STUDIES ON THE ROLE OF FUNGAL AND EARTHWORM POPULATIONS IN MAIZE FIELDS

ABSTRACT

By

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Maize being one of the major staple food crops grown throughout the state, was selected for the present study. And also keeping in view of the type of agricultural practices and altitude, two experimental sites (i) Terrace land agriculture at 5th Mile, Upper Shillong, situated at an altitude of 1725 m and lying between $25^{0}.34''$ N latitude and $91^{0}.52''$ E longitude and (ii) Permanent agriculture at Mawlai, situated at an altitude of 1400 m and lying between $25^{0}.34''$ N latitude and $91^{0}.52''$ E longitude, were selected for the present study.

Samplings of soil, the earthworms and their casts were carried out at the two study sites at monthly intervals for a period of 7 months, starting from the sowing period till harvest, *i.e.*, April to October, being the cropping season of maize. The following investigations were carried out for 2 crop cycles. The surface soil samples (0 -10 cm) were collected randomly from 5 places at each study site. Earthworm casts were collected randomly from the surface of the soil and thoroughly mixed to make a composite sample. Various physico-chemical characteristics such as p^{H}, moisture content, organic carbon, nitrogen and phosphorus of the samples were analysed. Walkley and Black's (1934) rapid titration method was followed for the determination of organic carbon. Kjeldahl's method was followed for the determination of nitrogen (Jackson, 1973), Molybdenum blue method (Allen, 1974) was followed for the determination of available phosphorus. The carbon di-oxide evolution was measured by absorption and titration method (MacFadyhen, 1970).

Soil temperature, moisture content, organic carbon, nitrogen and phosphorus of the soil were higher at low altitude than at high altitude in both the cropping seasons. A difference in the soil temperature of the two fields during the two cropping seasons corresponds to the difference in the atmospheric temperature during the study period. In the first cropping season, the moisture content of the soil was lower than that of the casts, whereas, in the second cropping season the moisture content of the soil was found to be higher than that of the casts.

The p^H of the soil and the casts was found to be acidic in both the fields with higher values in the casts than the soil. Higher organic carbon observed in the casts than in the soil in both the cropping seasons is due to the enrichment of organic carbon in the casts through the ingestion of plant and microbial residues by the earthworms and the production of large quantities of mucopolysaccharides by the earthworms during digestion or maybe due to the selection of soil fractions enriched in organic compounds by the earthworms.

Total nitrogen was also observed to be higher in the casts than in the soil, in both the cropping seasons in both the fields. Higher concentration in the total nitrogen in the casts than in the soil may be due to the excretion of urine in the gut in the form of ammonia and urea and also due to the presence of plant tissues in the casts which have passed through the gut with little chemical change. Available phosphorus was also observed to be higher in the casts than in the soil, in both the cropping seasons in both the fields. Carbon di-oxide evolution in the soil was observed to be higher at low altitude than at high altitude in both the cropping seasons. With maximum carbon di-oxide evolution recorded in the month of July at both the sites in the first cropping season, and in the month of June and July at high and low altitude respectively in the second cropping season. The physico-chemical characteristics of the soil were found to be higher at low altitude than at high altitude. Whereas, the physico-chemical characteristics of the casts was higher than that of the soil at both the altitudes.

The earthworm population was estimated by handpicking method (Edwards and Lofty, 1972) following randomnized-sampling procedure considering 50 sq cm cube. A cube of 50 x 50 x 50 cm was dug up. The earthworm population was observed to be higher in the soil at low altitude than at high altitude (fig.). The earthworms *Amynthas gracilis* (Kinberg) and *Metaphire houletti* (Perrier) were collected from the field at high altitude, whereas, *Amynthas gracilis* (Kinberg) and *Amynthas corticis* (Kinberg) were collected from the field at low altitude.

The soil plate method (Warcup, 1950) using Rose Bengal agar medium (Martin, 1950) was followed for the isolation of fungi. The fungal population was observed to be higher in the soil of low altitude than of soil from high altitude. Fungal population was observed to be higher in the casts than in the soil of low altitude during the first cropping season whereas, it was observed to be higher in the soil than in the casts at high altitude in the first cropping season as well as in the second cropping at both low and high altitudes. Altogether, 26 fungal species could be isolated from the soil at low altitude, 28 fungal species could be isolated from soil at high altitude, 24 fungal species could be isolated from the casts of the earthworms collected from low altitude and 26 fungal species could be isolated from the casts of the earthworms from high altitude. The fungal population in the foregut, midgut and hindgut was observed to be higher in earthworms collected from low altitude than from high altitude. The fungal population followed a trend of hindgut > midgut> foregut.

A total of 25 fungal species could be isolated from foregut, 30 fungal species could be isolated from midgut and 23 fungal specie could be isolated from hindgut of the earthworms from low altitude. Whereas, 28 fungal species could be isolated from foregut, 27 fungal species could be isolated from midgut of the earthworms and 22 fungal species could be isolated from hindgut of the earthworms from high altitude.

A few species were however restricted to each study site. *Mucor circinelloides, M. hemalis, Aspergillus flavus, Fusarium proliferatum, Humicola grisea, Penicillium canescens, P. janthinellum, P. polysporum, P. restrictum, P. waksmanii, Pseudoeurotium* sp., *Verticillium albo-atrum,* could be isolated only from the soil at high altitude.

Absidia cylindrospora Mortierella minutissima, M. parvispora, R. stolonifer, Cladosporium cladosporoides, F. poae, F. redolens, F. semitectum, P. frequentans, Trichoderma pseudokoningii, could be isolated only from the soil at low altitude.

Rhizopus storlonifer, Pythium irregulare, Aspergillus niger, Eupenicillium brefeldianum, P. javanicum, P. jensenii, P. waksmanii, Rhizoctonia sp. and T. *pseudokoningii* could be isolated only from the gut contents of earthworms from high altitude.

M. candelabrum, M. elongata, Aspergillus fumigatus, A. wentii, C. elegans, D. stemonitis, F. javanicum, F. oxysporum, F. poae, F. sporotrichioides, Paecilomyces sp. and *P. proliferatum* could be isolated only from the gut contents of earthworms from low altitude.

E. brefeldianum, F. poae, P. frequentans, H. grisea, T. harzianum, could be isolated only from the casts of earthworms from high altitude. *M. minutissima, M.*

parvispora and D. stemonitis could be isolated only from the casts of earthworms from low altitude.

Most of the fungal species isolated were found to be common in soil, casts and the earthworm gut.

p^H and percentage moisture content of the burrow soil were found to be higher than the surrounding soil.

The fungal population was slightly higher in the burrow soil than in the surrounding soil. Altogether, 14 fungal species were isolated both from the burrow soil and the surrounding soil. Qualitatively, there was not much difference in the fungal flora isolated from the burrow soil and the surrounding soil. Most of the species were found to be common in both the soil types. However, *M. racemosus, F. oxysporum* and *P. janthinellum* could be isolated only from the surrounding soil, whereas, *M. circinelloides*, white sterile mycelia and yellow sterile mycelia could be isolated only from the burrow soil.

Not much difference was observed on the growth of stems and leaves of maize between control plants and treated plants. A marked difference was, however, observed in the growth of roots between the control plants and the treated plants. More root growth was observed when earthworms were added to the treated plants. With the increase in the number of days there was a decrease in the number of earthworms, which affected the growth of maize roots as observed. With the increase in the number of days an increase in the growth of maize was observed. Plants treated with earthworms showed more growth in length as compared to the untreated plants. When stems, roots and leaves were taken as separate identity, an increase in the length of roots, stems and leaves was observed to be more in treated plants than that of the untreated plants. An increase in the length was observed with increase in the number of days. Gain in weight was observed as sampling period increased from 10-40 days followed by a decrease in weight towards the end of the sampling period.

An altered method of Mackay and Kladivko (1985) was followed for the study of the effect of earthworm on the decomposition of maize litter. The physico-chemical characteristics (p^H, moisture content, organic carbon, total nitrogen, available phosphorus and the CO_2 evolution, of the soil samples were determined. Slight increase in the p^H was observed in the soil in the presence of earthworms. Casts p^H was also slightly higher than the soil in the untreated pots. An increase in the percentage moisture content of treated soil than the untreated soil was observed throughout the study period. Higher percentage moisture content was recorded in the casts than that in the soil. Throughout the study period the percentage organic carbon was found to be maximum after 80 days in all the cases except in the casts collected from pots treated with root litter and the earthworms (ER) which showed its maximum percentage after 60 days. The percentage organic carbon in soil collected from the treated pots was higher than the untreated pots and the percentage organic carbon in casts was higher than that of the soil. The carbon di-oxide evolution was higher in the presence of earthworms. In pots where root litter was added, higher total nitrogen was recorded in the treated soil and the casts than the untreated soil. Higher total nitrogen was observed in the treated soil where root litter was added than the other treated soils. Peak period was observed after 60 days interval in soil from ER followed by a slight decrease after 80 days interval. Thereafter, an increase in the total nitrogen at the end of the experiment was observed. Total nitrogen in casts in ER also followed the same trend as that of the treated soil. In CR the total nitrogen was minimum at the initial stage whereas a gradual increase in the total nitrogen was observed in the latter stage. Peak periods were observed at 60 and 100 days interval. However, maximum total nitrogen was observed in the casts than that of the treated soil. In treated pots having stem as litter (ES), the maximum total nitrogen was observed at the end of the experiment i.e., after 100 days. Similar results were observed in the casts and the untreated soil. Minimum total nitrogen was recorded in untreated pots, with a higher value in the treated pots and the highest values in the casts. In treated pots where leaf litter was added (EL), the total nitrogen was higher in the treated pots than the untreated pots. The highest total nitrogen was observed at the end of the experiment i.e., after 100 days in treated soil and the casts. Whereas, the total nitrogen in untreated soil was maximum after 80 days interval. Overall percentage of total nitrogen was observed to be fluctuating throughout the study period. An increase in the total nitrogen was observed towards the end of the experiment in all the three types of treated pots. Whereas, a decrease in total nitrogen was observed in the untreated pots where stem and leaf litter were incorporated separately. Not much difference was observed in the available phosphorus in the treated soil and the untreated soil in all the three types of litter but a marked difference was observed in the available phosphorus in the casts in all the three types of treated soil. Highest available phosphorus was observed in the casts. Peak period of available phosphorus in the casts collected from ER was observed after 60 days interval followed by a slight decline after 80 days interval. In the casts collected from ES the available phosphorus showed a peak period after 40 days interval followed by a decline towards the end of the study period. Whereas, in the casts collected from ER the available phosphorus showed a steady increase from the beginning of the sampling period with its peak period after 80 days interval followed by a decrease after 100 days interval.

A gradual decrease in the weight of maize litter was observed in both the treated and the untreated pots in all the three types of litter. However, the percentage weight remaining was more in the untreated pots than the treated pots in all the three types of litter. Decrease in the amount of litter was the maximum in the pots where root litter was added in the untreated pots, whereas, in the treated pots the maximum decrease of litter was observed in the pots treated with leaf litter. Weight loss of litter in the untreated pots followed a trend CR>CL>CS and in the treated pots weight loss followed a trend EL>ER>ES. Decrease in the amount of litter in the treated pots ER and ES were gradual throughout the study period except at the end of the study period where the loss of weight was lesser than after 80 days interval. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease in the percentage cellulose, hemicellulose and lignin was observed in both the untreated and treated pots. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease in the percentage cellulose, hemicellulose and lignin was observed in both the untreated and treated pots. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease was recorded in the percentage cellulose, hemicellulose and lignin was in both the untreated and treated pots. The percentage weight loss of cellulose followed a trend CR>CS=CL in the untreated pots, whereas, it followed a trend EL>ES>ER in the treated pots. The percentage weight loss of hemicellulose followed a trend CR>CS>CL in the untreated pots, whereas, it followed a trend ER >ES> EL in the treated pots. And the percentage weight loss of lignin followed a trend CL>CR>CS in the untreated pots, whereas, it followed a trend EL>ER>ES in the treated pots. In the untreated pots having root litter (CR), the percentage weight loss of cellulose was the highest, followed by lignin and the least by hemicellulose. Whereas, in the treated pots (ER) the percentage weight loss of hemicellulose was the highest, followed by cellulose and the least by lignin. In the untreated pots having stem litter (CS), the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. Whereas, in the treated pots (ES) the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. In the untreated pots having leaf litter (CL), the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. Whereas, in the treated pots (EL) the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. Decrease in the amino acid was more in the treated pots than the untreated pots. At the initial stage the decrease in the amino acid was rapid followed by a slower rate in all the three types of litter. The decrease in the amino acid was more in stem litter followed by leaf litter and the least in the root litter. Decrease in the amount of sugar was more in the treated pots than the untreated pots. A sharp decline in the amount of sugar was observed in the initial stage of the experiment followed by a slow decline after 20 days interval in both the untreated and in the treated pots where stem and root litter were added. However, a gradual decline in the amount of sugar was observed where leaf litter was added. The weight loss of sugar in the untreated pots was highest in pots incorporated with root litter, followed by leaf litter and the least in pots having stem litter. Whereas, in the treated pots there was not much difference in the weight loss of sugar in the pots having root or stem litter. But the weight loss of sugar in the pots having leaf litter was lesser than in the pots having either stem or root litter.

From the present study it can be concluded that the presence of earthworms under suitable conditions improves the physico-chemical characteristics of the soil by producing mucus rich in polysaccharides thus enhancing the activity of the fungi in the decomposition of litter. Presence of earthworms during the growth of the maize plant stimulates more root growth, which may ultimately lead to more yields if long term study is carried out in field conditions. The earthworms can increase the total uptake of nutrients by plants by increasing the amounts of available nutrients in soil, and by secreting compounds in their casts that act like plant hormones and stimulate plant growth.

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DEDICATED TO

MY

MOTHER

NORTH-EASTERN HILL UNIVERSITY

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CERTIFICATE

I, Luckily Ranee, do hereby declare that the subject matter of the thesis entitled **"Studies on the role of fungal and earthworm populations in maize fields"** is the record done by me and that the contents of this thesis did not form basis of the award of any previous degree or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in and other University/Institute.

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CONTENTS

INTRODUCTION

Meghalaya tucked away in the north eastern region of India, lies between 25^0.00" and 26^0.15"N latitude and 89^0.45" and 92^0.47"E longitude. The state is characterised by diverse and undulating topography interspersed with hills, valleys and flatlands. High annual rainfall, precipitation and undulating topography leads to various types of agricultural practices. Agriculture being the mainstay of the people of Meghalaya, about 85% of the population depend totally on agriculture for their livelihood. Maize is one of the major staple food crops grown throughout the state with appreciable improvement in the yield.

The agricultural systems commonly practised are:

(i) Permanent agriculture in valley land,

(ii) Terrace agriculture on slopes and

(iii) Jhum or shifting cultivation.

(i) Permanent agriculture is practised in the plains and flat lands. The soil of this system of agriculture is generally rich in nutrients, which are transported from adjacent hills through erosion.

(ii) Terrace agriculture is comparatively of recent introduction due to non-availability of lands for shifting cultivation. The cultivation done on terraces checks soil erosion and runoff, thus, fertility as well as the soil moisture is maintained.

