthworm population with time (6.37, P=0.01) were statistically significant (Table 4.2). It may be inferred that the longevity of plantation increased the earthworm population.

C H A P T E R V

MICROBIAL POPULATION AND THEIR ACTIVITIES IN EARTHWORM CAST AND SOIL

INTRODUCTION

Earthworms constitute a major part of soil fungal biomass. The role of earthworms in plant residue decomposition by incorporating and mixing the surface residues into the soil through their burrowing, feeding and casting activities is well documented (Barley and Jennings 1959; Mackay and Kladivko, 1985). Feeding activity of earthworms increases the microbial population (Went, 1963; Gorbenko et al. 1986). The earthworms improve nutrient supply to the plants through casting and excretion (Lunt and Jacobson, 1944; Loquet et al. 1977; Brown et al. 1978; Kitchell et al. 1979; Syers et al. 1979; Vleeschauwer and Lal, 1981; Krishnamoorthy and Vajranabhaiah, 1986). They also make the phosphorus available to the plants from phosphate rocks through their feeding activity (Mackay et al. 1982).

Earthworms ingest fungal mycelium and other microorganisms present in the soil. Studies on the microflora in the intestinal tract of earthworms are not exhaustive (Bassalik, 1913; Dawson, 1947; Parle, 1963; Domsch and Banse, 1972; Dash and Cragg, 1972; Dash et al. 1979; Gorbenko et al. 1986). The changes brought about by the earthworms in soil microflora and their activities after passing through the guts have not been thoroughly investigated (Dash and Cragg, 1972; Dash et al. 1979). Very few studies are available on dehydrogenase, urease and phosphatase activities in the

earthworm casts (Businelli et al. 1984; Satchell and Martin, 1984; Satchell et al. 1984). For better understanding of the effect of earthworm activity on the soil fertility and microbe-mediated processes of soil ecosystem, knowledge on the microbial population and their activity in the earthworm casts is a prerequisite. It was, therefore, thought desirable to make a comparative study on the microbial population and enzyme activities namely- dehydrogenase, urease and phosphatase of the earthworm casts and surrounding soil with an aim to understand how the microbial population and their activities are altered in the soils after passing through the guts of earthworms.

REVIEW OF LITERATURE

Aristotle, first described earthworms as 'the intestines of the earth'. Darwin, (1881) noted that earthworms allow the air to penetrate deeply into the ground which facilitates the downward passage of roots.

Bassalik (1913) isolated more than 50 species of bacteria from the alimentary canal of Lumbricus terrestris.

Heymons (1923) observed the intestine of earthworm as a breeding place for bacteria. He pointed out that bacteria are responsible for the degradation of urea in the intestinal tract of earthworms.

Lunt and Jacobson (1944) reported that the casts

from a ploughed field had approximately three times concentration of exchangeable Mg, seven times of available P and eleven times of available K than the top 150mm of soil.

Dawson (1947) stated that the number of bacteria in earthworm casts was reduced by passage through the alimentary canal while the number of fungi remained unaffected.

Swaby (1949) stated that the intestinal bacteria of earthworms produced gums which cement the casts into water stable aggregates.

Barley and Jennings (1959) suggested that the plant litter is more easily attacked by other decomposers after the material has been subjected to the grinding action and chemical changes in the earthworm gut.

Parle (1963) showed that numbers of bacteria and actinomycetes increased 1000 fold during passage through the gut and oxygen consumption remained higher in earthworms casts than in soil for 50 days indicating an increased microbial activity.

Went (1963) noted that earthworm feeding enhances the bacterial population in mineral soil by incorporating organic matter from surface litter.

Medge (1969) showed that earthworms prefer soils with moisture between 12.5 to 17.20%.He stated that 23.3% moisture level was found to be optimum to produce casts.

Marshall (1970) stated that in absence of earthworms a layer of dead plant material is accumulated at the soil surface, which reduced the infiltration capacity of the soil. He further, suggested that not only do earthworms decrease loss of nitrogen and phosphorus through run off, they also increase leaching of potassium by improving drainage.

Domsch and Banse (1972) reported total destruction of fungi after passing through the earthworm digestive treat.

Dash and Cragg (1972) have shown that earthworms graze over soil microfungi and prefer some species of fungi as their food.

Sharpley and Syers (1976) noted that the surface casts contain approximately four times more loosely-bound in organic P and twice as much loosely-bound organic P as underlying soil. They further pointed out that the enhanced microbial activity may be responsible for increased phosphatase and urease activity.

Earthworms may stimulate not only the bacterial population but also the overall metabolic level of organic substrates (Brown et al. 1978; Mitchell et al. 1980.

Dash et al. (1979) studied the feeding behaviour of a tropical earthworm on fungi. They reported that earthworms are unable to utilize the antibiotic producing microorganisms or those having thick layered spore coats.

Syers et al. (1979) noted that seasonal variation in the total nitrogen and oxidizable carbon contents of casts were closely related to variations in litter production. They further noted that the seasonal variation in urease enzyme activity associated with fluctuations in organic matter contents, was more important than the effect of temperature on enzyme activity in accounting for seasonal variations in the NH_4^+ - N content of the casts.

Hornor and Mitchell (1981) observed that population of total anaerobes, nitrate reductase, sulphatic reductase and methanogens were not significantly affected by earthworm feeding.

Abbott and Parker (1981) studied the effect of quantity and quality of food on the earthworms. They observed that earthworms with more food gained weight faster than those with little or no supplementary food.

Vleechauwer and Lal (1981) in a comparative study between casts and surface soil found the presence of less sand, more silt and clay in the casts. They also found that casts had greater bulk density and structural stability than the surface soil. The higher amount of nitrogen, organic matter content, available phosphorus and cation exchange capacity were also estimated from the earthworm casts.

Lal and Akinremi (1982) studied the influence of crop management practices on physical properties of earth-

worm casts and surface soils. They noted that the physical properties of the casts significantly differ from the surface soil. The rate of cast production followed a trend of nontilled > ploughed > mulched > unmulched treatments.

Lal and Vleeschauwer (1982) reported that the nutrient status of both casts and soil in non-tilled plots was generally superior to that in conventionally ploughed treatments. Different rates of N and P application had a significant positive effect on the nutrient status of worm-casts.

Ross and Cairns (1982) described the presence of earthworms stimulated the activities of cellulose, sulphatase, invertase, amylase, urease and phosphatase enzymes and also the uptake of oxygen.

Mackay et al. (1982) reported that the ingestion of phosphate rock (PR) particles by the earthworms during feeding, could lead to an increase in the degree of intimate contact of the PR with the soil during passage through the digestive tract. This intimate contact could promote dissolution of the PR leading to an increase in the plant availability of P in the PR.

Syers and Springeet (1983) noted that the direct effects of earthworms on nutrient uptake are likely to be more important in soils of low nutrient status.

Flack and Hartenstein (1984) measured the growth of earthworms (Eisenia foetida) on microorganisms and cellulose mixtures. They noted that E. foetida doubled in weight on the diet of fungus Coriolus hirsutus with the addition of sand or ashed loam.

Businelli et al. (1984) estimated the chemical composition and enzymatic activities of some worm casts and recorded higher enzyme activities in the casts in comparison to the surface soil.

Satchell and Martin (1984) studied the phosphatase activity in the earthworm faeces and noted higher phosphatase activity in faeces than the ingested soil, resulting in an increase inorganic P released by mineralization of organic P.

Earthworms play an important role in the breakdown of residues. Mackay and Kladivko (1985) in one of their studies recorded greater breakdown of soybean and maize residues in presence of earthworms than in their absence.

Krishnamoorthy and Vajranabhaiah (1986) studied the biological activity of the earthworm casts and noted higher values of ammonia, urea, organic carbon content, organic matter, soluble phosphorus and ionic potassium levels in the casts.

Gorbenko et al. (1986) reported that the overall biomass of microorganisms (mainly fungal mycelium) decreased

abruptly while the content of bacterial cells increased in the faeces of earthworms and other invertebrates as compared to their number in the food of these animals.

Martin (1986) made a comparative study of earthworm gut contents and recorded highest amount of gut contents from the intermediate size of worms.

MATERIALS AND METHODS

The study was conducted at pineapple research station Nayabunglow. Earthworm casts and surrounding soil were collected aspeptically from 1, 5 and 10 years old pineapple plantations at monthly intervals and brought to the laboratory for the analysis of various physico-chemical and microbiological characteristics.

Estimation of microbial population(fungi and bacteria)of earthworm casts and soil :

For the estimation of microbial population (fungi and bacteria) of casts and surrounding soil, methods described in chapter II were followed.

Determination of physico-chemical characteristics of earthworm casts and the soils :

Soil moisture content, pH, organic carbon, total nitrogen, available phosphorus and exchangeable potassium of casts and the soil were determined by the methods as described in chapter I.

Assessment of dehydrogenase, urease and phosphatase enzyme activities in earthworm casts and soil:

The methods given in chapter II for the assessment of dehydrogenase, urease and phosphatase enzyme activities were followed.

Results reported in the figure, tables are the means of triplicate analysis. Data were analysed statistically by adapting the t test procedures.

RESULTS

Generally, surrounding soil contained higher moisture content than the casts except on 15th August, 1986 and 15th September, 1986 when earthworms casts showed higher moisture content than the soil (Table 5.1). Moisture content of the soil of 1 year varied between 13.05 and 26.60% and that of the casts varied between 11.98 and 33.85%. In case of 5 year plantation the soil moisture varied between 12.81 and 29.95% and that of the casts varied between 10.32 and 30.45%. In 10 year plantation moisture content of the soil ranged between 13.93 and 28.82% and that of the casts ranged between 13.21 and 37.46% (Table 5.1).

pH of the earthworm casts was found to be higher than the soil (Table 5.1). pH of 1 year plantation soil ranged between 5.52 and 5.44 and that of the casts ranged between 5.10 and 7.22. In case of 5 year plantation the

Table 5.1 pH and % moisture content of the soils and earthworm casts under pineapple plantations

Dates	1 year		5 year		10 year	
	Soil	Cast	Soil	Cast	Soil	Cast
15/4/86	[1] 5.00±.045	5.98±.021	4.65±.053	5.98±.003	5.24±.045	5.78±.009
	[2] 17.69±.069	12.23±.081	19.75±.067	11.58±.057	19.18±.089	13.21±.071
15/5/86	4.52±.043	6.22±.057	5.18±.038	6.35±.016	4.87±.038	6.13±.004
	25.80±.071	16.07±.058	25.72±.061	15.25±.081	24.73±.081	14.65±.019
15/6/86	4.99±.043	5.86±.076	5.26±.032	5.92±.054	4.81±.047	5.74±.023
	24.45±.069	20.47±.024	25.71±.052	19.03±.094	24.86±.091	18.25±.029
15/7/86	4.97±.038	5.75±.038	5.48±.043	5.69±.077	4.89±.037	5.47±.019
	26.22±.065	19.40±.056	25.11±.049	19.02±.023	27.80±.077	29.20±.023
15/8/86	5.44±.032	7.27±.091	5.82±.048	6.41±.013	5.61±.041	6.12±.005
	26.15±.075	33.85±.058	23.60±.067	30.45±.071	28.82±.085	32.00 ±.037
15/9/86	5.44±.037	6.91±.011	5.92±.039	6.94±.019	6.62±.039	7.11±.023
	22.75±.079	30.20±.021	19.82±.054	23.20±.024	27.30±.67	35.73±.045
15/10/86	5.25±.028	5.91±.004	4.89±.031	5.84±.023	4.86±.045	6.27±.021
	22.84±.081	23.16±.051	22.59±.061	20.77±.077	28.77±.058	37.46±.049
15/11/86	5.20±.034	6.40±.058	5.32±.039	5.81±.054	5.30±.033	6.05±.056
	13.92±.057	12.39±.023	13.85±.064	12.10±.059	20.27±.081	15.21±.066
15/12/86	5.17±.036	6.03±.007	5.48±.032	5.70±.078	5.38±.053	6.00±.046
	13.05±.059	11.98±.019	12.81±.067	10.32±.053	13.73±.098	14.65±.088
15/ 1/87	5.42±.045	6.51±.019	5.57±.023	5.61±.005	5.28±.054	5.39±.018
	19.40±.076	15.42±.023	23.15±.059	14.64±.067	22.15±.077	13.90±.067
15/ 2/87	5.23±.025	5.45±.023	5.21±.021	5.32±.007	4.97±.041	5.00±.011
	24.20±.049	23.80±.046	24.85±.081	23.89±.023	24.25±.071	22.60±.043
15/ 3/87	5.00±.043	5.10±.088	4.60±.053	4.97±.056	5.10±.047	5.24±.023
	26.60±.075	12.61±.091	27.95±.089	18.36±.045	23.10±.082	17.29±.033

1 = Soil pH

2 = Percentage soil moisture content

± = standard error.

soil pH varied from 4.60 - 5.92 and pH of the casts varied between 4.97 and 6.94. In 10 year plantation soil pH varied between 4.81 and 6.62 and pH of the casts varied between 5.00 and 7.11 (Table 5.1).

Assessment of microflora (Fungi and Bacteria):

In casts, fungal population was found to be higher than the soil (Fig.5.1). Generally, the trend of difference in fungal population of soil and earthworm casts was similar in all the plantations studied. Two peaks in fungal population noted; one in spring (April) at the time of commencement of the sampling and another in autumn (September). The peak noted during autumn in 10 year plantation was found comparatively lower than that of the peaks in 1 and 5 year plantations (Fig.5.1). During rainy summer (June) and winter the fungal population dropped to a very low level. Winter drop in case of 10 year plantation was less prominent than that of 1 and 5 year plantations (Fig.5.1).