(iii) Tribal people of the north eastern hill region of India extensively practise shifting agriculture (Jhum). It is the most primitive type of agricultural system. The system consists of felling of forest trees at various stages of development, followed by drying and burning of the slash before cropping. Almost total reliance is placed entirely on the bush fallow for maintenance of fertility. No fertilisers or manure are generally applied. Minerals added to the surface soil in the ash provide nutrients to the crops. The amount of the nutrients contributed by the ash depends on the soil type, the nature and development of the vegetation and also on the degree of burning. There is loss of nutrients through severe erosion and runoff. Part of the ash is lost by erosion due to heavy rainfall and wind (DeBano and Conrad, 1976). Heavy loss of nutrients takes place during the cropping, particularly in the absence of crop cover at the time of sowing (Ramakrishnan and Toky, 1981). As a result, the soil moisture is generally low and fertility of the soil diminishes with time.

Soil is a non-renewable resource and is fast depleting with a fairly rapid rate due to over exploitation and poor management. Any attempt to restore this vital resource and also for its optimum utilisation, knowledge of the structure and function of soil ecosystem is a pre-requisite. Soil is also the habitat of a diverse array of organisms, which include both micro-flora and fauna. These organisms contribute to the maintenance and productivity of agro-ecosystems. On their death, they add in the built up of the organic matter (litter) which is continuously added to the soil. The soil organisms are responsible for the breakdown of organic matter. They play an important role in organic matter transformation, which can be utilised by other organisms. Lavelle (1994) reported that the present of soil invertebrates influences the existence of other organisms that are smaller litter transformers, components of the 'microfood-webs' and the entire floral community.

The soil faunas that can dig soil and produce organo-mineral structures have been called ecosystem engineers (Stork and Eggleton, 1992 and Jones *et. al.* 1994). Earthworms, nematodes and isopods are such organisms, which not only fragment and mix litter with soil but also bring about chemical changes that enable bacteria and fungi to decompose it further.

Earthworms form the major soil macrofauna of the agro-ecosystems. Earthworms form their burrows by ingesting soil as they push through the soil and by pushing through the cracks and crevices. As they move from the surface to the subsoil, they gather food and deposit faeces. Some burrows form the permanent home of an individual earthworm, while other burrows are temporary. The burrows of some species are continuous, often branched and can extend from the soil surface to deep into the layers of the soil. As the earthworms dig into the soil, they secrete mucus in the form of nitrogenous matter which acts as a lubricant and cements the soil into a smooth wall and also forms a protective coat against noxious materials (Edwards and Bohlen, 1996). These burrows serve as a substratum for the growth of fungi and bacteria on their walls. Bhatnagar (1975) reported an occurrence of 40% of the total nitrogenous fixers and 13% of the total anaerobic fixers in the soil in the 2mm zone surrounding the earthworm burrows. Earthworms excrete their faeces around the walls of the burrows, while others deposit them at the mouth of their burrows. Earthworm burrows have major influence on soil macroporosity and movement of water and nutrients. Earthworms disperse the microorgnisms by ingesting them at one location from a particular food source and egesting them elsewhere, or by transporting microbes that adhere to their body surface. Many of the microorgnisms transported by earthworms are involved in the decomposition of organic matter. They consume and transport other beneficial microbial groups and antagonists of plant pathogen through the soil by dispersing spores and hyphal fragments. The spores of many species of fungi can pass through the earthworm gut without coming to any harm. The microorganisms form an efficient internal mutualistic relationship with the macrofauna which allow them to digest otherwise resistant materials. These microorgnisms constitute an important nutritional component of the earthworm diet.

Earthworms will not ingest plant litter until it is partly decomposed. Much information on the food preferences of earthworm has been derived from detailed examination of the contents of the alimentary canal. Some of the studies are contradictory and indicate that the same species do not necessarily have the same diet in different localities, but there is good evidence that at least some fungi and microorgnisms form important diet of earthworms. The importance of particular groups of microorgnisms as food for earthworms differs between different earthworm species, particularly those that have remarkably varying feeding habitats. Earthworms have many complex interrelationships with microorgnisms. They promote microbial activity in decaying organic matter by fragmenting it and dispersing the microorgnisms widely through the soils. The ingested organic matter is macerated, mixed with the ingested inorganic soil material, passed through the gut and excreted as casts with a slight change in chemical structure. The greater surface area of organic matter thus exposed to microbial activity facilitates its further decomposition. Not all earthworms deposit casts at the soil surface, most species that deposit casts do so in their burrows or in other soil spaces. Earthworms ingest food material at one place and lay casts at another place. Casts act as foci from which microorgnisms can spread into the surrounding soil (Lofty, 1974 and Dash *et.al.* 1979).

Earthworm population is extremely variable in size, ranging from only a few individuals to more than $1000/m^2$ (Edwards and Bohlen, 1996). Earthworms are not distributed randomly in soil. Guild (1952a) and Murchie (1958a) have proposed the possible factors which are responsible for the variability in distributions of earthworms as: (a) physico-chemical characteristics of the soil (p^H, soil temperature, soil moisture, inorganic salts, aeration and texture); (b) available food (herbage, leaf litter, dung, consolidated organic potential) and (c) reproductive power and dispersive powers of the species. Murchie (1958a) concluded that no single factor is solely responsible for the distribution rather, it is the interaction of several population factors that work together and thereby provide suitable conditions for earthworms. The number of earthworms in regularly arable soil is usually very few, due to mechanical damage during cultivation, to a loss of the insulating layer of vegetation, to a decreased supply of food as organic matter which gradually decreases with repeated cultivation or to predation by birds.

The soil is also impregnated with a variety of heterotrophic microorgnisms such as fungi and bacteria, which largely derive nutrition from organic substances. These organisms perform a vital role in the decomposition of organic matter. Thus, they hold a key position in the nutrient cycle and functioning of soil ecosystems. Fungi are one such microorgnisms, which play an important role in the decomposition system. Fungi develop an efficient internal mutualistic relationship with the macrofauna which allow them to digest otherwise resistant materials. These microorgnisms constitute an important nutritional component of the earthworm diet. Earthworms will not generally ingest plant litter until it is partially decomposed. Most of the species that occur in the alimentary canal of earthworms are the same as those in the soils in which the worms live (Ruschmann, 1953 and Dash and Patra 1977). Lavelle *et al.* (1983a) proposed a symbiotic association between earthworms and their gut microflora. They proposed that mucus produced by the glands in the anterior region of the gut passes back through the intestine with ingested food and provides a favourable substrate for symbiotic microorgnisms that decompose complex organic compounds in the ingesta to the mutual benefit of the earthworms and the symbionts. The microbial populations of the earthworm gut begins to change when the gut contents are voided as casts, that are usually rich in ammonia and partially digested organic matter and provide a good substrate for the growth of microorgnisms. They can enhance dispersal of microorganisms by ingesting them or by transporting the microbes that adhere to their body surface. Most of the microorganisms transported by the earthworms are those involved in the decomposition of organic material, but they can also consume and transport beneficial as well as harmful microbial groups. Organic matter that reaches the soil is subjected to various decomposing microorganisms and other agents. The tougher plant leaves and stems do not breakdown without first being disintegrated by soil animals. Earthworms play an important role in this initial process of the cycling of organic matter. They are responsible for the fragmentation of litter. Many types of leaf litter are not acceptable to earthworms when they first fall on the ground rather earthworms require partially decomposed litter because they become more palatable. Earthworms are more attracted to moist litter material than to dry ones, and they are therefore most active in moist soil and the litter, and the amount of turnover seems to be more dependent on the total amount of suitable organic matter than on other factors.

Earthworms pass a mixture of organic and inorganic matter through their guts. When feeding or burrowing, a large amount of water-soluble compounds are also added to the gut contents. As the food passes through the gut, the final process in organic matter decomposition or humification is accelerated due to the intestinal micro-flora in the gut. Tian *et. al.* (1997) reported that the soil fauna enhances the biodegradation and humification of organic residues in several ways: (i) by comminuting organic residues and increasing surface area for microbial activity; (ii) by producing enzymes which breakdown complex biomolecules into simple compounds, and polymerise compounds to form humus; (iii) by improving the environment for microbial growth and interactions of the different microbial groups. The major contribution of earthworms is breaking up of organic matter, combining it with soil particles and enhancing the microbial activity when humification is well advanced. Martin (1991) reported that casts of tropical earthworm *Millsonia anomala* had much less coarse organic matter than the surrounding soil, indicating that the larger particles of organic matter were fragmented during passage through the earthworm gut. The feeding habits of different earthworm species influence their effect on litter fragmentation and incorporation into the soil. *Lumbricus terrestris* incorporates a large amount of organic matter in soil, and is capable of breaking down and feeding on large litter fragments by stripping off smaller particles with the mouth parts (Edwards and Bohlen, 1996). Endogeic earthworms feed mainly on fragmented organic matter, mixing it thoroughly with the mineral soil. Soils with no earthworms or only a few earthworms often have a well-developed layer of undecomposed litter and organic matter on the soil surface, separated from the underlying mineral soil by a sharp boundary. Many of the influences of earthworms on nutrient cycling processes and the mineralization of organic matter are mediated by the interactions that occur between earthworms and the microorganisms.

Earthworms consume large amount of plant organic matter that contain considerable quantities of nitrogen, much of the nitrogen that they assimilate into their own tissues is returned to the soil in their excretions.

The rate of litter decomposition is influenced by a number of factors, including moisture, temperature (Donelly *et. al.* 1990 and Berg *et. al.* 1993), substrate quality, particularly the chemical composition of the decomposing material (Waksman and Tenney, 1927 and Singh and Gupta, 1977). The process is also influenced by lignin content (Meentemeyer *et. al.* 1978 and Melillo *et. al.* 1982), nutrient status of the soil (Verhoeven and Toth, 1995) and the nature of the microorganisms and soil fauna active in the decomposition process (Singh and Gupta, 1977). Madge (1966) reported that in tropical forests of Nigeria the litter fall was three to four times greater than in the temperate forests and earthworms were the most important animals causing its fragmentation and incorporation. Vimmerstedt and Finney (1973) reported large increases in deciduous litter disappearance on mine spoils following the introduction of *L. terrestris.* Cortez, *et. al.* (1989) reported relatively large increase in decomposition of plant litter on the soil by addition of earthworms.

The majority of the litter consists of structural components of plants such as cellulose, hemicellulose and lignin, all of which are broken down relatively slowly. Cellulose, a widely distributed polysaccharide is the vast replenishable resource and is recycled by the microbes. Cellulosic portion of the biomass can be converted to glucose by enzymatic hydrolysis. Lignin remains closely associated with cellulose and hemicellulose (Lundquist *et. al.* 1980). Sometimes the lignin degradation product particularly oxidised phenolics reacts with nitrogeneous compounds and limits the availability of nitrogen to decomposers.

For proper management and economic exploitation of agricultural lands and to evaluate the role of earthworms in agro-ecosystems, knowledge on their population densities, their relationships with fungal population, litter decomposition and the dispersal of microbes are of fundamental requisite. The decomposition study of the crop residues by earthworms is important for better understanding of the organic matter dynamics and the role of earthworms in nutrient cycling and this may be exploited for rapid decomposition and for their role in vermicomposting in organic waste management.

The importance of earthworms and their casts in soil fertility and their influence on the growth of microflora in agricultural soils will give better understanding of their activity.

Keeping these in view, the entire work has been carried out under the following heads:

(1) Physico-chemical characteristics of the two maize field soils and the casts.

(2) Identification and assessment of the earthworm population collected from both fields.

(3) Isolation of fungi from soil, earthworm guts contents and the casts.

(4) Effect of earthworms on the growth of maize plant in laboratory condition.

(5) Dispersal of soil fungi by earthworms.

(6) Decomposition of maize litter by earthworms in laboratory condition.

(7) Analysis of the chemical composition of the decomposed litter.

REVIEW OF LITERATURE

Physico-chemical properties of soil and earthworm casts:

Physico-chemical characteristics *viz.* temperature, moisture, p^H and nutrient contents of the soil regulate the population and activity of macro and microorganisms. Chemical and biological properties of the soil in turn are regulated by the soil organic matter, which is one of the major pool of carbon and nutrients, and also regulates to a large extent the physical properties of the soil. Interaction between plants, microbes and the physico-chemical processes in soil together with the soil organic matter dynamics influence nutrient and water availability to the plants. Nitrogen is the most limiting nutrient in many plant communities (Vitousek, *et. al.* 1982 and Vitousek and Howarth, 1991). Phosphorus is another essential element of all living organisms. Many workers have reported that earthworm casts are known to have more favourable physico-chemical properties for crop growth than the parent soil (Lunt and Jacobson, 1944; Lal and Akinremi, 1983; Mulongoy and Bedoret, 1989 and Krishnamoorthy, 1990).

Aldag and Graff (1975) kept the earthworms *Lumbricus terrestris* in pots and reported that the content of available nitrogen in their casts was 40% greater than in the surrounding soil.

Needham (1957) suggested that very little nitrogen is excreted in the faeces of earthworms but other workers have reported considerably more nitrogen in casts than in surrounding soil (Lunt and Jacobson, 1944 and Graff, 1971).

Barley and Jennings (1959) reported that the excretions, which include mucoprotiens secreted by gland cells in the epidermis, and ammonia, urea, and possibly uric acid and allantoin, in a fluid urine excreted from the nephridoiopores, contribute a significant amount of readily assimilable nitrogen to soil. The increase in inorganic nitrogen in casts is due to these excretory products and mucus, as well as through the increased rates of mineralization of organic nitrogen by microorganisms in the casts.

Sharpley and Syers (1976) observed that the rate of release of inorganic and organic phosphorus in the earthworm casts was about four times faster than that in the surface soil during 3 days of sequential extraction.

Deka (1981) studied the seasonal variation in organic matter content, nitrogen and available phosphorus in 1 year, 10 years and 20 years fallow and 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 followed by a subsequent period of almost uniform level of organic matter.

Fardeau (1981) showed that exchangeable and water extractable inorganic P in casts of *Pontoscolex corethrurus* was more abundant than in non-ingested control soils.

Lee (1985) reported that casts had higher quantities of carbon, phosphorus (5-10 times more) than the surrounding soil.

Shaw and Pawluk (1986a,b) reported a greater amount of clay-associated carbon in earthworm casts than in the surrounding soil.

Mulongoy and Bedoret (1989) noted higher p^H values, organic carbon and total nitro -gen in the casts as compared to the surrounding soil. They observed significant correlations between properties of the casts and of the corresponding soil for various chemical and bio-logical parameters.

Tiwari, *et. al.* (1989) observed a seasonal variation in the concentration of inorganic phosphorus in earthworm casts with highest levels relative to the surrounding soil occurring in the middle of July-August.

Rastin *et. al.* (1990) investigated a number of biological and biochemical factors in different horizons from the upper and lower slopes of a spruce forest. They reported that NH_4- and NO_3- N concentrations in the soil solution showed significant correlation with most of the biological and biochemical soil factors investigated.

Scheu (1991) reported that secretion of mucus in casts and from the body wall accounted for 63% of total carbon losses from a geophagus earthworm, *Octolasion lacteum*.

Lavelle *et. al.* (1992) observed that levels of inorganic N were often quite high in fresh casts.

Lopez-Hernandez *et. al.* (1993) reported that the contents of water soluble and exchangeable phosphorus were much greater in earthworm casts than in the surrounding tropical soil.