Bacteria :

Differences in bacterial population of soil and earthworm casts are shown in Fig.5.2. Earthworm casts showed the higher bacterial population than the soil in all the plantation studied. Among all the plantation studied no definite trend of temporal variation in bacterial population of soil and casts was observed. Two peaks in bacterial

Fig.5.1 Monthly variation in fungal population of earthworm cast and soil of pineapple plantations.

Fig. 5.1

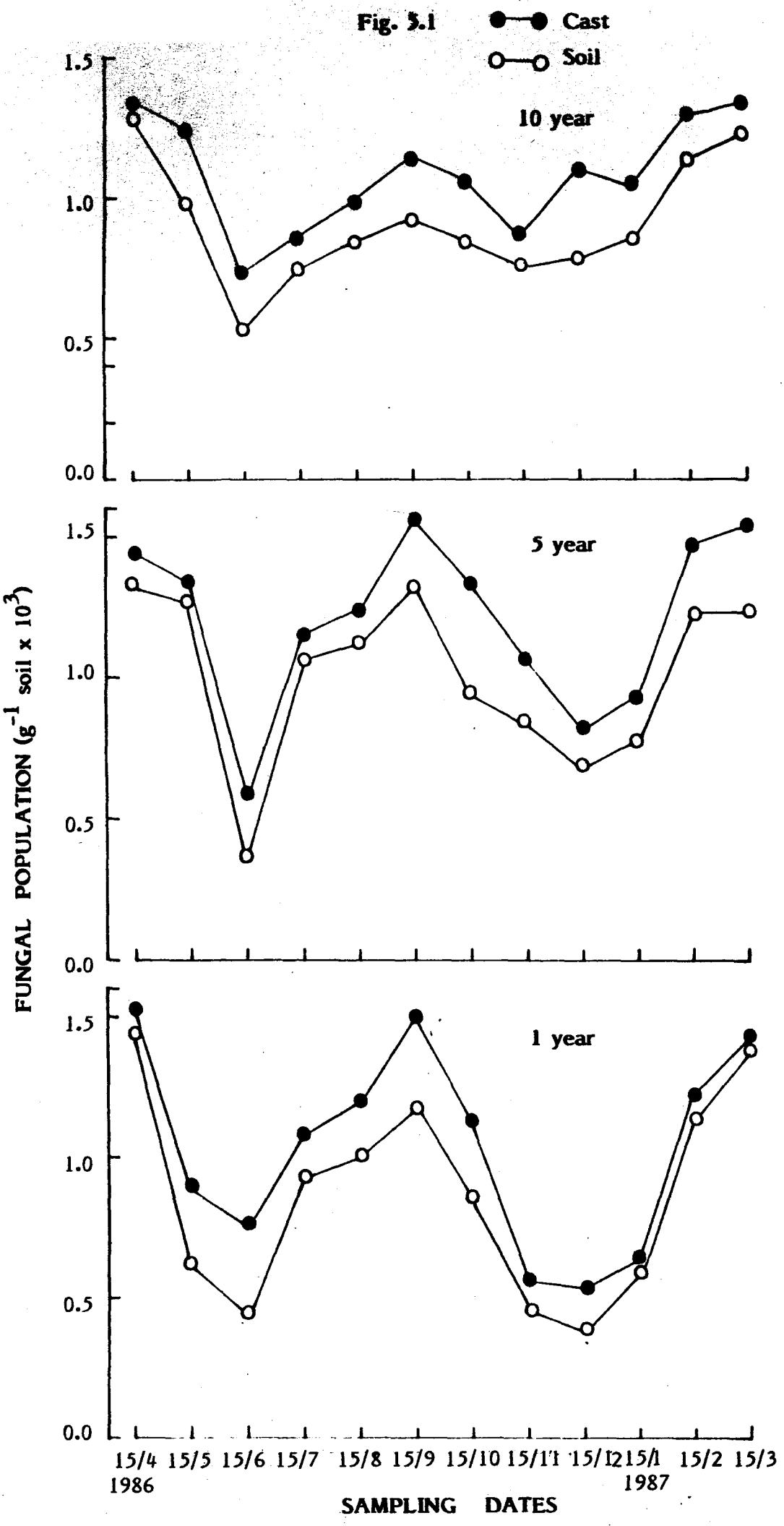
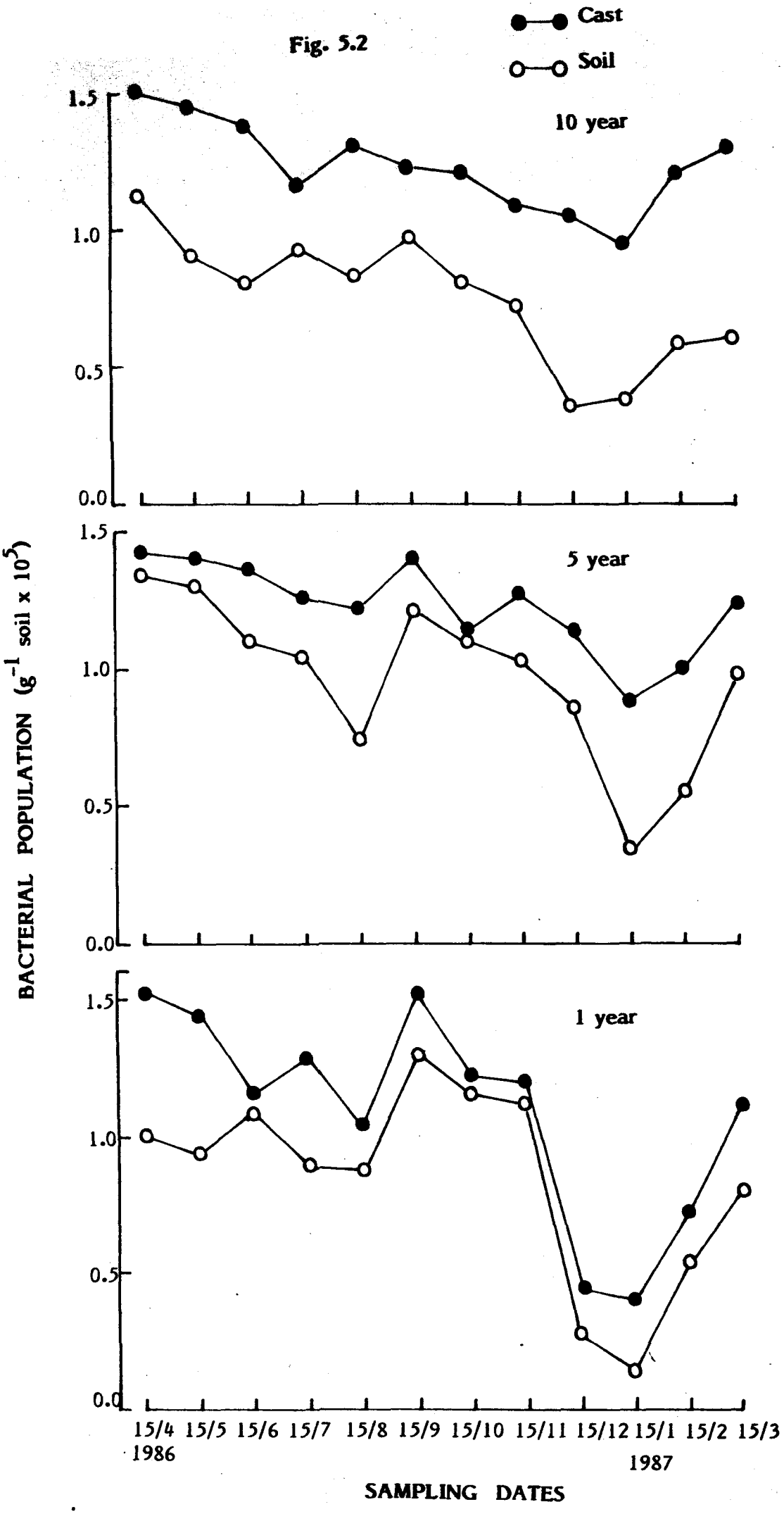

Cast
Soil
10 year
5 year
1 year
1.5
1.0
0.5
0.0
FUNGAL POPULATION (g^{-1} soil x 10^3)
15/4 15/5 15/6 15/7 15/8 15/9 15/10 15/11 15/12 15/1 15/2 15/3
1986
1987
SAMPLING DATES

Fig.5.2 Monthly variation in bacterial population of earthworm cast and soil of pineapple plantations.

Fig. 5.2


Cast
Soil
10 year
5 year
1 year
1.5
1.0
0.5
0.0
BACTERIAL POPULATION (g^{-1} soil x 10^5)
15/4 15/5 15/6 15/7 15/8 15/9 15/10 15/11 15/12 15/1 15/2 15/3
1986
1987
SAMPLING DATES

population were noted; one in spring (April) and another in autumn (September). Autumn peak differed in 10 year plantations. In 10 year plantation autumn peak was observed in August. During winter season drop in bacterial population was noted in all the plantation studied. In most cases bacterial population increased during the forthcoming spring season (Fig.5.2). The winter drop in bacterial population in case of 10 year plantation was found lower than that of drop occurred in 1 and 5 year plantation. The difference between the population of casts and soils was most pronounced in 10 year plantation (Fig.5.2).

Relative abundance of fungi in soil and casts :

Tables 5.2 - 5.7 lists the fungal species isolated from the soil and casts in all the plantations. In case of 1 year plantation a total number of 19 and 20 fungal species was isolated from the soil and casts respectively. All the species were common in soil and casts in 1 year plantation soil (Tables 5.2, 5.3). Absidia glauca, Aspergillus nedulans; A. niger, Gongronella butleri, Humicola fuscoatra; Mortirella ramanniana; Mucor hiemalis, Penicillium funiculosum; P. vermiculatum and Trichoderma koningii were isolated sporadically from soil as well as from the casts. Fusarium moniliforme; F. solani; M. racemosus; Penicillium chrysogenum and white sterile were the most dominant species recorded from the soils and casts.

Table 5.2 Lists of fungi isolated from soil and earthworm casts in 1 year plantation.
+ = Present - = Absent I = Soil II = Cast

Fungi	15/4/86		15/5/86		15/6/86		15/7/86		15/8/86		15/9/86		15/10/86		15/11/86		15/12/87		15/1/87		15/2/87		15/3/87	
Absidia glauca	I-	II+	-	-		-	-	-	-	-	+	-	-	-	-	-	+	+	-	-	-	-	-	+
Aspergillus nedulans	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
A. niger	+	-	-	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Fusarium moniliforme	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
F. solani	-	-	+	+	+	-	-	+	+	+	+	-	+	+	+	-	+	-	-	+	+	+	-	+
Gongronella butleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Humicola fuscoatra	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Mortierella ramanniana	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+
Mucor hiemalis	+	+	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-
M. racemosus	+	-	+	+	+	-	-	-	-	+	+	+	+	+	-	+	+	+	+	+	-	+	-	-
Paecilomyces lilliacinum	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Penicilliumchrysogenum	-	+	+	+	-	+	+	+	+	+	+	+	-	-	+	+	+	+	+	-	-	+	+	+
P. fellutanum	+	+	-	+	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+
P. funiculosum	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. javanicum	+	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
P. vermiculatum	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Trichoderma koningii	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+
T. viride	+	+	+	+	+	-	+	+	+	+	+	+	-	-	-	-	+	+	-	+	-	-	-	-
White sterile	-	-	-	-	+	-	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+
Yellow sterile	-	-	-	+	-	-	+	+	-	-	-	-	-	+	+	-	-	-	-	-	+	+	-	-

Table 5.3 Fungal population (g^{-1} dry soil x 10^3) of earthworm casts and surrounding soils in 1 year plantation at different sampling period. Values in parentheses are percentage relative abundance.

	15/4/86		15/5/86		15/6/86		15/7/86		15/9/86		15/9/86		15/10/86		15/11/86		15/12/86		15/1/87		15/2/87		15/3/87	
	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast
Absidia glauca	-	.126 (8.77)	.989 (10.00)	.158 (18.79)	-	-	-	-	-	-	.057 (3.92)	-	-	-	-	-	.025 (6.66)	.050 (9.52)	-	-	-	-	-	-
Aspergillus nedulans	-	-	-	-	-	-	-	-	-	-	.201 (13.72)	-	-	-	-	-	-	.025 (4.76)	-	-	-	-	-	-
A. niger	.061 (n.19)	-	-	-	-	.055	-	-	-	-	.155	-	-	-	-	-	-	-	.110	.183	.263	.393	.076	.143
Fusarium Monilliforme	.243 (16.66)	.177 (12.34)	.179 (20.00)	.211 (16.66)	.088 (30.04)	.111 (22.25)	.297 (30.00)	.330 (44.44)	.150 (15.15)	.201 (15.38)	.143 (9.84)	.541 (28.10)	.243 (30.00)	.329 (36.11)	.175 (33.33)	.076 (16.66)	.076 (20.00)	.151 (28.60)	(19.04)	(28.19)	(23.07)	(32.14)	(5.55)	(10.5
F. solani	-	-	-	-	.029 (6.66)	-	-	.082 (11.94)	.180 (18.18)	.201 (15.38)	-	-	.220 (26.87)	.101 (11.11)	.087 (16.31)	-	.025 (6.86)	-	.137 (23.33)	.157 (25.00)	.175 (15.45)	-	-	-
Gongronella butleri	-	-	.059 (6.66)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.100 (19.09)	-	-	-	-	.230 (16.66)	.28 (21.
Humicola fuscoatra	-	.126 (8.77)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.153 (11.11)	.21 (15.
Mortierella ramanniana	-	-	-	-	-	-	-	-	-	-	-	.035 (5.26)	-	-	-	-	-	-	-	-	-	.174 (21.59)	-	-
Mucor hiemalis	.322 (22.22)	.025 (1.75)	-	-	-	.083 (11.11)	-	-	-	-	-	.127 (7.01)	-	-	-	-	-	-	-	-	-	.131 (17.71)	-	-
M. racemosus	.107 (9.96)	-	.029 (3.36)	.052 (4.16)	.029 (6.66)	-	-	-	.067 (5.12)	-	.230 (15.68)	.031 (1.75)	.082 (10.00)	.050 (5.55)	-	.050 (21.13)	.025 (6.66)	.090 (9.52)	(19.08)	.078 (12.5)	-	-	.293 (27.7	.38 (26.3
Paecilomyces lilliacinum	-	.506 (38.08)	.089 (10.00)	.132 (10.41)	-	.027 (3.70)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Penicillium chrysogenum	-	.101 (7.01)	.149 (16.66)	.105 (8.33)	-	-	.363 (33.35)	.110 (14.81)	.210 (21.21)	.201 (15.39)	.316 (21.56)	.350 (19.29)	-	-	.117 (17.22)	.202 (44.44)	.051 (13.35)	.050 (9.52)	.137 (23.30)	.052 (8.33)	-	.087 (7.14)	.383 (22.29	.38 (6.34
P. fellutanum	.134 (17.25)	.101 (7.01)	-	-	.029 (6.66)	.055 (7.40)	-	-	-	-	.115 (7.84)	-	-	-	-	-	-	-	-	-	-	-	-	-
P. funiculosum	-	.025 (1.75)	.149 (16.66)	.105 (8.33)	.058 (13.33)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. javanicum	.134 (17.25)	-	.059 (6.66)	.052 (4.16)	-	-	.033 (3.33)	-	-	-	.057 (3.92)	-	-	-	-	-	-	-	-	-	-	-	.230 (16.66)	-
P. vermiculatum	-	.050 (3.50)	-	-	.029 (6.66)	.167 (22.22)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichoderma koningii	-	.152 (10.52)	-	-	-	.027 (3.70)	-	-	-	-	-	-	-	-	-	-	.025 (6.66)	-	-	-	-	-	-	-
T. viride	.081 (5.55)	.050 (3.50)	-	.185 (14.59)	.058 (13.33)	-	.066 (6.66)	.055 (7.40)	.210 (21.21)	.268 (28.22)	.230 (15.68)	.509 (28.07)	-	-	-	-	.076 (20.00)	.100 (19.04)	-	.105 (16.66)	-	-	-	-
White sterile	-	-	.089 (10.00)	.185 (14.58)	.117 (26.66)	.167 (22.16)	.165 (16.66)	.027 (10.70)	.240 (19.13)	.336 (25.64)	-	.191 (10.52)	.275 (33.33)	.455 (41.68)	.117 (17.22)	.126 (27.77)	.676 (20.00)	-	.092 (14.28)	.052 (8.33)	.219 (19.23)	.174 (14.28)	-	-
Yellow sterile	-	-	-	-	-	-	.099 (10.00)	.027 (10.70)	-	-	-	-	-	.050 (5.55)	.117 (17.22)	-	-	-	-	-	.483 (42.30)	.131 (7.14)	-	-

Table :5.4 Lists of fungi isolated from soil and earthworms casts in 5 year plantation.

I = Soil II = Cast + = Present - = Absent

Fungi	15/4/86		15/5/86		15/6/86		15/7/86		15/8/86		15/9/86		15/10/86		15/11/86		15/12/86		15/1/87		15/2/87		15/3/87	
Absidia glauca	I-	II-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Aspergillus niger	-	+	-	+	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Cunninghamella echinulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Curvularia maculans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Fusarium moniliforme	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
F. solani	-	+	+	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gongronella butleri	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Humicola fuscoatra	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Mucor hiemalis	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-
M. plumbeus	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. racemosus	+	-	-	-	-	-	-	-	+	-	+	-	+	+	-	-	+	+	-	-	-	-	-	+
Paecilomyces liliacinum	-	-	+	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Penicillium chrysogenum	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
P. fellutanum	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. funiculosum	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. javanicum	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
P. liliacinum	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
P. vermiculatum	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Trichoderma koningii	-	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	+	-	-	-	+	+	+	+
T. viride	+	+	-	-	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	-	-	-	+
Torula harbarum	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
White sterile	-	-	+	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
Yellow sterile	-	-	-	-	-	-	+	-	+	+	+	-	-	-	-	-	-	+	-	-	+	+	-	-

5.5 Fungal population (g^{-1} dry soil x 10^3) of earthworm casts and surrounding soils in 5 year plantation soil at different sampling period. Values in parentheses are percentage relative abundance.

	15/4/86		15/5/86		15/6/86		15/7/86		15/8/86		15/9/86		15/10/86		15/11/86		15/12/86		15/1/87		15/2/87		15/3/87	
Fungi	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast
Absidia glauca	.221 (14.81)	.150 (10.00)	-	-	-	-	.089 (9.09)	-	.114 (10.5)	-	-	-	.086 (9.09)	-	-	-	.050 (7.40)	-	-	-	-	-	-	.326 (21.10)
A. niger	-	.175 (11.66)	-	.209 (15.68)	-	-	-	-	-	.063 (7.71)	-	.231 (16.66)	-	-	-	-	-	-	-	-	-	-	.247 (20.00)	-
Curvularia maculans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.051 (11.11)	-	-	-	-	-	-	-	-
Fusarium moniliforme	.249 (6.66)	.201 (13.33)	.329 (26.19)	.209 (15.66)	.119 (33.34)	.247 (37.89)	.296 (18.19)	.247 (21.42)	.170 (15.38)	.159 (12.82)	.443 (29.62)	.376 (21.08)	.172 (18.18)	.308 (22.91)	.154 (33.33)	.176 (21.21)	.152 (22.22)	.230 (27.27)	.173 (22.22)	.208 (22.22)	.399 (32.14)	.219 (14.17)	.165 (13.13)	.245 (15.78)
F. solani	-	-	.029 (2.38)	-	.089 (25.00)	.137 (20.86)	.089 (9.09)	-	.057 (8.12)	.159 (12.82)	.110 (9.29)	.231 (16.66)	.172 (18.18)	.194 (14.58)	-	.025 (3.04)	-	-	.020 (25.94)	.130 (13.88)	.177 (14.28)	.262 (17.64)	-	-
Gongronella butleri	.249 (16.66)	.150 (10.00)	.119 (9.52)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Humicola fuscoatra	.055 (3.70)	.100 (6.66)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mucor hiemalis	.249 (16.66)	.201 (13.33)	-	-	-	-	-	-	-	-	-	.028 (2.08)	.057 (6.06)	-	-	-	-	-	-	-	-	.176 (11.80)	-	-
M. plumbeus	-	-	.119 (9.25)	.104 (7.84)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. racemosus	-	-	-	-	-	-	-	-	.028 (5.56)	-	.055 (3.70)	-	.057 (6.06)	.056 (4.16)	-	-	.050 (7.40)	.024 (3.03)	-	-	-	-	-	-
Paecilomyces lilacinum	-	-	.059 (4.79)	.183 (13.75)	-	-	.118 (12.12)	.082 (7.14)	.057 (8.12)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Penicillium chrysogenum	.304 (20.37)	.175 (11.66)	.239 (19.04)	.157 (11.36)	-	-	.148 (15.15)	.219 (19.07)	.086 (7.69)	.255 (20.51)	.221 (14.81)	.173 (12.53)	.114 (12.13)	.224 (16.66)	.051 (11.11)	.176 (21.21)	.101 (14.84)	.198 (24.24)	.086 (11.11)	.182 (19.44)	.044 (3.59)	.262 (17.64)	.165 (13.13)	.245 (15.78)
P. fellutanum	-	.100 (6.66)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. funiculosum	-	-	-	.471 (35.29)	-	-	-	.329 (28.57)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.247 (20.20)	-
P. javanicum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.025 (5.55)	.126 (15.15)	.025 (3.70)	-	-	-	-	-	-	-
P. liliacinum	-	-	.209 (16.66)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. vermiculatum	-	.050 (5.04)	.029 (2.38)	-	-	-	-	-	.057 (8.12)	-	-	-	-	-	-	-	-	-	-	-	-	-	.165 (13.13)	-
Trichoderma koningi	-	-	-	-	-	.082 (13.28)	-	.137 (11.90)	-	-	.055 (3.70)	-	-	-	-	-	-	-	-	-	.221 (17.85)	.087 (5.88)	.247 (20.20)	.245 (15.78)
T. viride	.138 (11.41)	.175 (11.66)	-	-	.149 (41.66)	.109 (12.04)	.178 (18.18)	.137 (11.90)	.258 (23.95)	.191 (15.38)	.304 (20.37)	.289 (20.83)	-	-	.128 (27.79)	.202 (24.24)	.127 (18.51)	.202 (24.24)	.244 (18.51)	.208 (22.22)	-	-	-	.245 (15.78)
Torula herbarum	-	-	-	-	-	-	-	-	-	-	.055 (3.70)	-	-	-	-	-	-	-	-	-	-	-	-	-
White sterile	-	-	.119 (9.52)	-	-	.054 (9.03)	.148 (15.15)	-	.086 (7.69)	.255 (20.51)	.194 (12.96)	.057 (4.61)	.229 (24.24)	.561 (27.53)	.051 (11.11)	.118 (15.15)	.152 (22.22)	.099 (12.13)	.173 (22.22)	.243 (22.24)	.310 (25.00)	.219 (14.70)	-	.245 (15.78)
Yellow sterile	-	-	-	-	-	-	.029 (3.03)	-	.057 (8.12)	.127 (10.25)	.027 (1.85)	-	.057 (6.06)	.056 (4.16)	-	-	.025 (3.70)	.074 (9.09)	-	-	.088 (7.14)	.262 (17.64)	-	-

Table 5.6 Fungi isolated from soil and earthworm casts in 10 year plantation soil.
+ = Present - = Absent I = Soil II = Cast

Fungi	15/4/86		15/5/86		15/6/86		15/7/86		15/8/86		15/9/86		15/10/86		15/11/86		15/12/86		15/1/87		15/2/87		15/3/87	
	I+	II+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Absidia glauca	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alternaria alternata	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aspergillus niger	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Curvulari maculans	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Fusarium moniliforme	-	-	-	-	+	+	-	+	+	+	+	-	+	+	+	+	-	+	+	+	+	+	-	-
F. solani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gongronella butleri	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Humicola fuscoatra	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mucor hiemalis	+	+	-	-	-	-	-	-	-	-	-	+	+	+	-	-	+	+	-	-	+	-	-	+
M. racemosus	-	-	+	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	+	-	-	-	+	-
Paecilomyces liliacinum	-	-	+	+	-	-	+	+	+	-	+	+	-	-	-	-	-	-	+	+	+	-	+	+
Penicillium chrysogenum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
P. claviforme	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
P. fellutanum	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
P. funiculosum	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. javanicum	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
P. liliacinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
P. verniculatum	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-
Trichoderma koningii	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+	+	+	+	-	-	-	-	-	-
T. viride	+	+	-	+	+	-	-	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	-	-
White sterile	-	-	+	+	+	+	+	+	+	+	-	+	+	+	+	+	-	+	-	-	+	-	-	-
Yellow sterile	-	-	-	-	-	-	+	+	-	-	-	-	-	-	+	+	-	+	-	-	+	-	-	-

Table 5.7 Fungal population (g^{-1} dry soil x 10^3) of earthworm casts and surrounding soils in 10 year plantation at different sampling period. Values in parentheses are percentage relative abundance.

	15/4/86		15/5/86		15/6/86		15/7/86		15/8/86		15/9/86		15/10/86		15/11/86		15/12/86		15/1/87		15/2/87		15/3/87	
Fungi	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast	Soil	Cast
Absidia glauca	.219 (14.81)	.153 (10.00)	.088 (9.09)	.156 (12.50)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.244 (18.75)	.241 (16.66)
Aspergillus niger	-	.179 (11.66)	-	-	-	-	-	-	-	.196 (18.18)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cunyalaria maculans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.052 (8.02)	-	-	-	-	-	-	-	-
Fusarium moniliforme	.247 (16.66)	.204 (13.33)	.177 (18.18)	.208 (16.66)	.176 (20.33)	.190 (26.92)	.061 (8.33)	.380 (44.44)	.156 (18.51)	.294 (29.18)	.397 (43.25)	.276 (20.61)	.280 (33.33)	.248 (33.33)	.167 (20.00)	.236 (32.00)	.180 (23.33)	.130 (11.90)	.119 (20.33)	.206 (20.51)	.304 (26.92)	.387 (30.00)	.163 (12.50)	.161 (11.11)
F. solani	-	-	-	-	.117 (22.22)	.054 (7.40)	-	.285 (33.33)	.156 (18.51)	-	.091 (10.00)	-	.156 (18.50)	.177 (18.31)	.111 (14.61)	.104 (13.33)	.025 (3.33)	.078 (7.14)	.228 (23.02)	.309 (30.76)	.130 (15.41)	.215 (16.66)	-	-
Gongronella butleri	.247 (16.66)	.153 (10.00)	.059 (6.06)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Humicola fuscoatra	.054 (5.59)	.102 (6.66)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.244 (18.75)	.161 (11.11)
Mucor hiemalis	.247 (16.66)	.204 (13.33)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.087 (7.69)	.172 (13.33)	-	-
M. racemosus	-	-	.029 (3.03)	.052 (4.16)	-	-	-	-	-	-	-	.069 (6.06)	.062 (7.40)	.248 (23.03)	-	-	.051 (6.68)	.052 (4.79)	-	-	.043 (13.84)	-	-	.161 (11.11)
Paecilomyces lilliacinum	-	-	.088 (9.09)	.130 (10.41)	-	-	.061 (8.33)	-	-	-	.122 (13.33)	.138 (12.00)	-	-	-	-	-	-	.057 (6.86)	-	-	-	.163 (12.50)	-
Penicillium chrysogenum	.302 (20.37)	.179 (11.66)	.206 (21.22)	.182 (14.58)	.088 (10.66)	.081 (12.84)	.030 (4.18)	-	.156 (18.51)	.098 (10.07)	.091 (10.00)	.103 (10.00)	.062 (7.40)	.248 (23.33)	.111 (14.61)	.104 (13.35)	.154 (20.00)	.234 (21.42)	.171 (20.00)	.154 (15.38)	.087 (7.69)	.043 (3.33)	.163 (12.50)	.241 (16.66)
P. claviforme	-	-	-	-	-	-	-	-	-	.065 (6.66)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. fellutanum	-	.102 (6.66)	-	-	-	-	-	-	-	.065 (6.66)	.061 (6.66)	.207 (20.00)	-	-	-	-	-	-	-	-	-	-	-	-
P. funiculosum	-	-	.177 (18.18)	.104 (8.37)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.086 (6.66)	-	-
P. javanicum	-	-	.059 (6.06)	.052 (4.16)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. liliacinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.163 (12.50)	-
P. vermiculatum	-	.051 (5.04)	-	-	.029 (5.25)	.135 (18.51)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.043 (3.33)	-	.161 (11.11)
Trichoderma koningii	-	-	-	-	-	-	-	-	-	-	.061 (6.66)	.069 (6.06)	-	-	-	-	.077 (10.00)	-	-	-	-	-	.163 (12.50)	-
T. viride	.137 (9.25)	.179 (11.66)	-	.182 (14.58)	.088 (10.66)	-	-	.190 (22.23)	.187 (22.23)	.326 (30.33)	.091 (10.00)	.103 (10.00)	-	-	.111 (14.61)	.131 (16.66)	.129 (16.66)	.130 (11.90)	.140 (16.66)	.206 (20.51)	-	-	-	.322 (22.24)
White sterile	-	-	.088 (9.09)	.182 (14.58)	.205 (30.88)	.244 (34.33)	.246 (33.33)	-	.187 (22.23)	-	-	.172 (15.15)	.280 (33.33)	.177 (18.31)	.223 (25.06)	.104 (13.33)	.154 (20.00)	.286 (26.19)	.114 (13.33)	.129 (12.84)	.261 (23.07)	.344 (26.69)	-	-
Yellow sterile	-	-	-	-	-	-	.338 (45.83)	-	-	-	-	-	-	-	.083 (11.11)	.026 (3.33)	-	.182	-	-	.174 (15.38)	-	-	-