Schrader and Zhang (1997) reported that the organic carbon content of the earthworm casts was higher than the parent soil. They also reported that the organic C content in the casts of *Lumbricus terrestris* was more than that of *Aporrectodea caliginosa*.

Fungal population of the soil, the casts and the earthworm gut:

Microorganisms constitute an important component of earthworm diet. Many reports suggested that fungal tissues are digested as the principle source of nourishment (Morgan, 1988). Several authors (Dash *et. al.* 1986 and Striganova *et. al.* 1989) after examinations of the contents of the alimentary tracts of earthworms and comparison with the surrounding soil have also made reports on preferential consumption of fungal species by earthworms in field studies after examinations of the contents of the alimentary tracts of earthworms and comparison with the surrounding soil.

The physico-chemical characters of the soil may regulate the microbial population and their activities (Mishra, 1966; Tiwari *et. al.* 1987; Waksman, 1927 and Warcup, 1950).

Waksman (1927) considered organic matter, soil p^H, moisture, temperature, aeration and nature of the crop grown to be responsible for the distribution and abundance of microbe in soil.

Ghilarov (1963) reported that increase in the number of microorganisms in the earthworm gut and casts were twice than that observed in the surrounding soil.

Went (1963) reported little or no difference between microfloral population of earthworm casts and soil.

Mishra (1966) suggested that factors like organic matter, pH, moisture content, aeration, temperature, season and the state of litter decomposition governed the distribution of microbes in the soil.

Mishra and Kanaujia (1972) analysed the ecological aspects of soil fungi in relation to climatic condition, vegetation and soil physico-chemical characteristics and they found the organic matter, p^H, soil depth and season played a critical role in the distribution of mycoflora.

Dash, *et. al.* (1979) reported that earthworm casts contained higher number of microorganisms than the surrounding soil.

Dkhar (1983) reported that maximum concentration of available phosphorus in the soil during the month of July in Jhum, Terrace and valley lands and suggested that this maybe due to the greater microbial activity and release of soluble phosphate because of suitable temperature.

Dkhar and Mishra (1987 &1992) observed that the microbial population was higher in the soils of permanent agriculture as compared to that of 'slash and burn' type of shifting agriculture. They further reported that the soil of the valley land harboured maximum microbial populations followed by the terrace land agriculture and minimum in the soil of jhum land agriculture

Tiwari *et. al.* (1987, 1989 & 1991) reported that soil moisture significantly alters the microbial population, its activity and relationships between parameters. They reported that earthworm casts contained higher microbial population as compared to the soil of pineapple plantations and also observed positive correlation between microfungal population and organic C, available P and exchangeable K in pineapple orchard soil.

Mulongoy and Bedoret (1989) reported higher microbial counts in the casts than in the surrounding soil.

Behera *et. al.* (1991) while conducting an ecological investigation of some microfungi in a tropical forest soil of Orissa could isolate 36 fungal species and one sterile mycelia from the soil. They observed seasonal variations of fungal population to be more pronounced in upper soil layers. They also observed positive correlation between fungal population, soil moisture and organic matter content.

Tiwari and Mishra (1993) sampled earthworm casts and adjacent soil at 30 different sites in India and observed that the casts usually contained larger fungal population and a greater number of fungal species than the surrounding soil.

Tiwari and Sharma (1998) reported that the fungal and bacterial populations in highland soils increased with increase in altitude upto 1100 m, but thereafter, the populations declined sharply. They also observed positive correlation between fungal and bacterial populations with organic matter content of the soil.

Edwards and Fletcher (1988) suggested that bacteria were of minor importance in the diet, algae of moderate importance while protozoa and fungi were the major source of nutrients Parle (1959 &1963a) showed that number of microorganisms increased exponentially from the anterior to the posterior portions of the earthworm gut.

Dash *et. al.* (1979) isolated 19 species of microfungi from the soil, 16 species from the anterior portion of the earthworm's gut and 8 species from the posterior portion of the gut.

Tiwari *et. al.* (1990) could isolate a total of 17 species of microfungi from the gut and casts, out of which 16 occurred in the anterior region, 12 in the middle region and 10 in the posterior region of the gut. They suggested that there existed a gradient with regard to the digestive capability of different regions of the gut of earthworms for utilisation of microfungi as food.

Dkhar and Mishra (1991) observed that the fungal population was maximum in the foregut and minimum towards the hindgut of the earthworm *Amynthas diffringens*.

Kristufek *et. al.* (1992) reported that the number of fungi increased during passage through the gut of *Lumbricus rubellus*.

Moody *et. al.* (1996) studied the fate of fungal spores associated with the wheat straw decomposition on passage through the guts of two earthworms *L. terrestris* and *Aporrectodea longa*. They found that the effect of passage through the earthworm gut on the viability of spores of saprophytic fungi was found to vary depending upon the fungal and earthworm species. They also found that *Fusarium lateritium, Agrocybe temulenta, Trichoderma* sp., *Mucor hiemalis and Chaetomium globosum* failed to germinate. They further reported that germination of *Trichoderma* sp. and *Mucor hiemalis* was significantly reduced in the case of *L. terrestris* whereas the reverse was observed in the case of *A. longa* in which there was a significant increase in the spore germination after gut transit.

Ranee and Dkhar (1998) observed that the fungal population in the gut of the earthworm was of the order: hindgut > foregut > midgut. They also observed that there was a gradual decrease in the number of fungal species from soil to hindgut.

Earthworm population:

Many efforts have been made in recent decades to find an optimal method to determine earthworm population in soils. Generally handsorting and formalin extraction seem to be the most suitable methods for the determination of earthworm populations in the field (Nordstrom and Rundgren, 1972; Walther and Snider, 1984; Lee, 1985; Mukherji and Singh, 1986 and Dunger and Fiedler, 1989). Handsorting and subsequent washing and sieving can also improve the efficiency of separating earthworms from soil (Lavelle, 1978; Walther and Snider, 1984 and Judas, 1988).

Evans and Guild (1947c) suggested that temperature and moisture of the soil and the obligatory diapause or the period of quiescence during adverse conditions is the another important factor affecting the activity of the earthworms.

Gerard (1967) reported that in pasture soil in England, *Aporrectodea chlorotica, A. caliginosa* and *A. rosea* usually occurred within 10 cm of the soil surface. However, when the soil temperature fell below 5^{o}C or when the soil became dry, individuals of these species move to deeper soil.

Edwards and Lofty (1977) suggested that earthworm population dynamics are relatively complex and that they depend principally on the availability of soil moisture and temperature for development and activity.

Lee (1985) suggested that the availability of organic matter was probably the most important factor determining the size of earthworm populations.

Reddy (1987) observed that earthworms were found in the upper (0-10cm) layer of the soil during the rainy season but penetrated downwards into the deeper soil as winter approached.

Bhadauria and Ramakrishnan (1989) reported that earthworm population declined significantly after slashing and burning. They also suggested that population size was significantly correlated with soil moisture, temperature and organic matter.

Reddy and Pasha (1993) reported that earthworms migrated to deeper layers during winter and summer. They suggested that their seasonal population structure was significantly influenced by the seasonal patterns in rainfall, soil temperature, p^H, phosphorus, organic carbon, nitrogen and potassium. They further suggested that the physical factors of the soil were collectively more effective in causing the seasonal variation in their population size than the chemical factors.

Decomposition by earthworms:

Earthworms play a major role in the breakdown of organic matter and the release and recycling of nutrients. They remove the partially decomposed plant litter and crop residues from the soil surface, ingest it, fragment it and transport it to the subsurface layer.

Edwards and Heath (1963) who placed disks, cut from freshly fallen oak and beech leaves in nylon bags of four different mesh sizes observed that after one year 92% of the total oak leaf material and 70% of the beech litter had been removed by earthworms. They observed that earthworms ate not only the softer parts of the leaves but also the veins and the ribs.

Anderson *et. al.* (1983) measured nitrogen mineralization in forest soil incubated with oak litter and with or without the earthworm *Lumbricus rubellus*. They observed that *L. rubellus* increased the mobilization of nitrate nitrogen by 10 times and that of ammonium nitrogen by 80 times relative to soil without earthworms.

Ferriere and Bouche (1985) reported that the entire carbon content of the earthworm could turnover in 40 days and also suggested that a considerable portion of this turnover was due to mucus secretion MacKay and Kladivko (1985) reported that after 36 days, pots with no earthworms had retained 60% of the soybean residues and 85% of the maize residues, whereas, pots with earthworms had only 34% of the original soybean residues and 52% of the original maize residues.

Hendrix *et. al.* (1987) estimated that earthworms were responsible for about 30% of the total heterotrophic soil respiration, during late winter and early spring, in a no-tillage agro-ecosystem in the south eastern U.S. The population densities at their site reached a maximum of nearly 1000 individuals/m^2.

Haimi and Huhta (1990) showed that *L. rubellus* increased the mass loss of coniferous forest humus by a factor of 1.4 in a 48 week laboratory incubation. They also observed that earthworm respiration accounted for 21-32% of the increase in CO_2 evolution. They further reported that the earthworm species *L. rubellus* and *Dendrobaena octaedra* significantly raised the p^H of the leaching waters and humus and observed that both the worms increased N-mineralization but influenced the level of PO_4^{3-}-P only slightly.

Haimi and Boucelham (1991) in a laboratory study reported that *L. rubellus* had a positive effect on CO_2 evolution during the period when the worms were present.

Ruz-Jerez *et. al.* (1992) reported that mineral nitrogen concentrations were about 50% greater in soils with earthworms than in soils without earthworms. They also observed that earthworms increased CO_2 evolution after the addition of clover and grass by 1.35 and 1.25 fold respectively.

Haimi and Einbork (1992) reported that the earthworm *Aporrectodea caliginosa tuberculata* had mixed the organic matter into the mineral layer of the soil. They also observed that p^{H} values and N concentrations in the leaching water showed no consistent differences between soil with and without earthworms. They further reported that the worm increased the CO_2 production of the soil.

Scheu (1993a,b) reported that earthworms increased the mineralization of ^{14}C-labelled lignin in limestone soils. He reported that during 253 days of laboratory incubations, *Octolasion lacteum* increased the mineralization of labelled lignin for the first 10 weeks, but decreased later.

Bohlen and Edwards (1995) reported that earthworms increased soil respiration rates during the first 15 days of incubation by 1.24 to 2.42 folds.

Schindler Wessels *et. al.* reported that earthworms had significant effects on soil respiration, but their effects varied seasonally and were influenced by environmental conditions. Most of the significant effects of earthworms on soil respiration were observed during the growing season.

Wessells *et. al.* (1997) reported that earthworms had significant effects on soil respiration but their effects varied seasonally and were influenced by environmental conditions.

Cortez and Bouche (1998) reported that anecic earthworms make litters more palatable by a particular type of behaviour. They reported that during the first stage of decomposition the litters were ploughed in by earthworm casts involving both an increase of microbial activity and preliminary microbial litter decomposition.

Role of earthworms in dispersal:

Earthworms can enhance the dispersal of microorganisms by ingesting them at one location from a particular food source and egesting them elsewhere or by transporting microbes that adhere to their body surface. They can spread soil fungi including pathogens, throughout the soil by dispersing spores and hyphal fragments.

Baweja (1939) suggested that earthworms dispersed the pathogenic fungus *Pythium.*

Khambata and Bhatt (1957) suggested that earthworms dispersed spores of harmful fungus *Fusarium.*

Hutchinson and Kamel (1956) inoculated sterilized soil with several species of fungi and reported that the rate of spread of the fungi through the soil was much greater when worms were present than when they were absent.

Hoffman and Purdy (1964) reported that teleospores produced by *Telletia controversa*, a pathogen causing dwarf bunt could pass through the earthworm gut without harm.

Redell and Spain (1991a) reported the spread of spores and hyphal fragments of mycorrhizal fungi in undigested root fragments in the gut of the earthworm *Pontoscolex corethrurus.*

Stephens *et. al.* (1994a,b) reported that *A. trapezoides* enhanced the rates of dispersal of *Rhizoctonia meliloti* as well as the levels of root nodulation in infected alfalfa plants. They further showed that the earthworm *A. trapezoides* dispersed the bacterium *Pseudomonas corrugata* 2140R strain through the soil thereby resulting in bacterial colonisation of the roots of wheat seedlings.

Toyota and Kimura (1994) found that the earthworm *Pheretima* sp. dispersed the soil borne plant pathogen *Fusarium oxysporum* in the topsoil but decreased the total propagules of this pathogen.

Brown (1995) suggested that by feeding, burrowing and casting activity earthworms influenced the dispersal of microorganisms throughout the soil.

Effect of earthworms on plant growth:

Many workers (Gavilov, 1963; Nielson, 1965; Russell, 1910; Edwards and Lofty, 1980 and Atlavinyte and Vanagas, 1982) have attempted to demonstrate the beneficial effects of earthworms on plant growth and yields of crops.

Russell, (1910) obtained increased dry matter yields of the order 25% in the presence of earthworms and attributed this to improvements in the physical condition of the soils. And reported that less evaporation occurred in pots containing earthworms, because the soil surface was covered by earthworm casts.

Gavilov (1963) processed extracts of the tissues, mucus, coelomic fluid and casts of *Lumbricus terrestris* and showed that they contained plant growth factors, probably produced by the coelamobytes.

Nielson (1965) claimed that he detected in eight species of lumbricids and two megascoleids, the production of some plant growth substances in the alimentary tract which are later voided as casts. He compared the increases in plant growth due to the earthworm extracts with those of IAA and reported a significant effect of these extracts on plant growth.

Springett and Syers (1979) compared the growth of ryegrass seedlings in the presence of casts of *A. caliginosa* and *L. rubellus* to the growth without casts, and concluded that the earthworms must alter the nutrient availability, alter the plant's ability to take up nutrients or affect the growth mechanisms of plants. They also concluded that L. rubellus casts probably contain an auxin-like substance, or some substances that modifies the effects of the plant's auxins.

Edwards and Lofty, (1980) investigated the influence of the earthworms on the growth and yield of barley in field soils that had been direct-drilled for 6 years and compared the growth of barley in the plots inoculated with earthworms with plots to which no earthworms were added. They found significant differences in the yield of barley, and the growth rate of the barley was greater in plots inoculated with earthworms.

Graff and Makeschin (1980) tested the effects of substances produced by L. terrestris, *A. caliginosa* and *E. fetida* on dry matter production of ryegrass in Germany and concluded that yield-influencing substances were released into the soil by all the three species, but did not speculate on the nature of the substances.

Atlavinyte and Vanagas, (1982) demonstrated a clear strong correlation between the number of earthworms and the growth of barley. Increased yields were proportional to the number of earthworms that had been added.

Tomati et. al. (1983) tested composts produced from organic waste by the action of earthworms as media for growing ornamental plants and reported that the composts influenced the dwarfing, time of flowering, lengthening of internodes and the stimulates rooting.

Tomati et. al. (1983) tested composts produced from organic waste by the action of earthworms as media for growing cereals and mushrooms and reported that the composts influenced their growth.

James and Seastedt (1986) reported a positive effect of earthworms on root growth of big bluestem.