From the 5 year plantation soil and casts a total number of 22 fungal species was isolated among which 13 species were common in soil as well as the casts. The main difference between the fungal species isolated from the soil and casts was that of Aspergillus niger; Penicillium funiculosum and P. fellutanum were isolated from the casts only while Curvularia maculans; Penicillium liliacinum and Torula herbarum were found restricted to the soils. 16 fungal isolates were common in soil as well as in casts. Aspergillus niger; Curvularia maculans; Humicola fuscoatra; Mucor plumbeus; Penicillium fellutanum; P. funiculosum, P. javanicum; P. liliacinum; P. vermiculatum; and Torula herbarum showed their rare occurrence in soil as well as in casts of 5 year plantation. Remaining 12 fungal species were frequently isolated (Tables 5.4,5.5).

A total number of 21 fungal species was isolated from the soil and casts of the 10 year plantations(Tables 5.6,5.7). Out of 21, 18 fungal species were recorded from the soil and 20 species were recorded from the casts. The main fungal species which were not recorded from the soil were Aspergillus niger, Curvularia maculans and Penicillium claviforme. Similarly, Penicillium liliacinum was not recorded from the casts of the 10 year plantation(Tables 5.2,5.7). The species which showed their rare occurrence in soil and casts were Absidia glauca, A. niger; Curvularia maculans; Gongronella butleri; Humicola fuscoatra;

Penicillium claviforme, P. fellutanum; P. funiculosum; P. javanicum; P. liliacinum and Trichoderma koningii; Fusarium moniliforme; F. solani; Penicillium chrysogenum; Trichoderma viride and white sterile were the most dominant fungi isolated from both the soil as well as the casts.

Enzyme activities in soil and casts :

Dehydrogenase :

Fig.5.3 depicts the dehydrogenase activity in soil and earthworm casts of three plantations. Higher dehydrogenase activity was recorded from the earthworm casts in all the cases (Fig.5.3). In case of 1 year plantation maximum dehydrogenase activity was estimated on 15th July, 1986.In case of 5 year plantation the activity in soil was maximum on 15th July, 1986 and in casts the maximum activity was recorded on 15th May,1986. In 10 year plantation, dehydrogenase activity peaked on 15th October, 1986 in case of casts and on 15th May or July in case of soil (Fig.5.3). After attaining the peak the dehydrogenase activity generally, decreased in all the cases. In most cases, the drop in activity continued upto 15th January,1986 and the increase was observed in the following month. Difference in dehydrogenase activity in soil and casts followed a trend 10 year > 5 year > 1 year plantation.

Urease :

Higher urease activity was also noted from the

Fig.5.3 Monthly variation in dehydrogenase activity of earthworm cast and soil of pineapple plantations.

Fig. 5.3

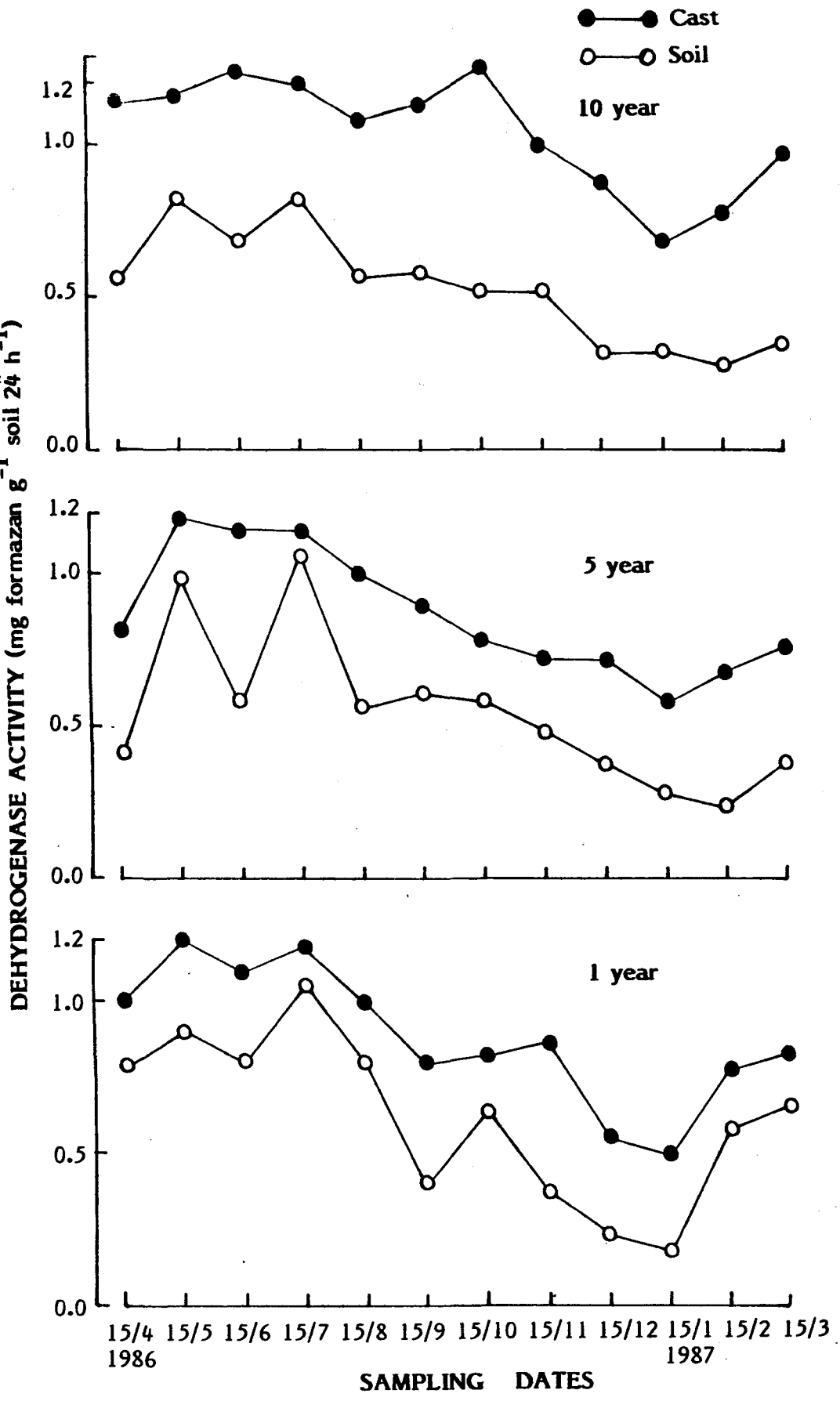

Cast
Soil
10 year
5 year
1 year
1.2
1.0
0.5
0.0
DEHYDROGENASE ACTIVITY (mg formazan g^{-1} soil 24 h^{-1})
15/4 15/5 15/6 15/7 15/8 15/9 15/10 15/11 15/12 15/1 15/2 15/3
1986
1987
SAMPLING DATES

Fig.5.4 Monthly variation in urease activity of earthworm cast and soil of pineapple plantations.

Fig. 5.4

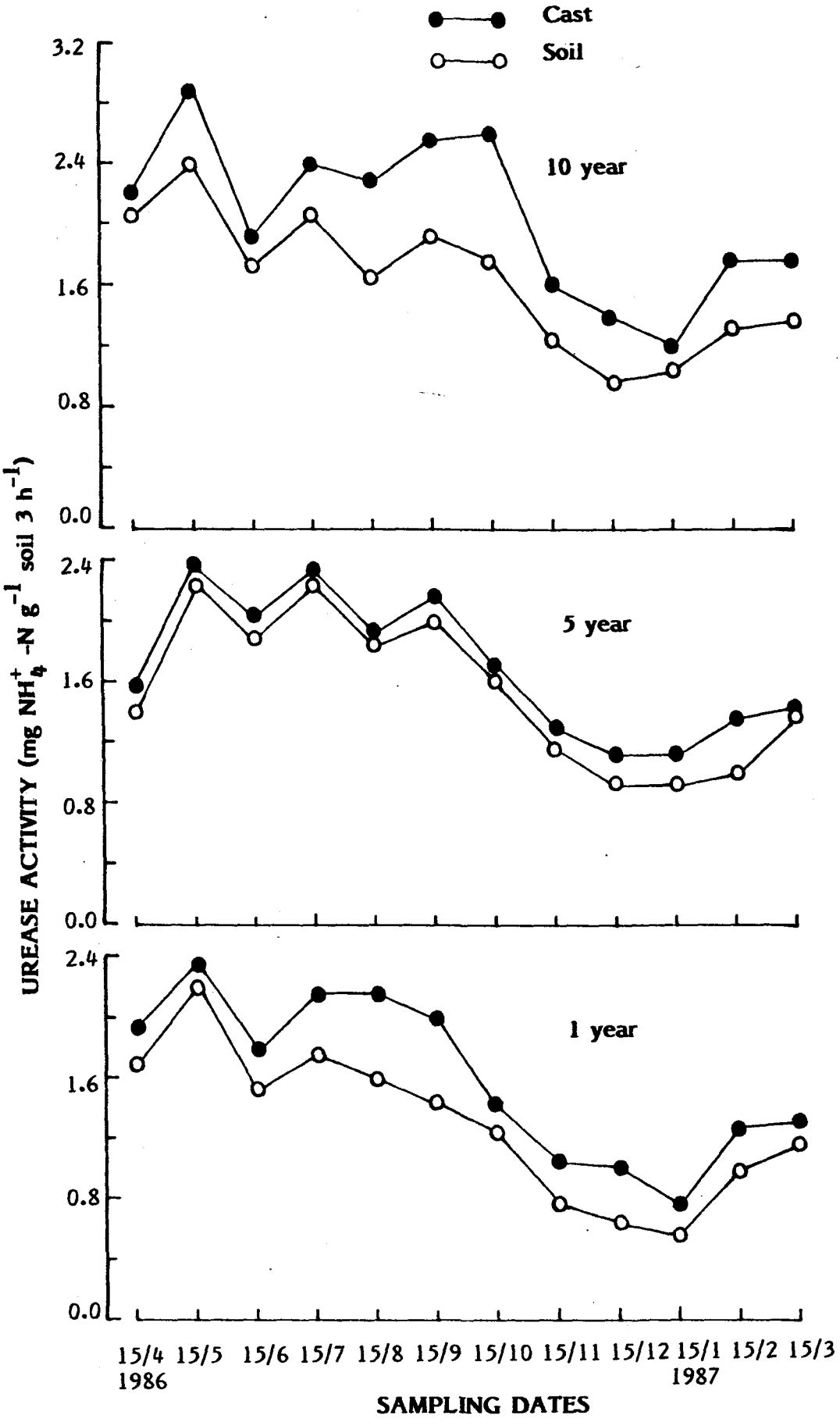
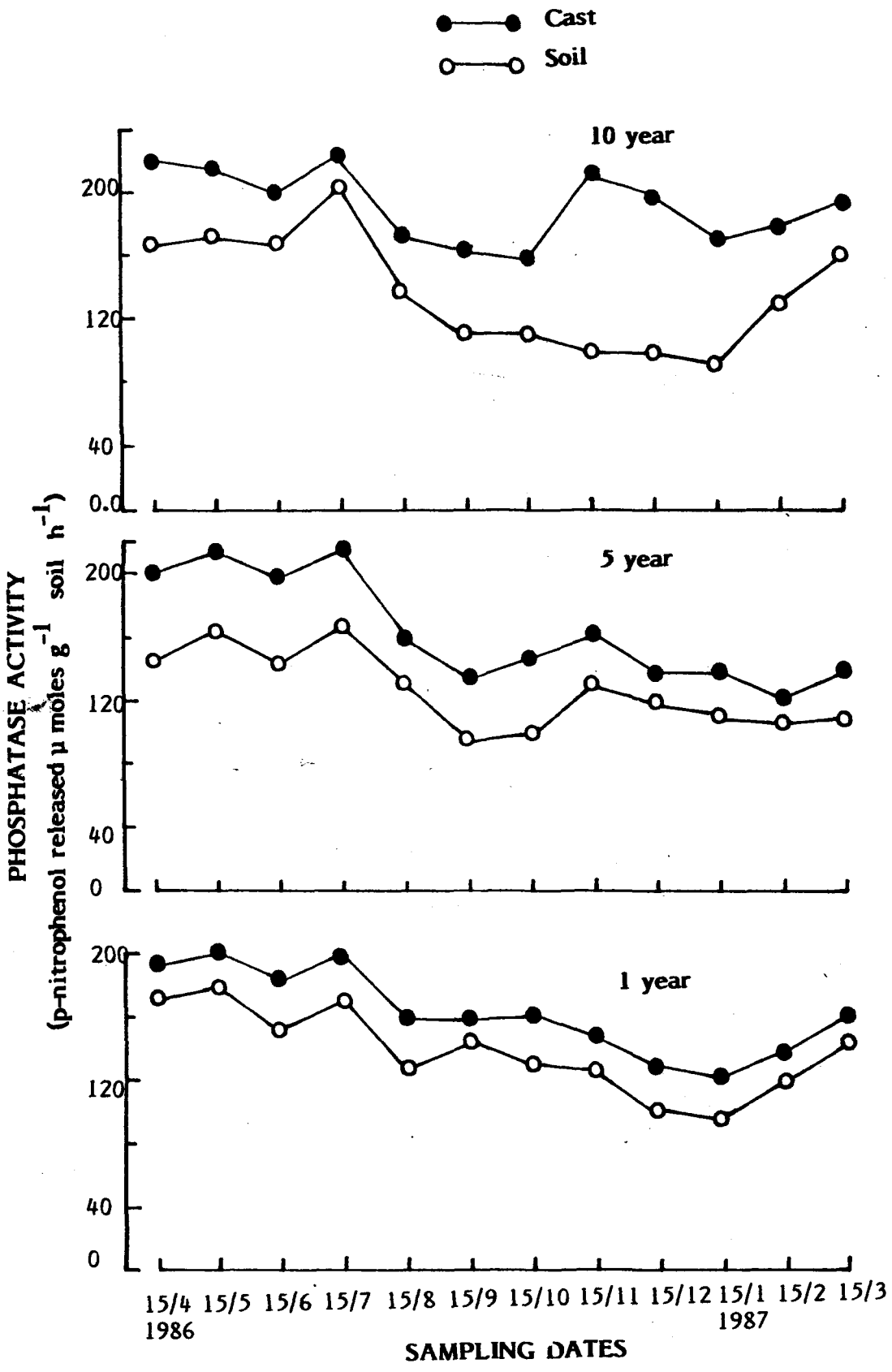

Cast
Soil
10 year
5 year
1 year
3.2
2.4
1.6
0.8
0.0
UREASE ACTIVITY (mg NH_4^+ -N g^{-1} soil 3 h^{-1})
15/4 1986
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1 1987
15/2
15/3
SAMPLING DATES

Fig.5.5 Monthly variation in phosphatase activity of earthworm cast and soil of pineapple plantations.

Fig. 5.5


Cast
Soil
10 year
5 year
1 year
200
120
40
0.0
0
PHOSPHATASE ACTIVITY
(p-nitrophenol released μ moles g⁻¹ soil h⁻¹)
15/4 1986
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1 1987
15/2
15/3
SAMPLING DATES

earthworm casts (Fig.5.4). Generally, the trend of temporal variation of activity in soil as well as in casts was similar in all the plantations. Urease activity peaked on 15th May, 1986 in all the cases. Thereafter, a sudden drop in activity was recorded from all the plantations. In 1 year plantation the activity increased on 15th July,1986. The drop in activity was again noted on 15th September,1986 which remained upto 15th January,1987. In case of 5 year plantation the activity increased on 15th July,1986 which was followed by a drop on 15th October,1986. Thereafter,the activity decreased and continued upto the sampling date 15th January,1987. Generally, similar trend of activity was recorded from the 10 year plantation as was in the case of 5 year plantation. After winter season the activity increased in most cases (Fig.5.4). Urease activity of soil and casts varied within a narrow range in case of 5 year plantation while in rest of the plantations the difference was more pronounced.

Phosphatase :

Generally, similar trend of temporal variation in phosphatase activity of soil and casts was noted from all the plantations. Earthworm casts contained higher phosphatase activity than the soil(Fig.5.5). During early samplings higher phosphatase activity was recorded in soil as well as in casts. Peak in phosphatase activity was noted on 15th

July,1986. Thereafter, phosphatase activity decreased in most cases. A slight increase in activity was noted on 15th November, 1986 in 5 year and 10 years plantations which was again followed by a drop. The activity increased on 15th February,1987 in most cases except that of 5 year plantation where increased activity was noted on 15th March,1987. Plantation-wise variation in phosphatase activity within soil and casts followed a trend 10 year > 5 year > 1 year (Fig.5.5).

Organ carbon :

Percentage organic carbon of the soil and casts are shown in Fig.5.6. Earthworm casts contained higher organic carbon than the surrounding soils (Fig.5.6). Generally, similar trend of temporal variation in organic carbon of soil and casts was noted from all the plantations. Initially, soil and casts contained higher organic carbon. The drop in organic carbon was noted after September, 1986 and upto sampling period 15th February,1987 the organic carbon content remained at a low level. Thereafter, the organic carbon content of the soils increased (Fig.5.6).

Nitrogen :

Fig.5.7 depicts the variations of percentage of nitrogen in soil and in casts. From the fig.5.7 it is evident that casts always contained higher nitrogen than the soil. Peak in nitrogen content was noted on 15th July,

Fig. 5.6 Monthly variation in phosphatase activity of earthworm cast and soil of pineapple plantations.

Fig. 5.6

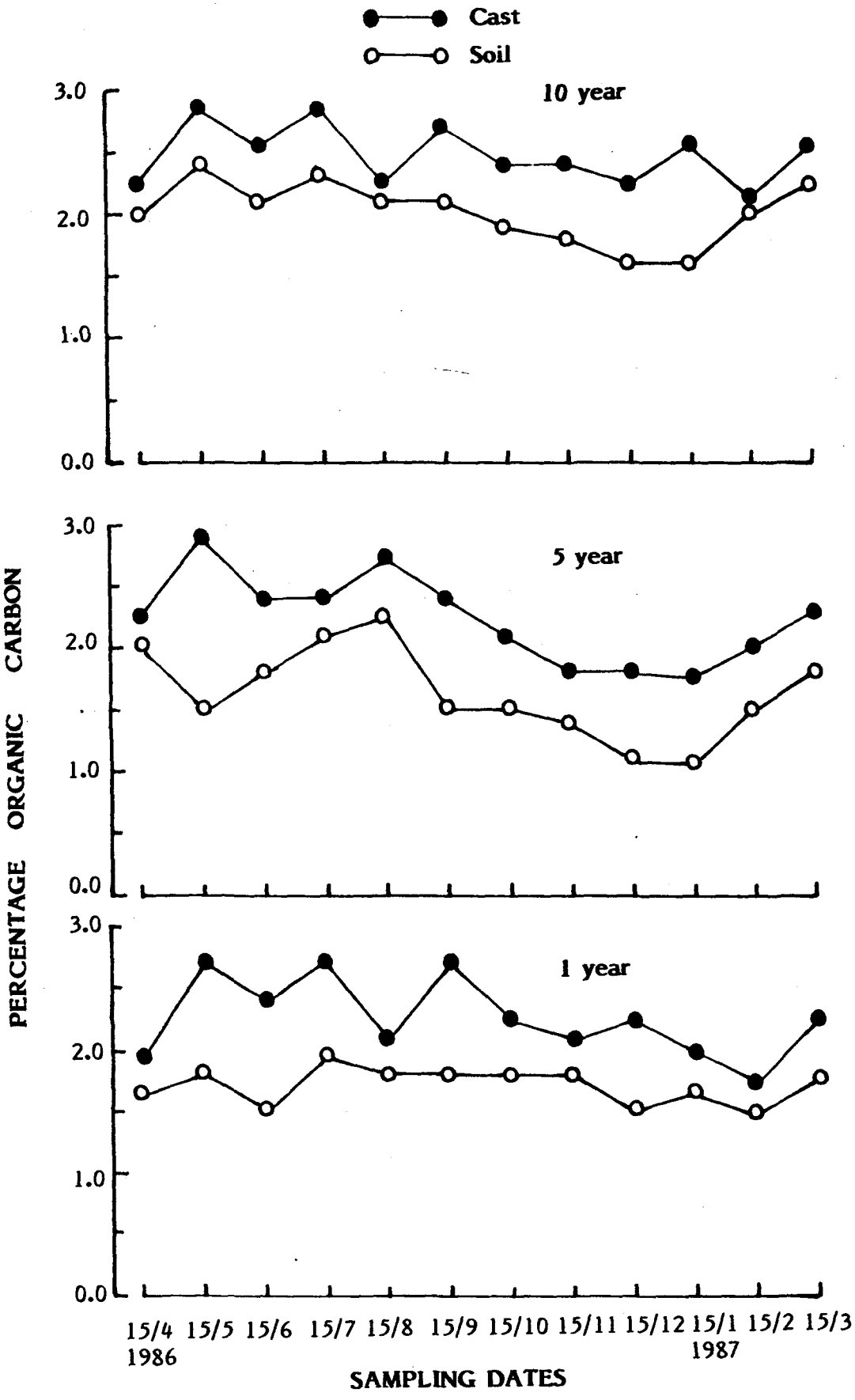

Cast
Soil
10 year
5 year
1 year
3.0
2.0
1.0
0.0
PERCENTAGE ORGANIC CARBON
15/4 1986
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1 1987
15/2
15/3
SAMPLING DATES

Fig. 5.7 Monthly variation in total nitrogen content of earthworm cast and soil of pineapple plantations.

Fig. 5.7

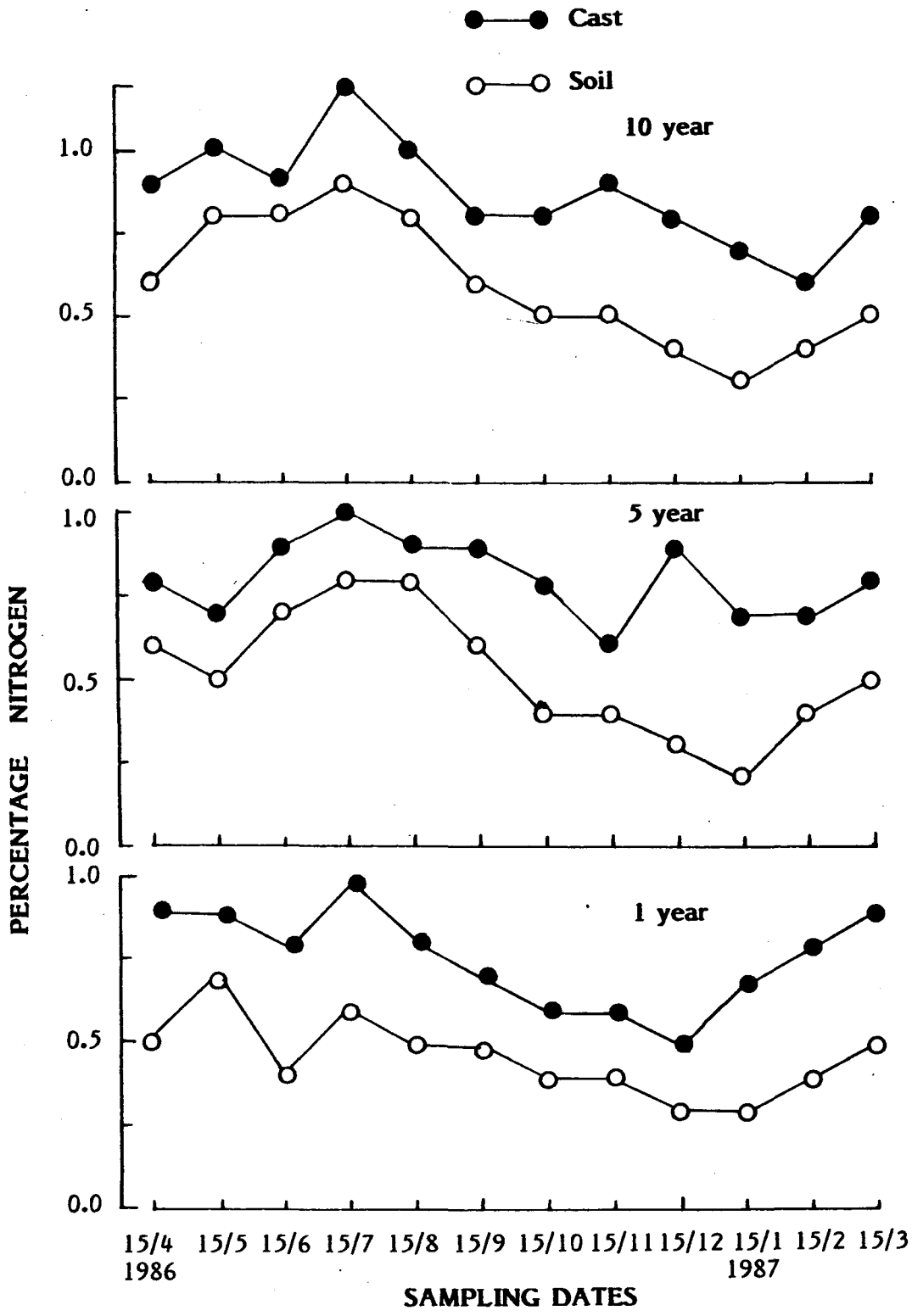

Cast
Soil
10 year
5 year
1 year
1.0
0.5
0.0
PERCENTAGE NITROGEN
15/4
1986
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1
1987
15/2
15/3
SAMPLING DATES

Fig.5.8 Monthly variation in available phosphorus of earthworm cast and soil of pineapple plantations.