Edwards and Burrows (1988) described data on the growth of a wide range of plants in media produced by the processing of organic waste by *E. fetida*. And speculated that the success of these media, even at high dilutions, and the growth patterns of the plants, could be explained best by postulating a hormonal effect on plant growth.

Lavelle, (1992) reported that the earthworm *Pontoscolex corethrurus* increased the growth of the grain crops.

Spain *et. al.* (1992) found that the growth of *Panicum maximum* increased significantly after inoculation of soil in which it grew in the presence of the earthworms *Chuniodrilus zielae* and *Stuhlmannia porifera.*

Decomposition:

Plant organic material is subjected to many agents that promote decomposition, including both microorganisms and animals. Much organic matter (litter) particularly the tougher plant leaves, stems and root material, breaks down more readily after being eaten by soil inhabiting invertebrates and acted upon by enzymes in their intestines. Earthworms are probably the most important invertebrates in many soils playing a major role in the recycling of organic matter. The plant litters differ in their chemical composition depending upon the species. The chemical composition of litter changes as the process of decomposition proceeds. The soluble organic and inorganic components leach out of the material within a very short span of time which may range from a week to few months depending upon the physical structure of the material. Macromolecules such as lignin, cellulose, hemicellulose, sugar, amino acid etc. have been generally considered as a measure of degree of decomposition.

Edwards and Heath, (1963) reported that earthworms ate not only the softer parts of the leaves but also veins and ribs.

Bohlen *et. al.* (1995b) studied the decomposition of crop residues in maize agroecosystems in which earthworms populations had been decreased, increased or left unmodified, in enclosed plots. They showed that earthworms, in particular *L. terrestris* actively selected crop residues that contain the greatest amount of nitrogen thereby increasing the loss of nitrogen from the residues to a greater extent than they increased the loss of carbon.

Parmelee *et. al.* (1990) reported significant increases in the amount of particulate organic matter in plots with decreased earthworm populations illustrates the extremely important role of earthworms in the fragmentation and breakdown of organic matter as well as in the release of nutrients that it contains.

Daniel (1991) showed that leaf litter consumption by juvenile *L. terrestris* could be described by a non-linear function of soil temperature, soil water potential and food availability. These three factors probably govern the amounts and rates of food consumed by most litter feeding earthworm species.

Martin (1991) reported that casts of the tropical earthworm *Millsonia anomala* had much less coarse organic matter than the surrounding soil, indicating that the larger particles of organic matter were fragmented during passage through the earthworm gut.

Curry and Bryne (1992) found that the decomposition rate of straw in the presence of earthworms was increased by 26-47% compared with straw from which earthworms were excluded.

Ketterings *et. al.* (1995) reported that earthworms can decrease the total amount of plant residues but appear to increase the C:N ratio of the remaining residues, which may have important consequences for patterns of nitrogen mineralization or immobilization by microorganisms associated with the residues.

Edwards and Bohlen (1996) reported that organic matter that passes through the earthworm gut and is egested in their casts is broken down into much finer particles so that a greater surface area of the organic matter is exposed to microbial decomposition.

Christensen (1988) reported that dead earthworm tissues contributed 20-42 kg nitrogen/ ha to the soil during the autumn in three arable systems in Denmark.

Sokolov and Karpova (1965) observed that during decomposition of starch, hemicellulose and amino acids in organic residues decomposed at a faster rate while lignin was the last to decompose.

Mishra and Tiwari (1984) reported that sugars and amino acid concentration declined very fast during the initial periods of decomposition and became stabilised in the later periods.

Berg and Stoaf (1980) suggested that decomposition of litter may be divided into at least two phases. In the first phase saprophytic fungi decompose soluble substances and then non-lignified carbohydrates (cellulose and hemicellulose). In the late decomposition phase, on the other hand, primarily lignin and lignified cellulose remained.

Dkhar and Mishra (1992) reported that the amount of cellulose, hemicellulose and lignin contents of the decomposing maize litters varied with different litter types. They observed maximum amount of lignin in the root followed by the stem and minimum in the leaf. They also observed significant positive correlation between percentage weight remaining and various chemical compounds associated with different types of litter.

STUDY AREA AND CLIMATE

Keeping in view of the type of agricultural practices and altitude, two experimental sites were selected for the present study. They were (i) Terrace land agriculture at 5th Mile, Upper Shillong, situated at an altitude of 1725 m and lying between $25^0.34''$ N latitude and $91^0.52''$ E longitude. The field lies 9 km away from Shillong and (ii) Permanent agriculture at Mawlai, situated at an altitude of 1400 m and lying between $25^0.34''$ N latitude and $91^0.52''$ E longitude. The field lies 5 km away from Shillong.

The climate of Shillong is cool with winter temperature dropping down upto 4.0^0C. The low temperature of winter results into frost, which can be seen sometime early in the morning during December to February. The maximum temperature goes upto 25.0^0C in the month of May. The average maximum temperature is 24.7^0C and the average minimum temperature is 5.4^0C. Rainfall had an average of 517mm and an average minimum rainfall of 0.6mm. The relative humidity ranged between 54.0-91.42%. (fig.1)

The typical summer is not found in Meghalaya. However, based on the meteorological condition the year can be divided into the following seasons:

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

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

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

Plate 1: Study site at High Altitude (Upper Shillong)

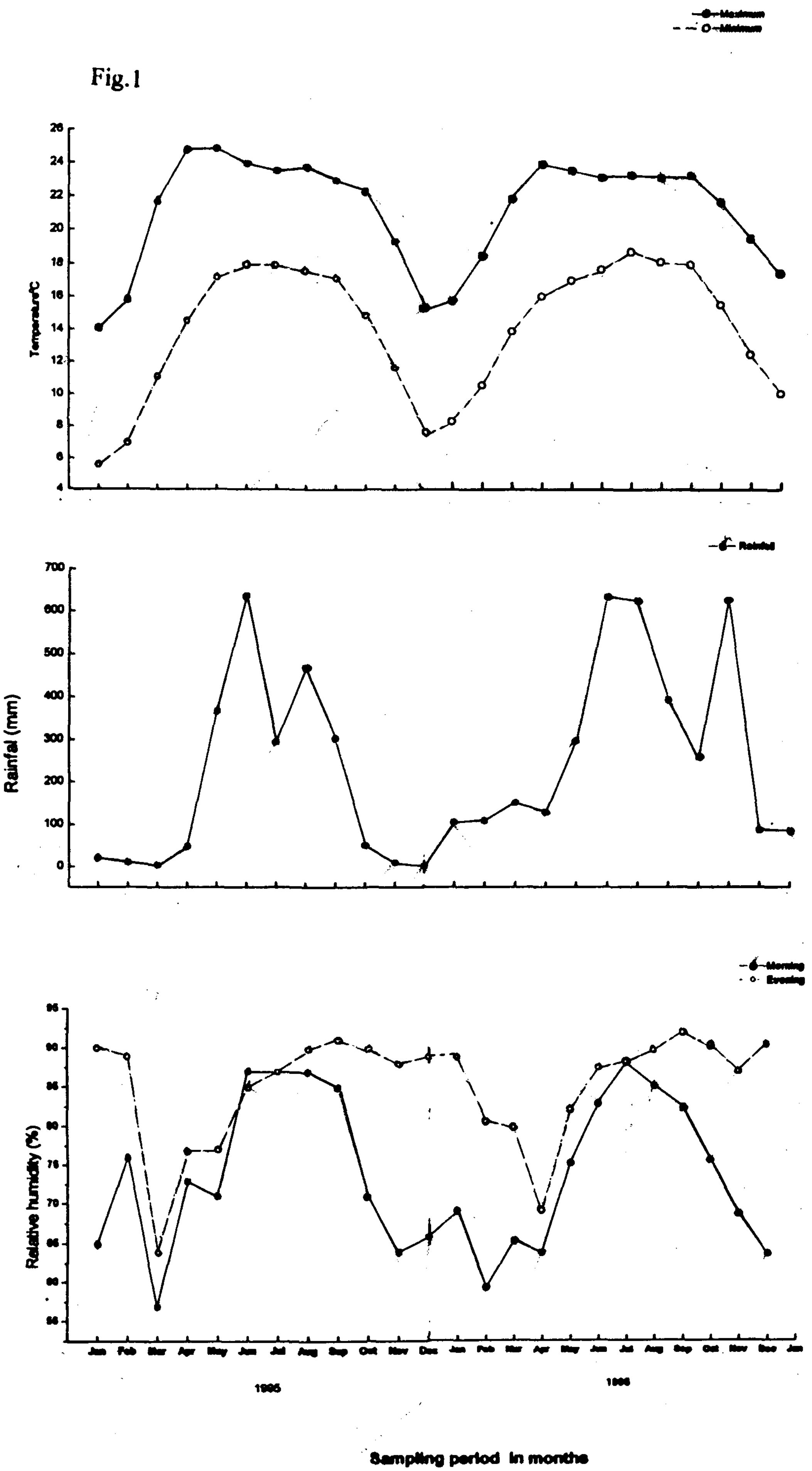
Plate 2: Study site at Low Altitude (Mawlai)

Plate 1

Plate 2

Fig. 1: Monthly variation in ambient temperature (●-●) = maximum, (0-0)=minimum; rainfall and percentage relative humidity (●-●)=Morning , (0-0)Evening

Fig.1


Maximum
Minimum
Temperature°C
Rainfall
Rainfal (mm)
Morning
Evening
Relative humidity (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
1995
1996
Sampling period in months

MATERIALS AND METHODS

Collection of samples:

Samplings of soil, the earthworms and their casts were carried out at the two study sites at monthly intervals for a period of 7 months, starting from the sowing period till harvest, *i.e.*, April to October, being the cropping season of maize. The study was carried on for 2 crop cycles and the following investigations were carried out. The surface soil samples (0-10 cm) were collected randomly from 5 places at each study site. Soil samples from each study site were thoroughly mixed to make a composite sample. This was done to minimize local variation in the microbial population. Earthworm casts were collected randomly from the surface of the soil and thoroughly mixed to make a composite sample as above. The samples were brought to the laboratory and were stored in the refrigerator at a temperature of 4.0^0C. Various estimations were carried out within 24 hours of collection. For the analysis of organic carbon, nitrogen and phosphorus the samples were air dried and sieved in a 0.2 mm sieve.

Soil temperature:

Soil temperature was recorded using a soil thermometer at the time of collection.

Moisture content:

Moisture content of the soil and the casts was estimated by drying known amount (10g) of the sample in a hot air oven at 105^0C for 2 hours and reweighing the dried samples till a constant weight was obtained. Three replicates were maintained for each determination. From the resulting weight loss, the percentage moisture content was calculated as follows:

$$\% \text{ Moisture Content} = \frac{\text{Loss in dry weight}}{\text{Initial sample weight}} \times 100$$

p^H:

Ten grams of soil was saturated with 50 ml of distilled water, thus maintaining a 1: 5 ratio suspension and was stirred for 15 minutes on a mechanical shaker. The p^H was read in a digital p^H meter.

Organic Carbon:

Walkley and Black's (1934) rapid titration method was followed for the determination of organic carbon. One gram of the air-dried sieved sample was taken in a 500 ml conical flask. 10 ml of 1N $K_2Cr_2O_7$ solution was then pipetted onto the sample and mixed by swirling the flask. 20 ml of concentrated H_2SO_4 was subsequently added and mixed by gentle rotation to ensure complete contact of the reagent with the soil. The mixture was allowed to stand for 30 minutes. A control blank (without soil) was run side by side. The solution was then diluted to 200 ml with distilled water and 10 ml of 85% phosphoric acid and 3 drops of diphenylamine indicator were added. The solution was titrated with 1N ferrous sulphate. The amount of ferrous sulphate used was then noted. The percentage organic carbon present in the soil was calculated as follows:

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

Where, B = ml $FeSo_4$ in blank titration.

S = ml $FeSo_4$ in sample titration.

and W = weight of the sample (g)

Total Nitrogen:

Kjeldahl's method was followed for the determination of nitrogen (Jackson, 1973). 2 g of air dried sieved soil was taken in a 300 ml digestion flask, 2 ml of distilled water was added to moisten the soil. 4 g of Na_2So_4 catalyst (1kg Na_2So_4 + 20 g $CuSo_4$ + 3 g HgO+1 g SeO_2) and 7 ml of concentrated H_2So_4 were added. The digestion was carried out on a digestion unit. At the end of the digestion, when the colour of the solution turned greenish-yellow, the heating was stopped and the flasks were allowed to cool. The content was diluted with distilled water. The solution was then ready for the determination of ammonium content by distillation. A control was maintained without the sample. 25 ml of 4% boric acid was taken into a 100 ml conical flask. To this, 2 drops of mixed indicator (0.5 g bromocresol green + 0.1 g methyl red dissolved in 100 ml of absolute alcohol) was added. The flask was placed at one end of the condenser fitted with a receiver tube. The tube was dipped in the boric acid in the flask. 10 ml of digestion solution was put into the distillation flask and then 80% of NaOH was poured drop by drop till the solution turned brown in colour. The released ammonia was absorbed in 4% boric acid and titrated with N/14 HCl. the percentage nitrogen was calculated as follows:

$$\% \text{ Nitrogen} = \frac{(T-B) \times N \times 1.4}{S}$$

Where, T = sample titration.

B = blank titration.

N = normality of the acid.

S = weight of the sample (g).

and 1.4 is a constant factor.

Available Phosphorus:

Molybdenum blue method (Allen, 1974) was followed for the determination of available phosphorus. The available phosphorus was first extracted in 0.5M sodium bicarbonate extraction solution. 4 g of air dried sieved sample was taken in a 100 ml conical flask to which 40 ml of extraction solution was added, and stirred for 15 minutes on a mechanical shaker. The extract was filtered through Whatman No 44 filter paper. 10 ml of the aliquot was pipetted into a 100 ml volumetric flask and 2 ml of double distilled water was added. 4 ml of ammonium molybdate and 2 ml of stannous chloride were added subsequently. The volume was then made upto 100 ml with double distilled water. The optical density was recorded at 700 nm in a spectrophotometer. A calibration curve from the standards was used to determine phosphorus in the aliquot. The percentage available phosphorus was calculated as follows:

$$\%\ \text{Available phosphorus} = \frac{\text{C (mg)} \times \text{solution volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample weight (g)}} \times 100$$

Preparation of Chemicals:

Preparation of ammonium molybdate solution:

25 g of $(NH_4)_6Mo_7O_{24}.4H_2O$ was taken in a beaker. 200 ml of double distilled water was added and warmed slightly. 200 ml of concentrated H_2So_4 was then mixed with 400ml double distilled water in a 1litre flask with alternate mixing and cooling. The two solutions were then mixed together and cooled.

Preparation of stannous chloride:

Stock solution: 10 g of stannous chloride was dissolved in 25 ml of concentrated HCl.

Working standard: 1 ml of stock solution was pipetted in 330 ml of double distilled water.

Extractant solution: 0.5 M $NaHCo_3$ - 42.01 g of Sodium carbonate dissolved in 1000 ml of double distilled water.