Fig. 5.8

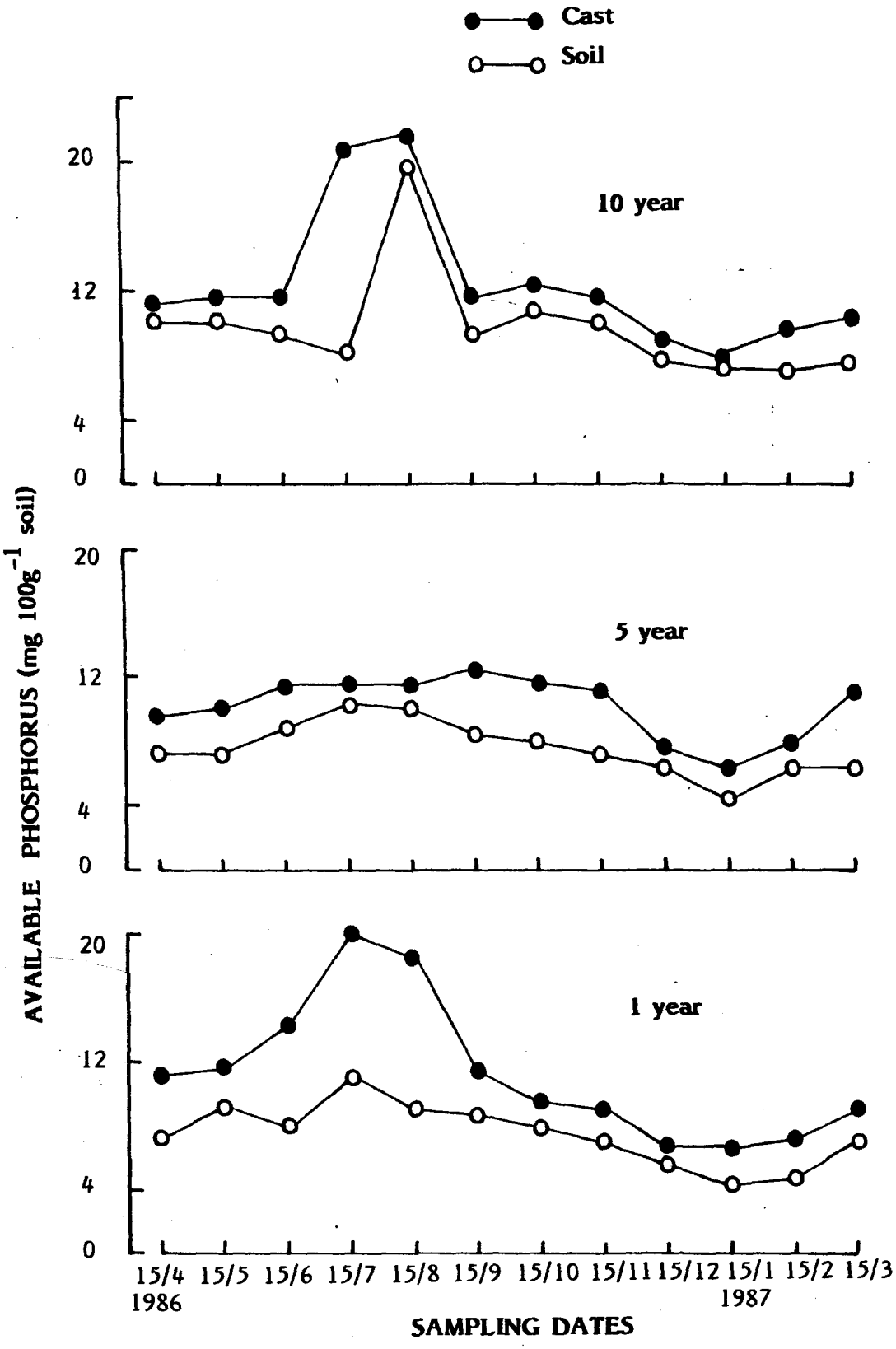
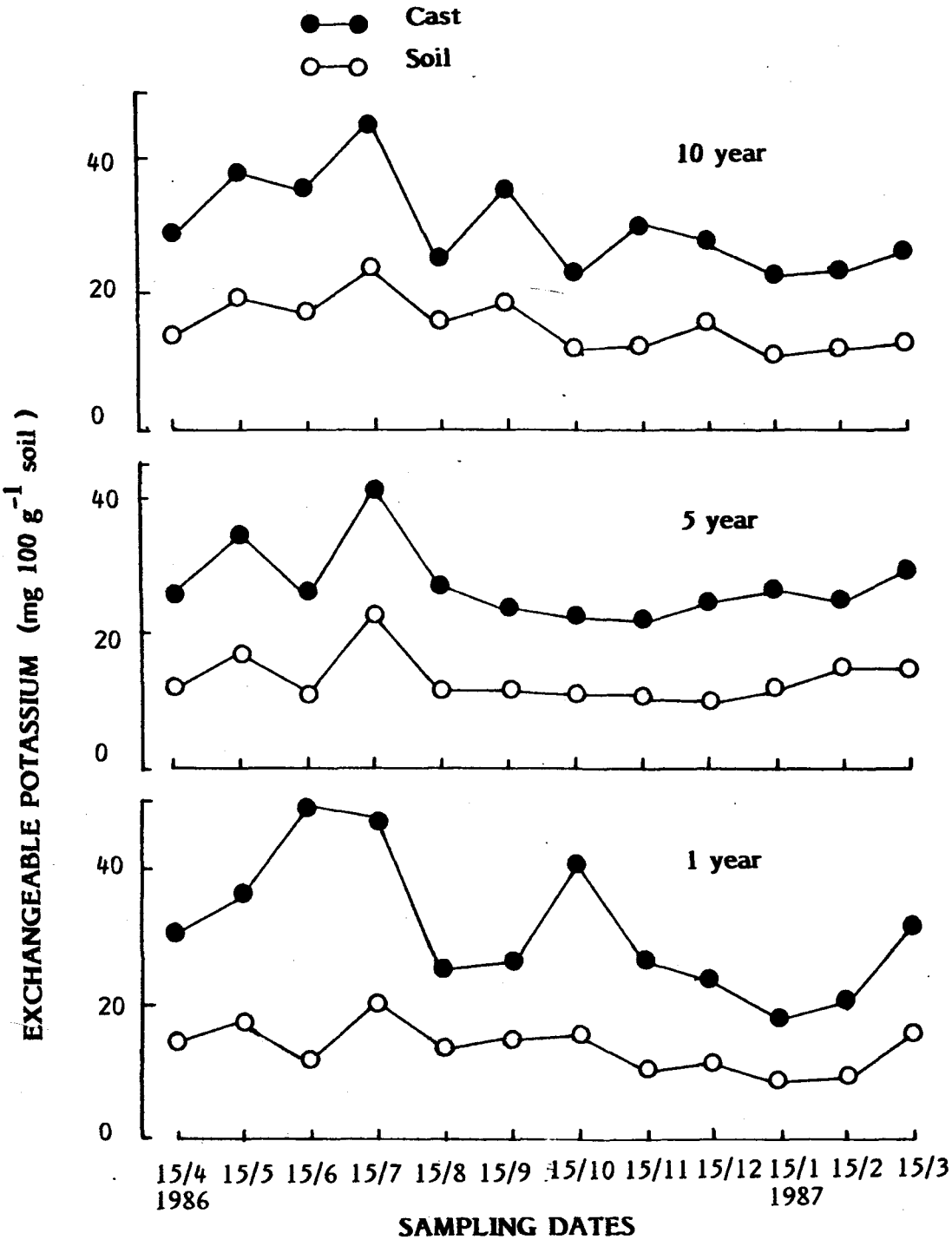

Cast
Soil
10 year
5 year
1 year
20
12
4
0
AVAILABLE PHOSPHORUS (mg 100g^{-1} soil)
15/4 15/5 15/6 15/7 15/8 15/9 15/10 15/11 15/12 15/1 15/2 15/3
1986
1987
SAMPLING DATES

Fig.5.9 Monthly variation in exchangeable potassium of earthworm cast and soil of pineapple plantations.

Fig. 5.9


Cast
Soil
10 year
5 year
1 year
40
20
0
EXCHANGEABLE POTASSIUM (mg 100 g^{-1} soil)
15/4 1986
15/5
15/6
15/7
15/8
15/9
15/10
15/11
15/12
15/1 1987
15/2
15/3
SAMPLING DATES

1986 in all the cases followed by a drop. An increase in nitrogen content was observed on 15th January, 1987 in case of 1 year plantation and 15th February, 1987 in case of 5 year and 10 year plantations.

Available phosphorus :

Available phosphorus of soil and casts is shown in Fig. 5.8. Phosphorus content of soil and casts in the three plantations differed in a wide range (Fig.5.8). In case of 5 year plantation the temporal variations were not much pronounced except that of a drop during winter (Fig.5.8). In 1 year and 10 year plantations a peak was observed during winter (Fig.5.8). In 1 year and 10 year plantations a peak was observed during July/August. The peak was more prominent in case of casts than that of the soil (Fig.5.8). In cases of 1 year and 10 year plantation phosphorus content decreased after attaining the peak and continued upto the sampling date 15th January, 1987. In most cases increased phosphorus content was noted on 15th February,1987.

Exchangeable potassium :

Fig.5.9 shows the variation in exchangeable potassium in soil as well as in casts. From the fig.5.9 it is quite evident that earthworm casts always contained higher exchangeable potassium than the soil (Fig.5.9). Generally, similar trend of variation in exchangeable potassium was noted from all the plantations studied. Peak in exchange-

able potassium was recorded on 15th July, 1986 in all the plantations and thereafter a decrease was noted. Rise in exchangeable potassium was generally, noted at the end of the sampling dates (Fig.5.9).

DISCUSSION

Vleeschauwer and Lal (1981) reported that earthworm casts had about two to six times more organic matter content, two to four times more nitrogen, two to eight times more bray phosphorus than the parent soil. Lal and Vleeschauwer (1982) further, assessed that worm casts contained 2.3 to 1.5 times more organic matter, 1.8 to 1.2 times more nitrogen, 1.6 to 1.3 times more bray phosphorus, 3.1 to 2.2 times more exchangeable potassium than the top 10cm of the soil. Syers et al. (1979) noted that casts contained higher total nitrogen (3.8mg N g^{-1}) than that of the underlying 0.5cm soil (2.3mg N g^{-1}). Sharpley and Syers (1976) found that the earthworm casts were enriched in water soluble phosphorus in comparison with the underlying soil. Recently Krishnamoorthy and Vajranabhaiah (1986) studied the biological activity of earthworm casts and found that it is rich in ammonia, urea, organic carbon content, soluble phosphorus and ionic potassium levels.

The results of present study are in general conformity with the observations of above authors. The nutrient

enrichment of casts relative to the soil matrix occurs because the organic materials ingested by earthworms contain a higher concentration of nutrients than the soil. Barley and Jennings (1959) suggested that the action of digestive secretions enhanced the decomposition of organic matter. The increase in the Nitrogen content of casts has been attributed to the intimate mixing of plant remains and animal manure with mineral soil in the digestive tract of the earthworms (Lunt and Jacobson, 1944). The main nitrogenous waste excreted by the earthworms is ammonia. Besides ammonia, other substances like urea, uric acid and amino acids are also excreted in much smaller quantities. These waste materials are discharged into the gut lumen from where they are eliminated with faeces. This may be the reason for nutrient enrichment of casts. Another reason for the high concentration of Nitrogen in the casts might be the rapid mineralization of crop residues because there is slight evidence in the support of the hypothesis that earthworms have a positive influence on N fixing bacteria (Day, 1950; Khambata and Bhatt, 1957).

Nitrogen content of the surrounding soil and the earthworm casts varied significantly (P=0.01). Feeding and burrowing activities of the earthworms enhance the availability of phosphorus to the plants. Mackay et al. (1982) suggested that ingestion of phosphate rock (PR) particles

by the earthworm during feeding, could lead to an increase in the degree of intimate contact of the phosphate rock with the soil during passage through the digestive tract. This intimate contact could promote dissolution of the PR, leading to an increase in the plant availability of phosphorus in the phosphate rock. Mackay et al. (1983) further suggested, that both burrowing and casting activity of earthworms indirectly increase the availability of phosphorus to the plant. The difference in the available phosphorus between the casts and the soil was found statistically significant (P=0.05).

In present investigation the higher values of organic carbon and exchangeable potassium were recorded from the casts. Syers et al. (1979) and Vleeschauwer and Lal (1982) also recorded several fold increase in organic matter and exchangeable potassium of the casts in comparison to the soil. Difference in organic carbon and exchangeable potassium in both cases (Casts and soil) was statistically significant (P=0.001, 0.05).

Numerous investigators have reported increase in numbers of microorganisms in either the gut or casts material of earthworm in relation to the surrounding soil (Satchell, 1967; Kozlovskaya, 1969; Dash et al. 1979; Brown, et al. 1978). Ponomareva (1962) observed 13 times more

bacteria in earthworm casts than the surrounding soil.

Several folds increase in numbers of fungi, bacteria and actinomycetes in earthworm casts was also reported by Parle (1963) and Dkhar (1983).