Carbon di-oxide evolution:

The carbon di-oxide evolution was measured by absorption and titration method (MacFadyhen, 1970). Roots were handpicked from the soil. 1 kg of the soil was placed in a glass jar. A glass beaker of 100 ml capacity containing 50 ml of 0.1N KOH solution was placed inside the jar. The jars were then sealed and made airtight. A suitable control jar with equal volume of sterilised sand was also used for the subtraction of atmospheric carbon di-oxide. After 24 hours of incubation at room temperature, the amount of carbon di-oxide fixed by KOH solution was measured by titrimetric method using 0.1N HCl as titrant and phenolphthalein as an indicator. Three replicates were used for each soil. Carbon di-oxide evolution was expressed in mg CO_2 evolved per kg dry soil per day basis by taking into consideration the moisture content of the soil. It was calculated as follows:

CO_2 (mg) = (B-V) N x E

Where, B = volume of acid titrated without the sample

V = volume of acid titrated with soil sample

N = normality of the acid

and E = equivalent of CO_2 = 22 (constant)

Estimation of Earthworm population:

The earthworm population was estimated by handpicking method (Edwards and Lofty, 1972) following randomnized-sampling procedure considering 50 sq cm cube. A cube of 50 x 50 x 50 cm was dug up. The earthworms were then picked up from each quadrant, counted and placed in a sterilised polythene bag and brought to the laboratory. Five replicates were maintained for each sampling period. The population was then expressed in terms of numbers.

Isolation of fungi from the soil, casts and the gut of earthworms collected from both sites:

The investigation and isolation of the soil, casts and earthworm gut microflora was carried out on a monthly period for two cropping seasons. The surface soil samples (0-10 cm) and the casts of the earthworms in the fields were collected as mentioned in the previous method for the estimation of physico-chemical characteristics of the soil and casts. With the samples collected the following studies were made:

Isolation of fungi from soil and the casts:

The soil plate method (Warcup, 1950) using Rose Bengal agar medium (Martin, 1950) was followed for the isolation of fungi. A small amount (0.01 g) of the sample was taken from the composite sample with the help of a sterile nichrome spatula having a flattened tip. The sample aggregates were crushed and dispersed in a few drops of sterile distilled water in the bottom of the sterile Petri dishes. Approximately 10-15 ml of melted and cooled (below 45^0C) Martin's Rose bengal agar medium supplemented with Streptomycin sulphate was poured and the sample particles were dispersed throughout the medium by gentle shaking and rotating of the dishes. Three replicates were maintained for each sample. The plates were then incubated upside down at a temperature of 25 ± 1^0 C for 5-6 days in a BOD incubator. The number of colonies was counted and the total number of fungi per gram dry soil was calculated by taking into consideration the moisture content of the soil. The isolation was carried out in a Laminar flow chamber. The pure culture of fungi was maintained in culture tubes containing agar slants of Czapex-Dox agar medium and preserved in the fridge at 4^0 C. The identification of the fungi, the books consulted were those of Gilman (1957), Barnett and Hunter (1972), Subramanium (1971) and Domsch, *et.al.* (1980).

Composition of media for the isolation of fungi:

(a) Peptone-dextrose rose Bengal agar (Martin, 1950).

Agar	20.0g
KH_2PO_4	1.0g
$MgSO_4.7H_2O$	0.5g
Peptone	5.0g
Dextrose	10.0g
Rose Bengal (1%)	3.3ml
Streptomycin	30.0mg.
Distilled water	1000ml.

(b) Czapex-Dox agar (Raper and Thom, 1949)

Agar	15.0g
$NaNO_3$	3.0g
K_2HPO_4	1.0g
$MgSO_4.7H_2O$	0.5g
KCl	0.5g
$FeSO_4$	10.0mg
Sucrose	30.0g
Distilled water	1000ml.

Determination of Percentage Relative Abundance:

The determination of percentage relative abundance of a particular species of fungi was done by means of the following formula:

$$\text{Relative abundance (\%)} = \frac{\text{Total number of colonies of the particular species}}{\text{Total number of colonies of all the species}} \times 100$$

Estimations of fungal populations in earthworm gut contents:

3 large earthworms (6cm approximately) were brought to the laboratory, cleansed thoroughly with sterilised distilled water and killed in 70% alcohol. The body cavity was opened ventrally and flooded with Ringer's solution. The gut was partitioned *in situ* by a double ligature placed between the midgut and the hindgut; additional single ligatures were placed around the oesophagus and rectum. The midgut and hindgut were dissected free and collected in sterilised Petri dishes and agitated gently in 3-4 changes of Ringer's solution. Preliminary experiments showed that this treatment reduced contamination from the cut ends of the gut to an insignificant level. A small amount of the gut contents of the different parts was inoculated in sterilised Petri dishes by soil plate method (Warcup, 1950) using Martin's Rose Bengal agar medium (Martin, 1950) for isolation of fungi.

Composition of Ringer's solution:

NaCl	0.9g
KCl	0.042g
$CaCl_2$	0.025g
Distilled water	100ml

Effect of earthworms on maize growth in greenhouse condition:

An altered method of Mackay and Kladivko (1985) was followed for the study of the effect of earthworms on maize growth. A greenhouse study using pots was conducted for a period of 50 days. Soil collected from the field was sieved through a sieve of < 8mm and kept moist before use. One kg of sieved soil was sterilised for each pot. The sterilised soil was then potted. Three sterilised maize seeds were then sown in each pot. Four adult earthworms whose length and weight were measured were then introduced into each pot. Control pots were maintained for each harvest, wherein, no earthworms were introduced. Triplicates were maintained for the whole experiment. The microcosm was then watered regularly to maintain adequate moisture level. Harvest was done at an interval of 10 days.

Length of the stem and the roots was measured and their biomass was determined on an oven dry basis, and expressed in grams. Length of the earthworms and their biomass were also measured after each harvest of maize.

Estimation of dispersal of fungi by earthworms:

Soil from burrows and the surrounding soil were collected separately from five different places, in sterilised polythene bags. The samples were then thoroughly mixed to make a composite sample. The samples were brought to the laboratory and stored at a temperature of 4^0C. The p^H and the moisture content of the samples were estimated. Isolation of fungi from both the soils was done following the soil plate method (Warcup, 1950) using rose bengal agar medium (Martin, 1950).

Decomposition of maize litter by earthworms in laboratory condition:

An altered method of Mackay and Kladivko (1985) was followed for the study of the effect of earthworm on the decomposition of maize litter. Maize litter was collected shortly after harvest. Moisture content and p^H of the maize residues were determined. The maize residues were then oven dried and cut into small pieces and separated into stem, roots and leaves. Soil was collected from the field, sieved and kept moist before use. Ten grams of the maize residues i.e., stem, roots and leaves were added separately to each pot containing 1kg of sieved soil. The residues were thoroughly mixed with the soil. The earthworms *Amynthas gracilis* (Kinberg) were weighed and their length measured. 4 Adult earthworms were introduced into each pot and the microcosm was moistened with water. Control pots were also maintained throughout the study period. The whole set-up was maintained in triplicates. Samplings were done at an interval of 20 days for 100 days to represent 5 months of cultivation. The residue breakdown is determined by taking out the soil from each pot and sieved through a sieve of 6mm. Residues were then recovered by washing the sieved samples on a 0.3 mm sieve. The samples were then oven dried and the final weight of the residues was taken into consideration. The residues were then used in the determination of cellulose, hemicellulose and lignin. The p^H, moisture content, organic carbon of the soil were analysed. CO_2 evolution was measured following methods described in the earlier paragraphs.

Cellulose, hemicellulose and lignin were estimated by following the method of Peach and Tracy (1955).

(a) Estimation of cellulose and hemicellulose:

0.3 g of ground material was treated with 20 ml of 25% aqueous KOH (w/v) and kept at room temperature for 12 hours. The mixture was then centrifuged at 3000 rpm for 15 minutes. The decant obtained was used for the detection of hemicellulose. The residue left was washed with distilled water till traces of KOH were removed. It was then oven dried at 60^0C for 24 hours and cooled at room temperature over anhydrous calcium chloride in a dessicator and weighed. The amount thus obtained was total cellulose. The decant obtained was neutralised with equal amount of glacial acetic acid and ethanol. The precipitate was filtered, washed, dried and weighed as above for the determination of hemicellulose. Three replicates were taken in each case.

(b) **Estimation of lignin:**

For the estimation of lignin, 0.25 g of dried litter powder was taken in a test tube and treated with 10 ml of 72% H_2SO_4 and kept in a deep freeze for 24 hours. It was then centrifuged and the residue was collected, washed thoroughly to remove the traces of H_2SO_4 present. It was then oven dried at 60^0C and weighed. The amount so obtained gave the total lignin content in the litter. The cellulose, hemicellulose and lignin content were estimated on the initial dry weight of the litters.

Quantitative estimation of Total sugar and Amino acid:

Methods described by Mahadevan and Sridhar (1982) were followed for the estimation of sugar and amino acid. 0.3 g of dried powdered litter was weighed into a test tube and treated with 15 ml of 80% alcohol. Occasionally, when any colour developed, it was treated with activated charcoal and centrifuged at 6000 rpm. The solution was then filtered through a Whatman No. 1 filter paper. The clear filtrate was boiled on a hot water bath to remove the last traces of alcohol and then distilled was added to the test tube to make the volume upto 5 ml. To 3 ml of this solution, 6 ml of anthrone reagent (0.4% in H_2SO_4) was added gently to the test tube from the side while the test tube is kept in cold water. The test tubes were gently shaken and warmed in a hot water bath for a few minutes till a green colour is developed. The optical density of the filtrate was read in a Spectrophotometer at 610 nm. Standard curve was prepared from transmittance of varying concentration of glucose solution treated with anthrone reagent as described for the samples.

From the standard curve the values of total sugar of the samples were calculated and expressed in mg/g dry weight of the samples.

To the rest of the 2 ml solution, 2.5 ml of ninhydrin citrate buffer solution was added. The mixture was then placed on a hot water bath for one hour. A light purple colour then developed and the optical density was read in a Spectrophotometer at 540 nm. Standard curve was prepared from transmittance of varying concentration of leucine solution treated with ninhydrin citrate buffer solution. From the standard curve the values of total amino acid of the samples were calculated and expressed in mg/g dry weight of the samples. The estimation in each case was done in triplicates.

RESULTS

Soil temperature:

Temperature of the soil was observed to be higher at low altitude than at high altitude in both the cropping seasons (fig. 2). At high altitude the temperature ranged between 19.5^0C-26.0^0C, whereas, at low altitude the temperature ranged between 21.1^0C-28.5^0C. Maximum temperature at high altitude was recorded in the month of May and June in the first and second cropping season respectively, whereas, maximum temperature at low altitude was recorded in the month of May and August in the first and second cropping season respectively.

Moisture content:

Moisture content of the soil was observed to be higher at low altitude than at high altitude in both the cropping seasons (fig. 3). At high altitude the moisture content of the soil ranged between 7.0-40.0% and in the casts, it ranged between 6.0-46.4% whereas, at low altitude the moisture content of the soil ranged between 10.0-49.4% and in the casts, it ranged between 5.0-45.4%. In the first cropping season, the moisture content of the soil was lower than that of the casts, whereas, in the second cropping season the moisture content of the soil was found to be higher than that of the casts. Maximum moisture content of the soil was recorded in the month of October and September at both high and low altitude respectively, in the first cropping season, whereas, it was recorded in the month of September at both the sites. Maximum moisture content of the casts was recorded in the month of August and September at both high and low altitudes respectively, in the first cropping season, whereas, it was recorded in the month of September at both the sites, in the second cropping season.

Fig.2: Soil Temperature at high and low altitudes respectively during the two cropping seasons.

Fig.2

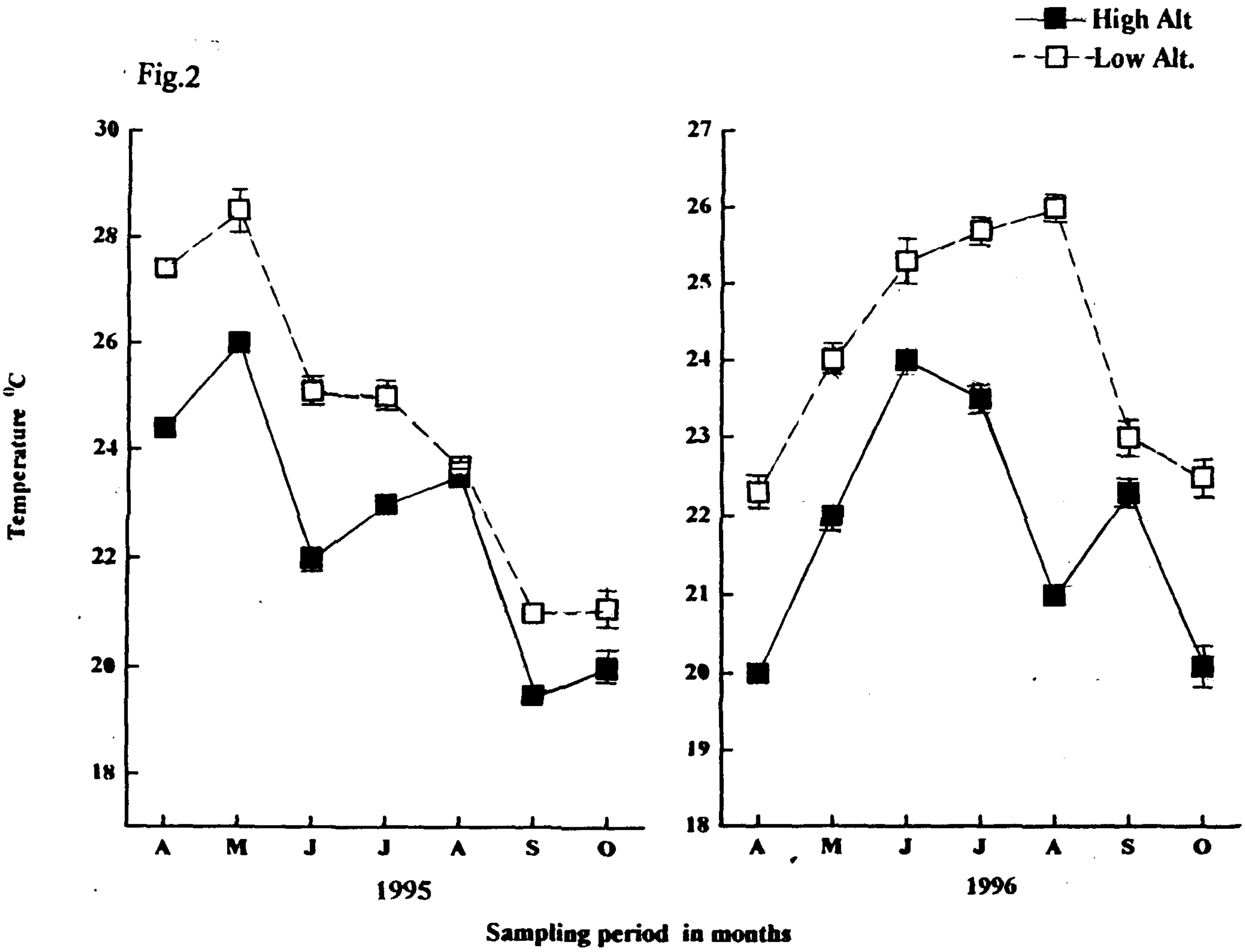
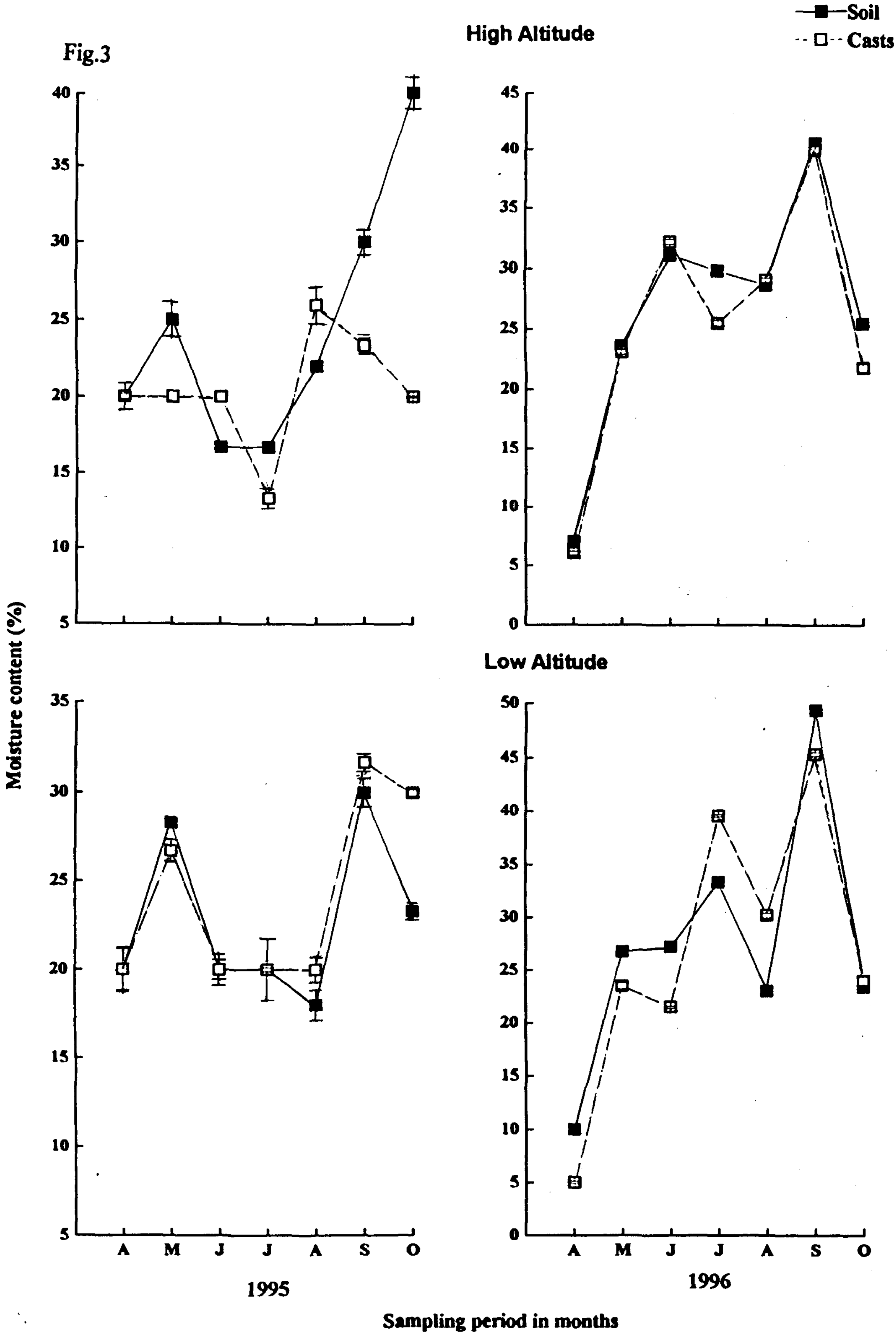