Earthworm casts harboured higher bacteria and fungi in the present study also. Presumably the conditions were less suitable for the growth of fungi in the earthworm tract because the difference in fungal population between casts and soil was less than that of the bacterial population. Recently Gorbenko et al. (1986) have noted that the fungal mycelium decreased abruptly and bacterial cell content increased in faeces of earthworm. Domsch and Banse (1972) reported total destruction of fungi after passing through the earthworm intestine. Dawson (1947) observed that the number of bacteria was reduced by passage through the digestive canal while fungi were unaffected.

Higher microbial activity in earthworm casts might be due to intensification of the mineralization process (Kozlovskaya 1969). Another possibility for difference in microbial population in earthworm casts and surrounding soil may be due to environmental changes within the earthworm's digestive tract or due to the food material ingested which provides a rich substrate for the growth of microorganisms.

Qualititatively the microflora of soil and casts did not differ much. Generally, fungi isolated from casts were also found in the soil. Satchell (1967) and Lofty (1974)also reported a similar finding.

Earthworms do not digest all the fungal species which they ingest with their food (Nielson, 1962). There is some evidence that some of the microorganisms which are taken by the earthworm are digested during their passage through the earthworm gut and the spores of some fungi germinate after passing through the earthworm gut (Dash et al.1979).

From tables 5.2 - 5.7, it is evident that Penicillium liliacinum and Torula herbarum were found to be present in the surrounding soil and were not recorded from the casts, thereby indicating that these species are digested in the alimentary canal of the earthworms. On the other hand, Aspergillus niger; Curvularia maculans and Penicillium fellutanum; P. funiculosum; P. claviforme and Curvularia maculans which were not present in the soil were isolated from the earthworm casts. Probably these fungi were taken by the earthworms from other sources besides soil. Another possibility is that probably the spores of the above fungi germinated after passing through the digestive tract while in the soil although they might have been present and could not be isolated as they did not germinate. Presence of Fusarium moniliforme; F. solani; Mucor hiemalis; M. plumbeus,

M. racemosus; Absidia glauca; Trichoderma viride; T.koningii; Penicillium chrysogenum; P. fellutanum; P. funiculosum. P. javanicum; P. vermiculatum; Alternaria alternata; Aspergillus niger; Cunninghamella echinulata; Gongronella butleri; Humicola fuscoatra; Mortierella ramanniana; Paecilomyces liliacinum; white and yellow sterile in both the soil as well as in casts indicated that these species were not affected by the passage through the digestive tract of the earthworms.

The type and quality of ingested material helps to determine the size of microfloral populations in casts. The composition of fungal species of earthworm casts possibly depends on the flora of the plant material recently eaten by them. Further, the occurrence of similar type of fungal species in the soil as well as in the casts of the earthworm indicates that majority of them are not digested in the gut of the earthworms.

Differences in fungal population between casts and soil were not found to be statistically significant. While statistically significant (P=0.05) difference was noted in the bacterial population of the earthworm cast and surrounding soil.

Seasonal variation in the microbial population and their activities of the earthworm casts and soil might be due to variation in the organic matter content, soil pH and

moisture. Increase in dehydrogenase, urease and phosphatase activity were noted in casts than the soil. Syers et al. (1979); Roos and Cairns (1982); Businelli et al. (1984) and Satchell and Martin (1984) also reported several fold increase in the dehydrogenase, urease and phosphatase enzyme activities in the earthworm casts. The number of microbes fungi and bacteria increased several folds after passing through the gut which might be responsible for the increase in microbial activity (Parle, 1963). This enhanced microbial activity is probably responsible for the increased dehydrogenase (Ross and Roberts, 1970), urease (Syers et al.1979) and phosphatase (Sharpley and Syers, 1976) enzyme activity of the earthworm casts.

The higher urease activity in the casts could be attributed to increase in amounts of organic matter content (Syers et al.1979). Urease is known to be highly correlated with the organic matter contents (Beri et al.1978).

Higher phosphatase activity in casts may collectively be due to the substantially increase directly by the worms own enhanced enzymestic level and also indirectly by the stimulation of the microflora (Satchell and Martin, 1984; Sharpley and Syers, 1976).

Seasonal variations in enzymes activities of surrounding soil and earthworm casts are generally associated with fluctuations in soil moisture, temperature, microbial

population, organic matter and available phosphorus content.

Differences in the enzymeactivity estimations of soil and casts were analysed statistically and most of the differences were statistically significant. Difference between the enzymes activities (dehydrogenase, urease, phosphatase) of soil and casts were found to be statistically significant (P=0.05).

Feeding and burrowing activities of earthworm increased the microbial activity and nutrient status of the soils. It may be concluded that earthworms are responsible for the distribution of soil fungi, enrichment of casts in C,N,P,K contents and microbial activity. Earthworms bring out favourable changes in nutrient contents of the soil which is probably done through the enhanced microbial populations and rates of biochemical processes.

GENERAL DISCUSSION

Physico-chemical characteristics viz., soil temperature, moisture, pH and C,N,P,K contents of three plantation soils showed a decreasing trend along depth (Fig.1.1-1.7). Higher soil temperature recorded from the surface (0-10 cm) soils was due to heating by solar radiations. Low soil temperature in deeper soils could be ascribed to the insulation effect of the upper soil and litter layer. Higher moisture content in surface soils was found to be directly correlated with the rainfall (Fig.1.2). During winter the higher moisture content in deeper soils and lower in surface soils might be attributed to the less rainfall and high evoperation rate during the same period. pH of the soils did not differ significantly in all the three plantations and at different depths. In general, the surface soils of pineapple plantaion soils was more acidic than the deeper soils. Monthly variation in %moisture, temperature and pH of pineapple plantation soils was more pronounced in surface (0-10 cm) soils as also reported by Das(1980), Baruah (1983) and Dkhar (1983) from the forest, rice and maize field soils respectively. Generally, similar trend of temporal and depthwise variation in these properties of the soils was noted from all the three plantation soils. These characteristics of all the three plantation soils did not differ much which might be attributed to the little site variations. However, monthly and depthwise variations among all the plantations soil varied in a wide range which was in correspondence to the climatic changes.

Surface (0-10 cm) soils of all the plantations showed higher concentrations of C, N, P and K (Figs.1.4-1.7) which might be due to higher organic matter present on the surface of soils (Blackmore, 1966; Dkhar, 1983). Surface layer is continuously enriched by the nutrients released from the decomposing litter, this may be the another reason for the higher concentration of nutrients in surface soils. For these elements the deeper soils mainly depend on the mineralization process at the surface layer, because the nutrients released in this layer percolate down the profile along with the water. Temporal variations in nutrient contents is related to the variations in 'biological activity' occurring in this zone.

Depth-wise, organic carbon content of the pineapple plantation soils showed a trend 0-10 cm > 10-20 cm > 20-30 cm depth soils. Temporal variation in organic carbon content was more pronounced in surface soils than those of the deeper soils (Fig.1.4). These variations may be partly related to the release of organic matter from the accumulated litter on the surface. Similar result was also noted by Singh (1980) in broad leaved forest soils. Increased organic carbon during spring (March) might be due to addition of more organic matter from the decomposing litters during the same period. Because during spring a large amount of litter in the form of dead and old leaves was added to the soil. Higher microbial activity during the same period may

transfer the soluble organic matter from decomposing litters. During spring and following summer the activity of microorganisms was maximum. Thus, a large amount of organic matter is lost through soil respiration and mineralization resulting into lower values of organic carbon and nitrogen during winter months (Tiwari et al. 1987 c). Depth-wise distribution of N content was found to be quite similar to that of the organic carbon content (Fig.1.5). Phosphorus content of the soils did not vary much along depth however, surface (0-10 cm) soil showed higher phosphorus content. Increased phosphorus content of the soils in spring is related to the greater microbial activity during the same period as also reported by Ahlgren and Ahlgren (1965). Little variations of phosphorus contents in deeper soils might be due to the immobility of the phosphates (Bieleski, 1973). Exchangeable potassium of the soil was in correspondence with the soil temperature as higher concentration of this cation was noted during the higher temperature conditions. Haagsma and Miller (1963) also reported the similar results Moisture content of the soils was also found directly related to the availability of potassium as was also noted by Kuchenbuch et al. (1986).

Higher concentrations of all nutrients (C,N,P and K) was noted from the surface (0-10 cm) soils which decreased with increase in depth (Figs.1.4-1.7). Increased levels of all nutrients were noted during spring (March)

and lower values were generally, recorded during winter in all the plantation soils (Figs. 1.4-1.7).

Temporal and depth-wise variation in physico-chemical characteristics of the pineapple plantation soils was quite similar to variations in agricultural soils of this region (Baruah, 1983; Dkhar, 1983).

Microbial population (fungi and bacteria) showed more or less similar trend of monthly variation in all the plantations studied (Figs.2.1,2.2). Fungal and bacterial population per gram dry soil was highest in surface (0-10 cm) soils which decreased with increasing depth(Fig.2.1). In case of fungi higher number of fungal propagules was recorded from the deeper soils during winter (Fig.2.1). Higher fungal population was recorded during spring (March) while lower population was recorded during winter (Fig.2.1). Low fungal population during winter in all the plantation soils appears to be due to effect of low temperature during the same period (Fig.1.1). The effect of low temperature was more pronounced in surface soils. Probably, due to insulation, fungi of deeper soils were less affected resulting into higher populations in deeper soils. Results of the present study are also in conformity with the observations of Dwivedi (1965); Tyagi (1973) and Behera and Mukerji (1985). Increase in fungal population of deeper soils, was, however, not observed by these workers could be the above studies were conducted at lower altitudes where winter

temperature did not drop beyond the tolerance limit of the fungi. Two peaks in bacterial population were noted; one in September and another in April during both the study years (Fig.2.2). In September the increased moisture level of soils might be responsible for the increased bacterial population. During April higher bacterial population is ascribed to the onset of rains resulting into increased moisture which may transfer the soluble organic matter from decomposing plant litter as most of the litter are added to the soil during this period. Rise in temperature may also be responsible for the increased bacterial population during the same period (Fig.1.1). The drop in bacterial population during winter may be ascribed to the low temperature (Fig.1.1). and/or depletion of soluble organic matter. Higher microbial population (fungi and bacteria) in surface (0-10 cm) soils could be attributed to the higher organic carbon and favourable moisture content in the layer (Tate and Terry, 1980; Baldenosperger, 1981; Deka, 1981; Kauri, 1982; Baruah, 1983; Dkhar, 1983). Temporal variation in microbial population (fungi and bacteri) is in correspondence with the changes in soil organic matter content, moisture content, temperature and pH (Dwivedi, 1966; Mishra, 1966; Wong, 1975; Dunn et al. 1985; Dkhar and Mishra, 1987; Tiwari et al. 1987 b). Fungal population correlated positively with soil moisture, temperature, organic carbon, total nitrogen, available phosphorus, exchangeable potassium contents, dehydrogenase and

urease activity. However, a negative correlation was also observed between fungal population and CO_2 evolution (Tables 2.19-2.21). Bacterial population correlated positively with soil temperature, phosphatase and urease activity (Tables 2.19-2.21).

Fungal flora of different plantations did not vary significantly (Tables 2.1-2.18). Similarly, the fungal species did not show marked differences along depths. Majority of the fungal species were generally isolated from all the depths and from all the plantations studied. Pugh (1962) and Wohlrab et al. 1963) pointed out that each vegetational community harbours a specific mycoflora. More or less fungal flora of all the plantations are attributable to the similarity in type of vegetation cover (Mishra and Kanaujia, 1972). From the tables 2.1-2.18, it is evident that different fungal species were not confined to a particular soil horizon. Hardly a few species were found to be restricted to a specific depth or plantation. Distribution of most of the fungal species to all depths may be ascribed to the activities of soil animals (earthworms) because their feeding and burrowing activity homogenize the species composition along all the depths.

Higher activities of all the studied enzymes namely; dehydrogenase, urease and phosphatase were found in surface (0-10 cm) soils which decreased with increasing depths (Figs.2.3-2.5). Increased enzyme activities were generally

noted during spring in all the plantation soil. During winter the activities of all the enzymes were minimum. Generally, similar trend of variation in the activities of the enzymes were noted in all plantations. Dehydrogenase activity in pineapple plantation soils is related to the soil temperature, moisture and organic carbon content of the soil as during the period of higher dehydrogenase activity they were also higher (Figs. 1.1,1.2,1.4). Fungal and bacterial populations were not found to be correlated with dehydrogenase Similarly, Das and Mishra (1986) also did not find any correlation between organic matter content, microbial population and dehydrogenase activity. But contrary to the above several other worker found dehydrogenase activity to be correlated with bacterial population (Dash et al. (1981; Baruah, and Mishra, 1983; Dkhar and Mishra, 1984) and organic carbon (Rao and Ghai, 1985; Tiwari et al. 1987 b). Urease activity was found principally associated with organic carbon, soil temperature, moisture and bacterial population (Figs. 1.4,1.1,1.2,2,2). Results of the studies of Dalal (1975), Tabatabai (1977), Beri et al. (1978), O'Toole et al. (1985) and Tiwari et al. (1987 b) were also in conformity with the present investigation. In the present study phosphatase activity was found to be regulated by soil temperature and bacterial numbers (Figs. 1.1,2.2). Nannipieri et al. (1979), Appiah and Thomas (1982) and Chhonkar and Tarafdar (1984) also reported positive correlation between organic carbon

content, bacterial population and phosphatase activity. pH and phosphorus content, of the soil did not exert any effect on phosphatase activity in soils of pineapple plantations (Tables 3.19-2.21). CO_2 evolution decreased with increase in depth which is in general conformity with the observations of Baruah(1983) and Tiwari et al. (1987 c). In present investigation CO_2 evolution was not found to be correlated with the fungal and bacterial populations estimated by plate culture procedures as CO_2 evolution was maximum during the periods when microbial population was minimum (Figs. 2.1,2.2). During winter CO_2 evolution was maximum which is contrary to the observations of earlier workers (Siddiqui and Singh, 1981; Dkhar, 1983; Singh, 1984). Although it is difficult to understand what factor actually was responsible for the increased CO_2 evolution during winter. However, one possible explanation may be that during winter months the moisture level dropped (Fig.1.2).which increased the aeration of soil favouring the gasseous exchange. A part of the CO_2 evolved during winters might have come from the dead and decaying microbes as winter months showed lower microbial population levels (Figs. 2.1,2.2).