High Alt
Low Alt.
Temperature °C
30
28
26
24
22
20
18
27
26
25
24
23
22
21
20
19
18
A
M
J
J
A
S
O
1995
1996
Sampling period in months

Fig. 3: Moisture content in soil and casts at high and low altitude respectively during the two cropping seasons.

Fig.3



Soil
Casts
High Altitude
Low Altitude
Moisture content (%)
40
35
30
25
20
15
10
5
45
0
50
A
M
J
J
A
S
O
1995
1996
Sampling period in months

p^H:

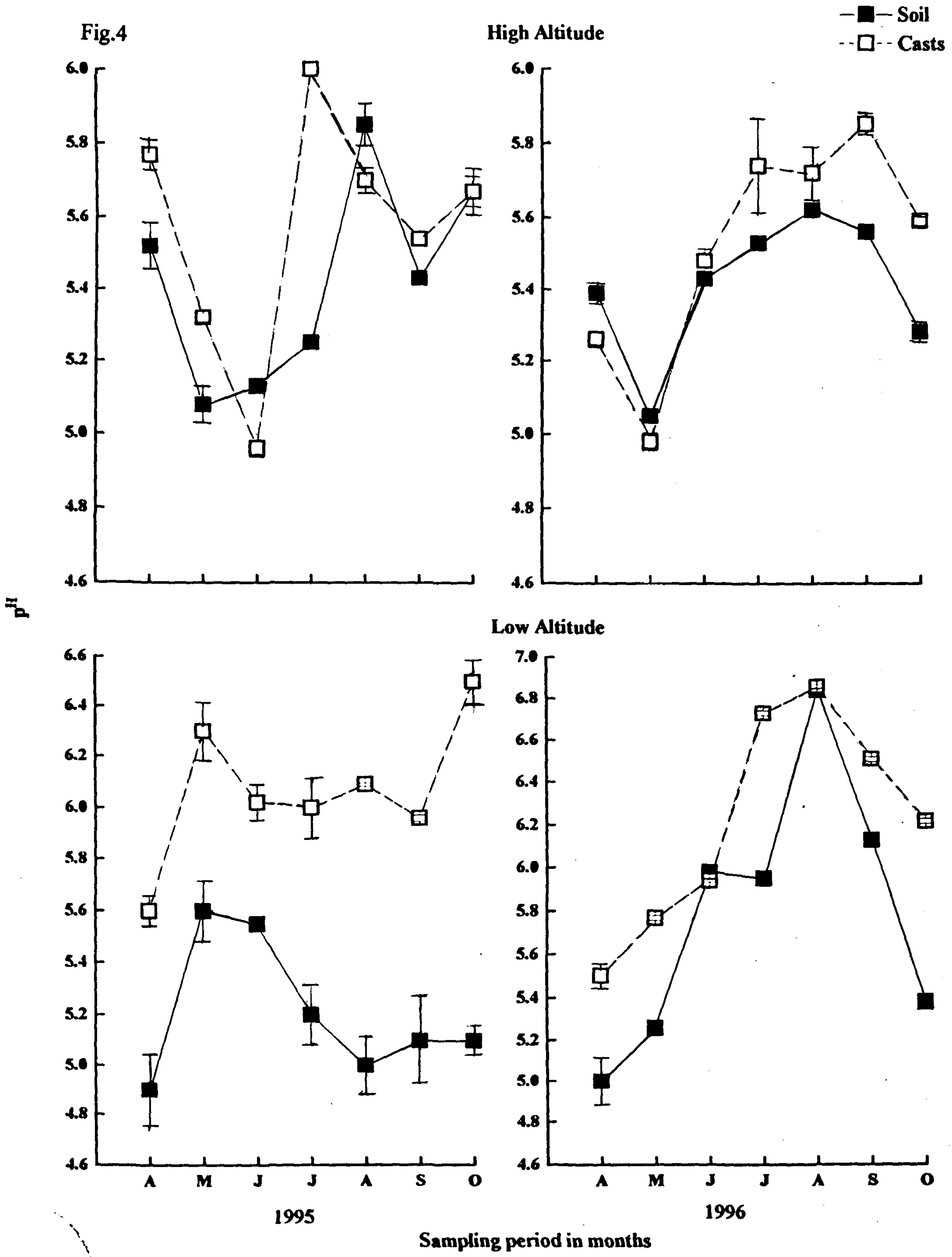
There was monthly variation in p^H of the soil and the casts. p^H of the soil was observed to be higher at high altitude than at low altitude in the first cropping season, whereas, it was higher at low altitude than at high altitude in the second cropping season. (fig. 4). The p^H of the casts was observed to be higher at low altitude than at high altitude in both the cropping seasons. The p^H of the soil ranged between 5.05-5.83 at high altitude and between 4.90-6.80 at low altitude. The p^H of the casts ranged between 4.90-5.90 at high altitude and between 5.50-6.86 at low altitude. Maximum p^H of the soil was recorded in the month of August at high altitude in both the cropping seasons. As well as in the soil at low altitude in the second cropping season, whereas, maximum p^H of the soil was recorded in the month of May at low altitude in the first cropping season. Maximum p^H of the casts was recorded in the month of July and October in the first cropping season at high and low altitude respectively. Whereas, maximum p^H of the casts was recorded in the months of September and August in the second cropping season, at high and low altitude respectively.

Organic carbon:

Organic carbon was observed to be higher at low altitude than at high altitude in the soil and the casts, in both the cropping seasons (fig. 5). Organic carbon content ranged between 1.05-2.0% and 1.38-2.26% in the soils at high altitude and low altitude respectively. In the casts, organic carbon content ranged between 1.11-2.8% and 1.9-3.67% at high altitude and low altitude respectively. Maximum organic carbon content was recorded in the month of May and August in the soils at high altitude and low altitude respectively in the first cropping season. Whereas, it was maximum in the month of September and April in the soils at high altitude and low altitude respectively in the second cropping season.

Fig. 4: p^{H} in soil and casts at high and low altitudes respectively during the two cropping seasons.

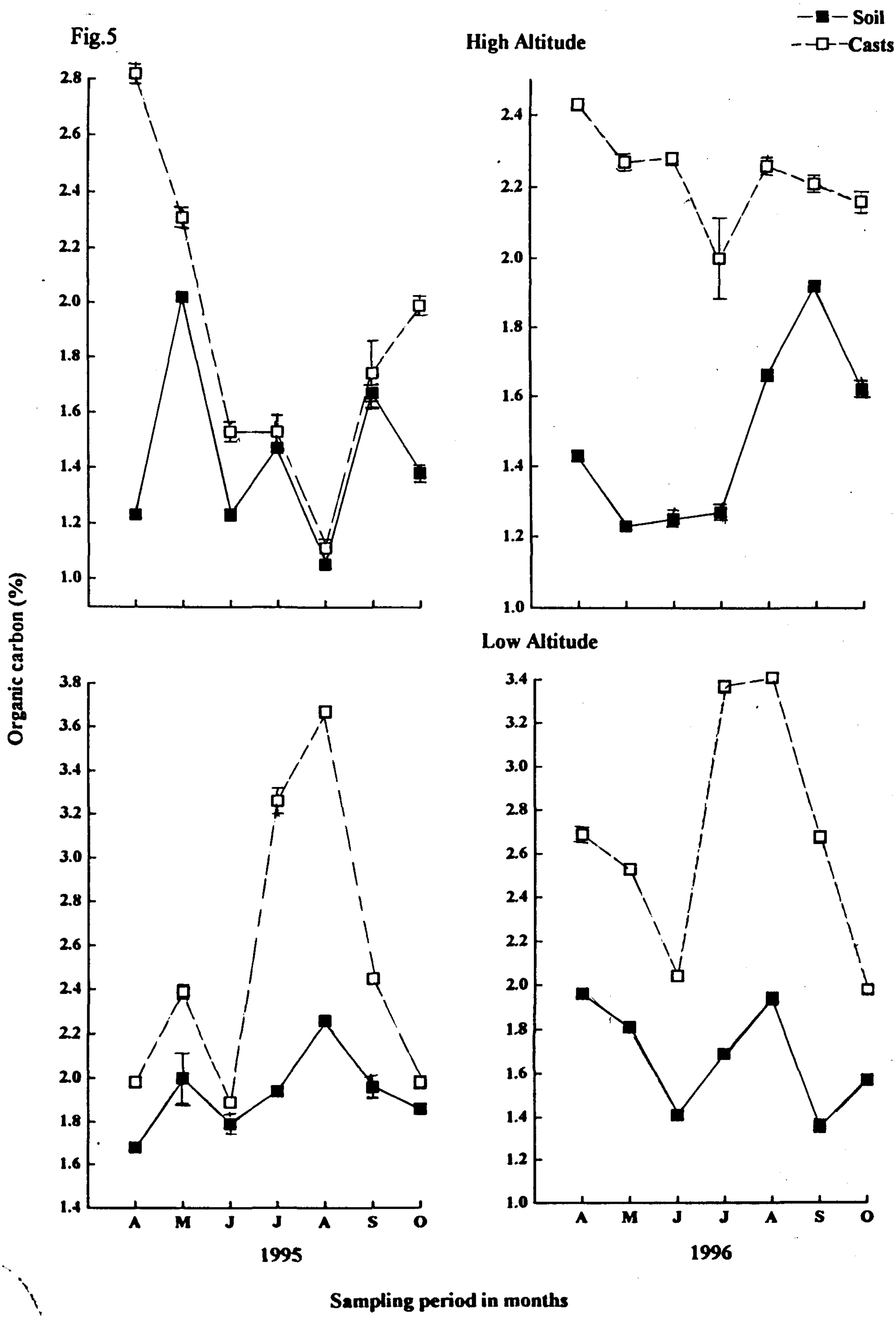
Fig.4



High Altitude
Low Altitude
Soil
Casts
p^H
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
6.6
6.4
6.2
7.0
6.8
A
M
J
J
A
S
O
1995
1996
Sampling period in months

Fig. 5: Organic carbon in soil and casts at high and low altitudes respectively during the two cropping seasons.

Fig.5



Soil
Casts
High Altitude
Low Altitude
Organic carbon (%)
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
3.8
3.6
3.4
3.2
3.0
A
M
J
J
A
S
O
1995
1996
Sampling period in months

Maximum organic carbon content was recorded in the month of April and August in the casts at both the sites in both the cropping seasons.