Decrease in enzymes activity with increasing depth might be due to unfavourable environmental conditions prevailing in the deeper region of the soil (Duxbury and Tate, 1981). Another reason for decreased microbial activity in deeper soils may be the lower microbial population and

nutrient status of the deeper soils. Seasonal and depth-wise variation in microbial population (fungi and bacteria) was mainly regulated by soil moisute, temperature,, available phosphorus, exchangeable potassium and organic carbon contents.Soil pH did not correlate with fungal population (Tables 2.19-2.21).Monthly and depth-wise variation of bacterial population was mainly dependent on soil temperature while moisture content had no effect on the bacterial population.

Similar trend of temporal and depth-wise variations in microbial population and their activities reflects that most of these parameters are regulated by same or similar set of environmental factors. Soil temperature, moisture, organic carbon, total nitrogen, potassium and available phosphorus content appeared to be most important factors that regulate the population and activities of microorganisms in the soils of pineapple plantations. Different r values for the three plantations (Tables 2.19-2.21) revealed that age of plantation has a definite influence on the interrelationship among various physico-chemical and microbiological characteristics of soil.The seasonal pattern in microbial activity in the pineapple plantation soils is more like forest soils of this region (Das and Mishra, 1986) than the soils under annual crops (Baruah and Mishra, 1984). It may be concluded from the present study that within the same climatic belt the seasonality of microbial activity differs widely

depending on the types of vegetation and agricultural practice.

Results of the study on decomposition of pineapple litter showed that leaf litter decomposed more rapidly than the root litter. Rapid breakdown of leaf litter may be ascribed to the rapid losses of polysacchrides from the leaf (Dkhar, 1983; Smith, 1966). The slow rate of decomposition during early period may be attributed to the low moisture temperature (Table 3.1) and microbial population (Figs.3.2, 3.3). Increased rate of decomposition in both cases at 120-300 days might be due to higher moisture and microbial population during the same time (Moore, 1986). At 360 days the rate of breakdown dropped in both cases which are ascribed to the depletion of food reserve which resulted into lower microbial activity (Shukla, 1976).

Population of microorganisms (fungi and bacteria) was low at the early phase of the decomposition. Fungal and bacterial population peaked at the 120 and 480 days when the moisture content was also higher which probably helped in the rapid growth of the microbes. It may be suggested that release of suitable nutrients from the litter coupled with favourable moisture and temperature played an important role in the growth of microflora during the decomposition of litters. Higher fungal population recorded from the leaf litter might be due to larger surface area of the leaf as it provides better chances for microbial colonization.

Mycoflora of decomposing leaf and root exhibited more or less similar spectrum of fungal species (Tables 3.2,3.3). It suggests that fungi are non-selective and they can utilize a wide variety of substrates. Fungal species Cladosporium herbarum was restricted to leaf litter and Aspergillus nedulans, Curvularia maculans, Penicillium javanicum were found restricted to the root litter (Tables 3.2,3.3). Generally, Fusarium moniliforme, F. solani and Penicillium chrysogenum occurred on both the decomposing litters. Presence of these fungi on decomposing of litters. Temporal variations in decomposition rate may be ascribed to changes in climate and physico-chemical characteristics of the litters and microbial activity during the decomposition process (Pugh, 1958; Witkamp, 1963; Holm and Jenson, 1972; Shukla and Singh, 1984).

Results of the present study demonstrated that process of litter decomposition is largely governed by the chemical composition of substrate, climate and microbial activity. The increase in the nitrogen content during the later phase of decomposition may be attributed to the immobilization of nitrogen to the microbial biomass (Saito, 1957; Iverron, 1973; Das, 1980).

Earthworm population in different plantation soils followed a trend 10 year > 5 year > 1 year. Higher population in older plantations may be ascribed to the higher moisture content, pH and organic matter content of the soils

(Figs. 4.2,4.3). Higher amount of litter production,less degree of disturbance in older plantations may also be one of the reasons for the higher earthworm populations. In 1 year plantation low earthworm population is attributed to the low moisture and production of less amount of easily available food and organic matter to the earthworms.Higher degree of disturbance during transplantation may also be ascribed to the low counts of the earthworm in 1 year plantation soils (Syer and Springeet, 1984). In the present study earthworms were isolated from April to November (Fig. 4.4) which might be due to suitable soil temperature and moisture as these are the most important factors which regulate the earthworm population in the soils (Cotton and Curry, 1982). During dry winter, earthworm population is dropped and during the coldest months earthworm population is reduced to zero (Fig.4.4). With the onset of coldest months earthworms might have gone under diapause or may have become quiescent (Syers et al. 1979).

From the results it could be inferred that soil temperature and moisture were the most important factors regulating the earthworm population in soils. During winters low soil temperature was found responsible for the low population of earthworms during the same time. Peak in earthworm population during July was largely due to moisture. The variations among plantations were largely due to

the variations in organic carbon content. Variations in earthworm population with time (P=0.01) as well as due to plantation age (P=0.01) were statistically significant (Table 4.2). It may be concluded that the longevity of plantation, increase the earthworm population.

Comparative study of the earthworm casts and surrounding soils revealed that casts showed several fold higher microbial population (fungi and bacteria), their activities (dehydrogenase, urease, phosphatase) and C,N,P,K contents. The nutrient enrichment of casts may be ascribed to the selective feeding of earthworms on the soils rich in organic materials. Similar observations were also reported by Syers et al. (1979) and Krishnamoorthy and Vajranabhaiah (1986). Increase in the nitrogen content of casts has been attributed to the intimate mixing of plant remains and animal manures with mineral soil in the digestive tract of the earthworms (Lunt and Jacobson, 1944). The excretory product (ammonia, urea, uric acid, amino acids) which are eliminated with faeces may also be attributed to the nutrient enrichment of casts. Feeding and burrowing activities of earthworms increase the availability of phosphorus in the soil. Mackay et al. (1983) also reported the similar results. Difference in nutrient contents of the casts and soils were statistically significant.

Increase in bacterial population was more pronounced than the fungal population in earthworm casts.

Presumably the conditions were less suitable for the growth of fungi in the earthworm tract. Recently, Gorbenko et al. (1986) noted that fungal population decreased in the faeces of earthworms. Increased microbial population in earthworm casts might be due to the intensification of the mineralization process. Another reason for the difference in microbial population in casts and soil may be attributed to the environmental changes within the earthworm's digestive tract or to the food material ingested which provides a rich substrate for the growth of microorganisms. Qualitatively fungal flora of casts and soil did not differ much. Only a very few species were found restricted either to casts or to the soil. Penicillium liliacinum and Torula herbarum were found restricted in the soil. It appeared that these species were digested in the alimentary canal of the earthworms. On the other hand, Aspergillus niger; Curvularia maculans; Penicillium fellutanum; P. funiculosum; P. claviforme and Curvularia maculans were isolated only from the casts. Probably these fungi were taken by the earthworms from other sources besides soil. Another reason for the presence of these species in the casts; maybe that the spores of these fungi germinated after passing through the digestive tract while in the soil although they might have been present but could not be isolated as they did not germinate. Differences in fungal population between casts and soil were not found to be statistically significant while statistically significant variation was noted in the bacterial population of the

earthworm casts and surrounding soil. Seasonal variation in the microbial population may be ascribed to the variation in soil moisture, pH and organic matter contents.

The number of microbes (fungi and bacteria) increased several folds after passing through the gut which might be responsible for the increase in microbial activity (Parle, 1963).This enhanced microbial activity is probably responsible for the increased dehydrogenase, urease and phosphatase enzyme activity in earthworm casts. Ross and Roberts, (1970), Sharpley and Syers (1976) and Syers et al. (1979) also reported the increased levels of such enzyme in earthworm casts. Seasonal variations in enzymes activities of soil and casts are generally, associated with fluctuations in soil moisture, temperature, microbial population, organic matter and available phosphorus content. Differences in enzyme activities of soil and casts were statistically significant.

Feeding and burrowing activities of earthworms increased the microbial activity and nutrient status of the soils. It may be concluded that earthworms are responsible for the distribution of soil fungi and they bring out favourable changes in nutrient contents of the soil which is probably done through the enhanced microbial populations and rates of biochemical processes.

The study was carried out in pineapple (Ananas comosus L.) plantations of three ages viz., 1 year, 5 year and 10 years. The soils of these plantations were analysed for soil moisture, temperature, pH. Organic carbon, total nitrogen, available phosphorus and exchangeable potassium. Generally, soil temperature, moisture, and pH showed a decreasing trend along increasing depth. During winter higher moisture content was recorded from the deeper soils. The contents of the C, N, P and K was higher in surface (0-10 cm) soils which decreased with increase in depths. Temporal variation in physico-chemical characteristics was more pronounced in surface soils in comparison to the deeper soils. Higher concentration of all elements (C,N,P,K) was recorded in spring (March) while lower levels were recorded in the winter.

In general, microbial population (fungi and bacteria) and their activities were found to be higher in surface (0-10 cm) soils which decreased with increasing depths. Temporal variations in microbial population and their activities showed more or less similar trend in the three plantations. Increased populations and activities of microorganisms were noted in spring (March-May) which decreased during winter. Higher levels of dehydrogenase, urease and phosphatase were recorded from the surface soils. The deeper soils showed low levels of all the studied enzymes. The CO_2 evolution was higher in surface soil than the deeper

soils. The maximum CO_2 evolution was recorded in winter (December).

Qualitatively fungal flora of different plantations did not differ much. Similarly, depth-wise distribution of fungal species also did not show marked difference. Majority of the fungal species were common to all the depths. A total number of 33 fungal species were isolated from all the three plantations soils. 1 year plantation soils exhibited highest number (31) of fungal isolates which was followed by 5 year (29) and 10 years (28) plantations soils. Alternaria alternata and Monilia sp. were not recovered from 1 year plantation soils. Aspergillus versicular; Curvularia lunata; Monilia sp; Mortierella ramanniana and Verticillium chlamydosporum were not isolated from 5 year plantation soil. Cunninghamella echinulata and Mycogone alba were not recorded from the 10 year plantation soils. Species of Fusarium were isolated throughout the study period from all the three plantation soils. Soil temperature, moisture, organic carbon, total nitrogen, potassium and available phosphorus contents appeared to be the most important factors which regulate the population of fungi and bacteria. Similarly, these factors were also found to be regulating the dehydrogenase urease, phosphatase and CO_2 evolution in soils.

Microbial decomposition of pineapple litter (leaf and root) was studied in field condition. Olson's (1963)

exponental decay model was followed and it was found that in case of leaf the 95% life was (1911.07) while in case of root it was (2575.99) days. The present study demonstrated that leaf decomposed more rapidly than the root. In general, during spring and rainy summer seasons the rate of decomposition was higher. During dry winter the rate of litter decomposition was slow. In general, the leaf litter contained higher concentrations of N and K while P content was higher in root litter. The concentrations of all elements increased during the early phase of decomposition which was followed by a drop. Concentration of all the elements again increased during the last phase of the decomposition. Quantitatively and qualitatively fungal flora of decomposing litters (leaf and root) did not differ much. Majority of the fungal isolates were common on both the litter types. Aspergillus niger; Fusarium moniliforme; Mucor hiemalis; Penicillium chrysogenum and Trichoderma viride were the most common fungal isolates recorded from both the litters. Cladosporium herbarum was found restricted to the leaf litter while Aspergillus nedulans; Curvularia maculans and Penicillium javanicum were found to be restricted to the root litter. Generally, a similar trend of temporal variation in fungal and bacterial population was noted from both the decomposing litters (leaf and root).

Earthworm population in three plantations soils showed a trend 10 year > 5 year > 1 year. All the

plantation soils showed a similar trend of temporal variation in earthworm population. The maximum earthworm population was recorded during rainy summer in all the three plantations. Thereafter, a drop in earthworm population was noted. During coldest periods (January-February) no earthworm population was recorded. Earthworm population significantly correlated with the soil temperature ($P=0.05$), moisture ($P=0.01$) and pH ($P=0.01$) of the soils. Variations in earthworm population with time ($P=0.01$) as well as due to plantations age ($P=0.01$) were statistically significant.

Physico-chemical and microbiological characteristics of earthworm casts were compared with the surrounding soils with an aim to see the effect of earthworm digestive tract on these characteristics of the soils. The results demonstrate that earthworm casts contained higher microbial population (fungi and bacteria) and nutrient contents than the surrounding soils. Fungal population of the soils was least affected while the bacterial population increased several folds. An increase in the enzyme activities (dehydrogenase, urease and phosphatase) was also recorded in earthworm casts. The increment was more in case of dehydrogenase activity as compared to the urease and phosphatase activity. Fungal flora of casts and soil did not differ much. Most of the fungal species were recorded from both the cases. However, Aspergillus niger, Curvularia maculans and Penicillium claviforme were restricted to casts and

Penicillium liliacinum was restricted to soils only. Both casts and soil showed similar trend of temporal variations in physico-chemical characteristics as well as microbial population and their activities. The differences in above studied parameters between soil and cast were analysed statistically and they were found statistically significant (P=0.05, 0.01, 0.001).

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1. Temporal and depth-wise variation in CO_2 evolution and microbial population in pineapple plantation soils. J. Soil. Biol. Ecol., 6 : 67-76 (1986).
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