Total Nitrogen:

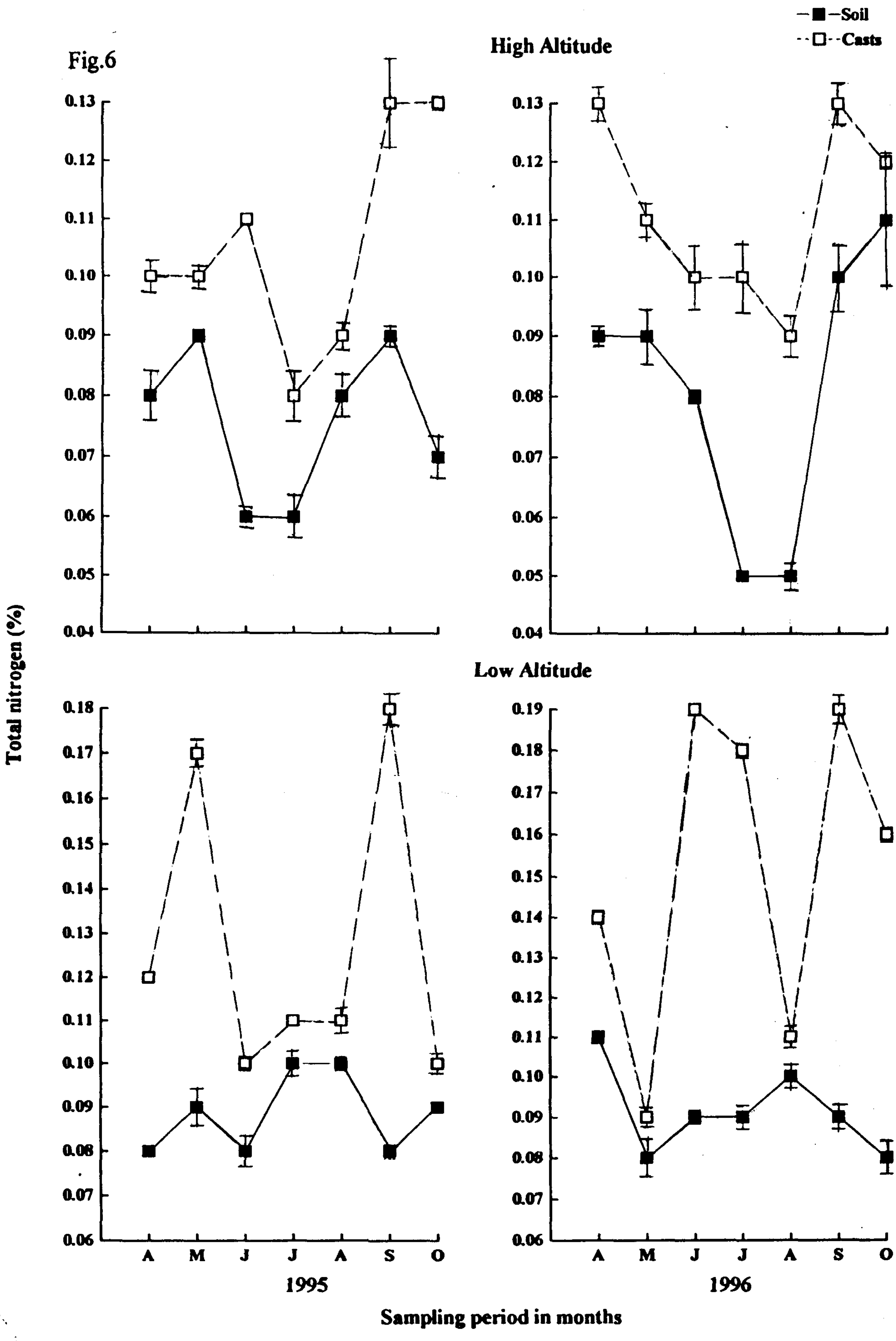
Not much difference was observed in the nitrogen content in the soils at both high and low altitude, whereas, the nitrogen content was higher in the casts at low altitude than that from low altitude (fig. 6). The nitrogen content in the soil ranged between 0.05- 0.11% and 0.10-0.11% at high and low altitude respectively. The nitrogen content in the casts ranged between 0.08-0.13% and 0.09-0.19% at high and low altitude respectively. Maximum total nitrogen was recorded in the month of May and September in the soils at high altitude and in the month of July and August in the soils at low altitude during the first cropping season. Whereas, maximum total nitrogen was recorded in the month of April and October in the soils at high altitude and in the month of April in the soils at low altitude during the second cropping season. Maximum total nitrogen was recorded in the month of September and October in the casts at high altitude and in the month of September in the casts at low altitude during the first cropping season. Whereas, it was maximum in the month of June and September in the casts at high altitude and low altitude during the second cropping season.

Available Phosphorus:

The available phosphorus in the soil and the casts was observed to be higher at low altitude than at high altitude (fig. 7). The available phosphorus in the soil ranged between 0.0019-0.0034% at high altitude, whereas, it ranged between 0.0015-0.0035% at low altitude. Available phosphorus in the casts ranged between 0.0020-0.0047% at high altitude and between 0.0020-0.0054% at low altitude. Maximum available phosphorus in the soil was recorded in the month of September and August at high and low altitudes respectively

Fig. 6: Total nitrogen in soil and casts at high and low altitudes respectively during the two cropping seasons.

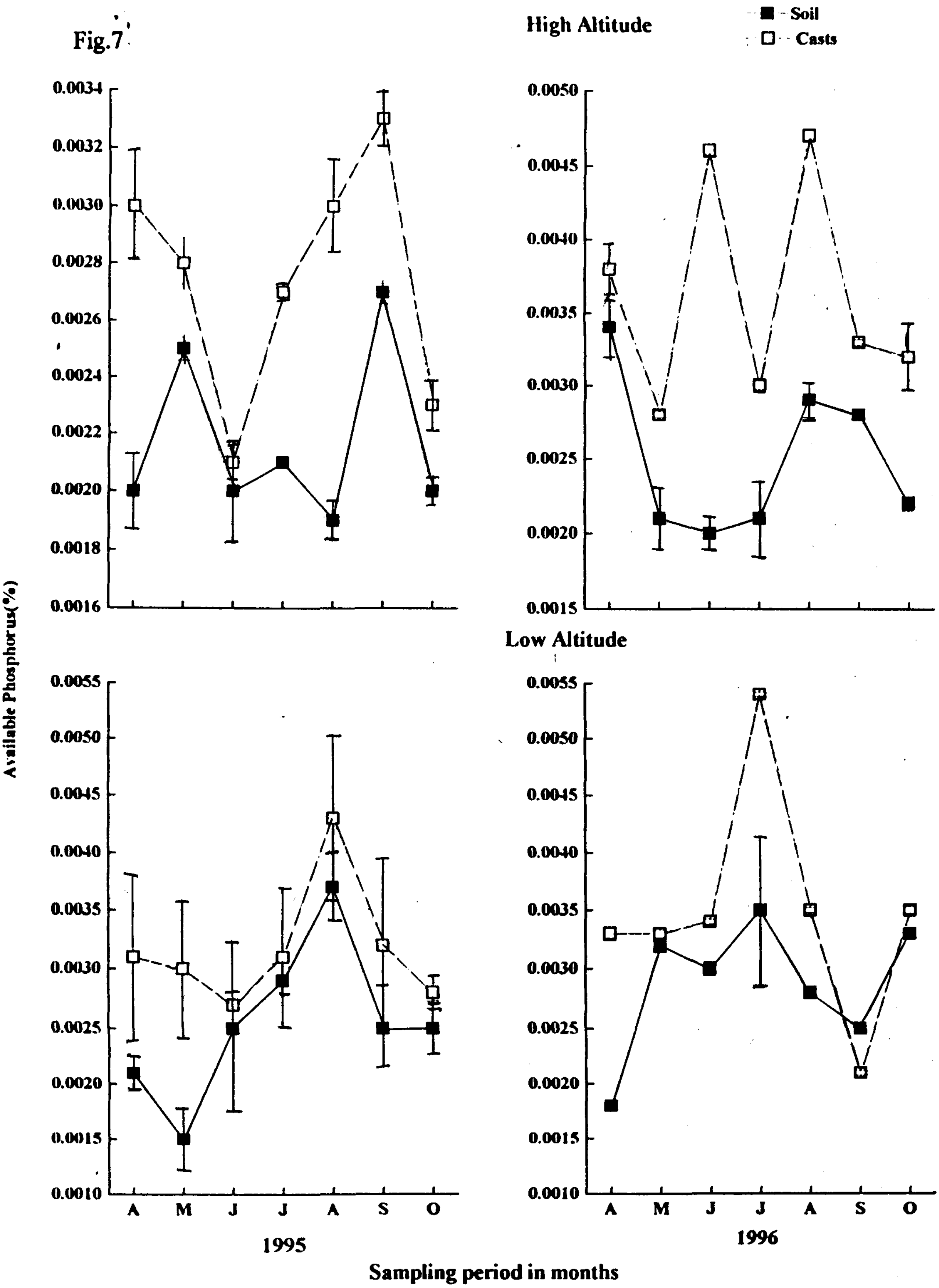
Fig.6



—■—Soil
- -□- -Casts
High Altitude
Low Altitude
Total nitrogen (%)
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.19
0.18
0.17
0.16
0.15
0.14
0.06
A M J J A S O
1995
1996
Sampling period in months

Fig. 7 : Available phosphorus in soil and casts at high and low altitudes respectively during the two cropping seasons.

Fig.7


High Altitude
Soil
Casts
Low Altitude
Available Phosphorus(%)
0.0034
0.0032
0.0030
0.0028
0.0026
0.0024
0.0022
0.0020
0.0018
0.0016
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
A M J J A S O
1995
1996
Sampling period in months

in the first cropping season and in the months of April and July at high and low altitudes respectively in the second cropping season. Maximum available phosphorus in the casts was recorded in the month of September and August at high and low altitudes respectively in the first cropping season and in the months of August and July at high and low altitudes respectively in the second cropping season.

Carbon di-oxide:

Carbon di-oxide evolution in the soil was observed to be higher at low altitude than at high altitude in both the cropping seasons. (fig. 8) The carbon di-oxide evolution ranged between 0.867-10.987 mg/kg dry soil/day at high altitude, whereas, it ranged between 1.157-14.067 mg/kg dry soil/day at low altitude. Maximum carbon di-oxide evolution was recorded in the month of July at both the sites in the first cropping season, whereas, it was maximum in the month of June and July at high and low altitude respectively in the second cropping season.

Earthworm population:

The earthworm population was observed to be higher in the soil at low altitude than at high altitude (fig. 9). The number of earthworms per 50 sq cm^3 ranged between 4-12 at high altitude and between 5-21 at low altitude. The highest earthworm population was recorded in the month of August at both the study sites, during both the cropping seasons. The earthworms' *Amynthas gracilis* (Kinberg) and *Metaphire houletti* (Perrier) were collected from the field at high altitude, whereas, *Amynthas gracilis* (Kinberg) and *Amynthas corticis* (Kinberg) were collected from the field at low altitude.

At high altitude, (Table A) the earthworm population was negatively correlated with the temperature of the soil ($P<0.10$) and also with the percentage organic carbon of the casts ($P<0.05$), whereas, it was positively correlated with the p^H of the soil and the casts

Fig.8: CO_2 evolution of soil at High and Low Altitude during the two cropping seasons

Fig.8

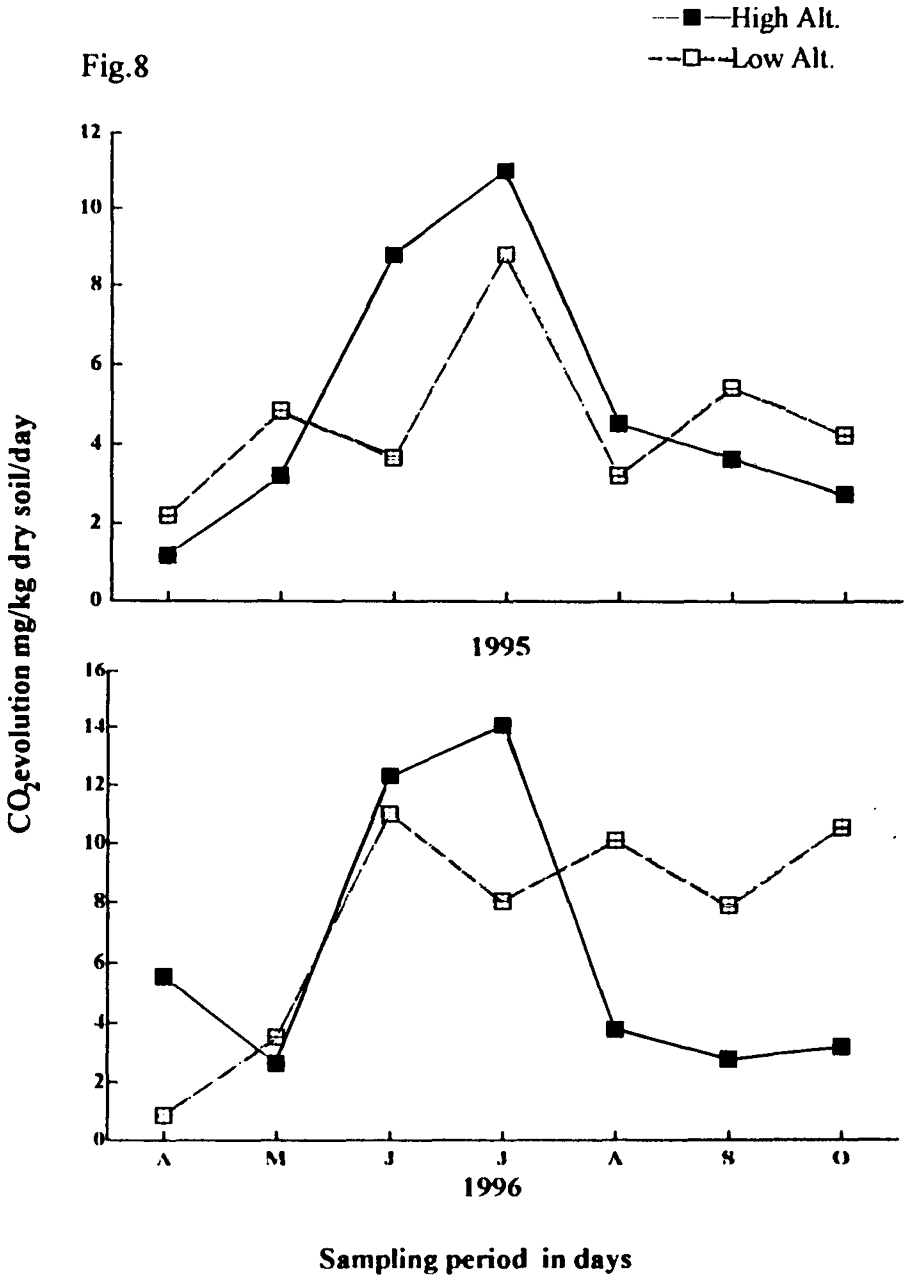
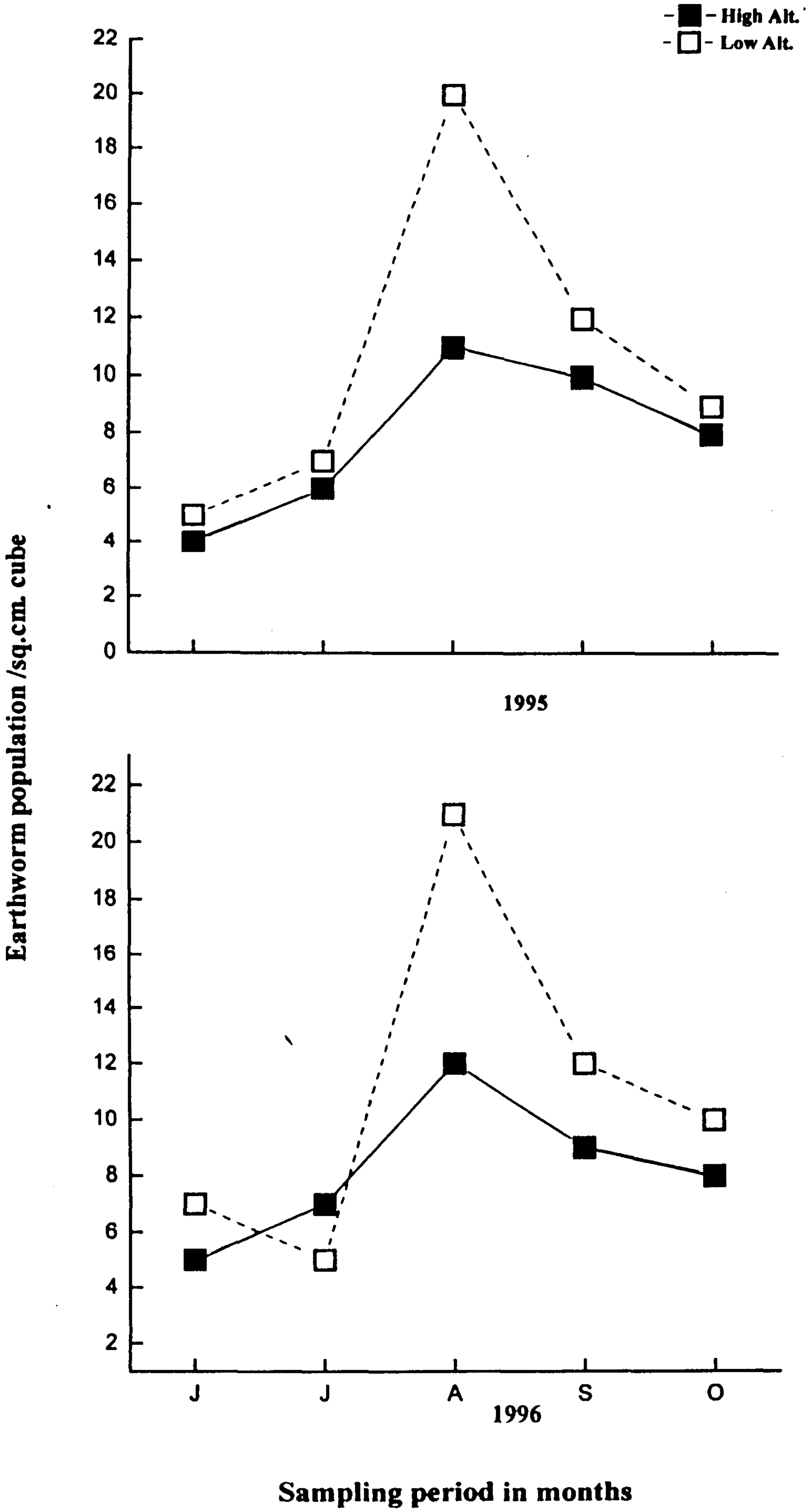

High Alt.
Low Alt.
CO2 evolution mg/kg dry soil/day
12
10
8
6
4
2
0
1995
16
14
12
10
8
6
4
2
0
A
M
J
J
A
S
O
1996
Sampling period in days

Fig. 9: Earthworm population in the two fields during the sampling period

Fig.9



High Alt.
Low Alt.
Earthworm population /sq.cm. cube
22
20
18
16
14
12
10
8
6
4
2
0
1995
22
20
18
16
14
12
10
8
6
4
2
J
J
A
S
O
1996
Sampling period in months

(P<0.10) respectively. Whereas, the earthworm population was positively correlated with the moisture content of the soil and the casts (P<0.10) respectively, and it was positively correlated with percentage organic carbon of the soil (P<0.10).

At low altitude, there was a positive correlation between the earthworm population and the temperature of the soil (P<0.10), p^H of the soil and the casts (P<0.02, P<0.05) respectively, and also with the percentage organic carbon of the soil and the casts (P<0.05, P<0.10) respectively.

Fungal population of the soil and the casts of the two maize fields:

Tables1-20 show the monthly variation of fungal population in the maize field soils, casts and gut contents of earthworms collected from high and low altitudes during the study period. Values in parentheses shows the relative abundance. The fungal population was observed to be higher in the soil of low altitude than of soil from high altitude. (fig. 10) It was observed to be higher in the casts than in the soil of low altitude during the first cropping season whereas it was observed to be higher in the soil than in the casts at high altitude in the first cropping season as well as in the second cropping at both low and high altitudes. The fungal population ranged between 1.12-6.74/g dry soil x 10^2 in the soil at high altitude, whereas, it ranged between 1.16-7.06/g dry soil x 10^2 in the soil at low altitude. In the case of the casts, fungal population ranged between 1.13-4.20/g dry soil x 10^2 in the soil at high altitude, whereas, it ranged between 1.25-5.47/g dry soil x 10^2 in the soil at low altitude. Monthly fluctuations in the fungal population were observed. The fungal population in the soil was observed to be maximum in the month of May and October in the first and second cropping season respectively. In the case of the soil at low altitude, the fungal population was observed to be maximum in the month of May and September in the first and second cropping season respectively. In the case of the casts, at high altitude, the

Table A : Correlation coefficient values(r) for various parameters in the two maize fields.

		High Altitude							Low Altitude						
Sources of variation	D.F	T^0C	p^H		M.C.(%)		O.C(%)		T^0C	p^H		M.C.(%)		O.C(%)	
		Soil	Soil	Casts	Soil	Casts	Soil	Casts	Soil	Soil	Casts	Soil	Casts	Soil	Casts
Earthworm population	5	-0.690*	0.723*	0.888***	0.674*	0.637*	0.635*	N.S.	0.695**	0.888**	0.781*	N.S.	N.S.	0.775**	0.661*
Fungal population	5	N.S.	N.S.	N.S.	N.S.	0.671**	0.829**	N.S.	N.S.	N.S.	0.875***	N.S.	N.S.	0.671*	N.S.

P< 0.10, 0.05,0.01 (*,**,*** respectively)

Table 1: Monthly variation of fungal population (per gram dry soil x 10^2) in the maize field soil at Mawlai during the sampling period (1995). Values in the parentheses are percentage relative abundance.

	Months						
Fungi	April	May	June	July	August	September	October
Mortierella minutissima	–	–	–	–	–	0.19 (10.00)	–
M. parvispora	–	–	–	–	–	0.10 (5.00)	–
M. racemosus	–	–	–	0.08 (6.26)	0.54 (19.40)	–	–
Rhizopus stolonifer	–	–	–	–	–	0.43 (22.50)	0.35 (21.62)
Pythium intermedium	–	0.05 (1.36)	0.29 (23.33)	–	0.13 (4.48)	0.62 (32.50)	0.44 (27.03)
Cladosporium cladosporoides	0.25 (19.36)	–	–	–	–	–	–
Cunninghamella elegans	–	–	–	0.16 (12.50)	–	0.24 (12.50)	–
Fusarium merismoides	0.38 (29.04)	0.70 (20.55)	0.04 (3.33)	0.94 (71.86)	–	0.10 (5.00)	0.65 (40.54)
F. oxysporum	–	–	–	–	0.75 (26.87)	0.19 (10.00)	0.17 (10.81)
F. poae	0.08 (6.48)	–	–	–	–	–	–
F. redolens	–	–	–	–	0.42 (30.00)	–	–
F. semitectum	–	–	0.42 (30.00)	–	–	–	–
F. sporotrichioides	–	–	–	–	0.88 (31.34)	–	–
Penicillium brevicompactum	–	1.54 (45.21)	–	–	–	–	–
P. chrysogenum	–	0.19 (5.48)	0.47 (13.33)	–	–	–	–
P. frequentans		–	–	–	0.08 (2.99)	–	–
Trichoderma harzianum	0.21 (16.70)		–	–	–	–	–
T. koningii	0.04 (3.20)	–	0.04 (3.33)	–	–	–	–
T. pseudokoningii	0.29 (22.55)	–	–	–	–	–	–
T. viride	–	–	–	0.12 (9.38)	–	0.05 (2.50)	–
White sterile mycelia	–	0.93 (27.40)	0.29 (23.33)	–	–	–	–
Yellow sterile mycelia	0.04 (3.20)	–	–	–	–	–	–

Table 2: Monthly variation of fungal population (per gram dry soil x 10^2) in the maize field casts at Mawlai during the sampling period (1995). Values in the parentheses are percentage relative abundance.

Fungi	April	May	June	July	August	September	October
				Months			
Mortierella minutissima					0.13 (6.82)	_	_
M. parvispora	_	_	_	_	_	0.54 (31.43)	_
Mucor hiemalis	0.04 (1.87)	_	0.04 (3.70)	_	_	_	_
M. mucedo	_	_	_	_	_	0.49 (28.57)	_
M. racemosus	_	_	_	0.88 (32.3)	0.13 (6.82)	_	_
Pythium intermedium	_	_	0.08 (7.41)	0.29 (10.80)	_	0.59 (34.29)	0.91 (59.38)
Cunninghamella elegans	_	_	_	_	0.13 (6.82)	_	_
Doratomyces stemonitis	_	_	0.13 (11.11)	_	_	_	_
Fusarium merismoides	0.21 (9.45)	1.18 (72.22)	0.17 (14.82)	1.42 (52.30)	0.83 (45.45)	_	0.62 (40.62)
Penicillium brevicompactum	_	0.05 (2.78)	0.04 (3.70)	_	0.21 (11.37)	_	_
P. canescens	_	_	_	_	0.04 (2.27)	_	_
P. chrysogenum	_	_	0.08 (7.41)	_	_	_	_
P. waksmanii	_	_	0.21 (18.51)	_	0.38 (20.45)	0.10 (5.72)	_
Trichoderma koningii	0.33 (15.11)	_	0.17 (14.82)	_	_	_	_
T. viride	1.25 (56.59)	_	_	0.13 (4.60)	_	_	_
Verticillium albo-atrum	_	_	0.04 (3.70)	_	_	_	_
White sterile Mycelia	0.38 (16.98)	0.32 (19.45)	0.17 (14.82)	_	_	_	_
Yellow sterile Mycelia	_	0.09 (5.55)	_	_	_	_	_

Table 3: Monthly variation of fungal population (per gram dry soil x 10^2) from the fore-gut of earthworms collected from Mawlai during the sampling period (1995). Values in the parentheses are percentage relative abundance.

Fungi	Months						
	April	May	June	July	August	September	October
Mortierella candelabrum	_	_	_	0.67 (22.22)	_	_	_
M. parvispora	_	_	_	_	_	6.67 (54.07)	_
Mucor hiemalis	0.67 (10.00)	_	_	_	0.33 (9.10)	_	_
M. mucedo	_	_	0.33 (12.41)	_	0.33 (9.10)	_	_
Pythium intermedium	_	1.00 (59.88)	_	_	0.3 (8.19)	_	0.67 (12.50)
Aspergillus wentii	_	_	0.33 (12.41)	_	_	_	_
Cunninghamella elegans	_	_	_	_	_	1.00 (8.11)	_
Fusarium merismoides	_	_	0.33 (12.41)	0.33 (11.11)	_	_	3.00 (56.25)
F. oxysporum	_	_	_	_	0.67 (18.47)	1.33 (10.80)	1.67 (31.25)
F. poae	_	_	1.67 (62.77)	_	_	_	_
F. sporotrichioides	_	_	_	0.67 (22.22)	_	_	_
Paecilomyces sp.	5.00 (75.00)	_	_	_	0.67 (18.47)	_	_
Penicillium canescens	0.33 (5.00)	_	_	_	_	2.00 (16.22)	_
P. frequentans	_	_	_	_	0.33 (9.10)	_	_
Trichoderma koningii	_	0.67 (40.12)	_	0.33 (11.11)	_	_	_
T. viride	0.33 (5.00)	_	_	_	0.33 (9.10)	_	_
White sterile Mycelia	_	_	_	_	0.67 (18.47)	1.33 (10.80)	_
Yellow sterile Mycelia	0.33 (5.00)	_	_	1.00 (33.67)	_	_	_

Table 4: Monthly variation of fungal population (per gram dry soil x 10^2) from mid-gut of earthworms collected from Mawlai during the sampling period (1995). Values in the parentheses are percentage relative abundance.

Fungi	Months						
	April	May	June	July	August	September	October
Mortierella candelabrum	_	_	_	0.33 (14.29)	_	_	_
M. elongata	_	_	_	0.33 (14.29)	_	_	_
M. gamsii	_	_	_	_	1.32 (26.67)	_	_
M. parvispora	_	_	_	_	_	4.33 (28.26)	_
Mucor hiemalis	1.00 (9.37)	0.67 (22.22)	_	0.33 (14.29)	_	_	_
M. mucedo	_	_	0.67 (22.22)	_	_	1.00 (6.52)	_
Pythium intermedium	_	0.67 (22.22)	_	1.00 (42.84)	_	_	2.67 (57.14)
Rhizopus pusillus	_	_	0.33 (20.00)	_	_	_	_
Aspergillus fumigatus	0.67 (6.24)	_	_	_	_	_	_
Cunninghamella elegans	_	_	_	_	0.33 (6.67)	5.00 (32.62)	_
Fusarium merismoides	_	_	0.67 (40.00)	0.33 (14.29)	_	_	2.00 (42.86)
F. oxysporum	_	_	_	_	1.98 (40.00)	_	_
Penicillium brevicompactum	_	_	_	_	_	_	_
P. canescens	0.67 (6.24)	_	_	_	_	4.67 (30.44)	_
P. janthinellum	0.33 (3.12)	_	_	_	_	_	_
Trichoderma harzianum	_	_	_	_	_	0.33 (2.16)	_
T. koningii	_	_	0.29 (17.78)	_	1.34 (26.67)	_	_
T. viride	0.33 (3.12)	0.67 (22.22)	_	_	_	_	_
White sterile Mycelia	4.66 (43.77)	1.00 (33.34)	_	_	_	_	_
Yellow sterile Mycelia	3.00 (28.14)	_	_	_	_	_	_

Table 5: Monthly variation of fungal population (per gram dry soil x 10^2) in the hind-gut of earthworms collected from Mawlai during the sampling period (1995). Values in the parentheses are percentage relative abundance.

Fungi	Months						
	April	May	June	July	August	September	October
Mortierella parvispora	_	_	_	_	1.00 (20.00)	2.33 (12.49)	_
Mucor hiemalis	_	_	0.33 (16.50)	_	0.67 (13.4)	_	_
Pythium intermedium	_	_	_	_	_	_	2.67 (53.33)
Cunninghamella elegans	_	_	_	_	_	2.33 (12.49)	_
Fusarium merismoides	_	_	1.33 (67.00)	_	_	_	2.33 (46.73)
F. oxysporum	_	_	_	_	1.00 (20.00)	_	_
F. proliferatum	_	_	_	3.33 (20.00)	_	_	_
Penicillium canescens	0.33 (4.16)	0.33 (20.00)	_	6.67 (40.00)	0.33 (6.60)	13.00 (69.67)	_
P. janthinellum	5.00 (62.50)	_	_	_	_	_	_
P. javanicum	_	_	_	_	_	1.00 (5.35)	_
Trichoderma koningii	_	_	_	_	1.00 (20.00)	_	_
T. viride	1.33 (16.67)	1.33 (80.00)	_	_	_	0.67 (13.40)	_
White sterile Mycelia	_	_	0.33 (16.50)	6.67 (40.00)	0.33 (6.60)	_	_
Yellow sterile mycelia	1.33 (16.67)	_	_	_	_	_	_

Table 6 : Monthly variation of fungal population (per gram dry soil x 10^2) in the maize field soil at Upper Shillong during the sampling period (1995). Values in the parentheses are percentage relative abundance.

Fungi	Months April	May	June	July	August	September	October
Mucor hiemalis	0.03 (1.60)	_	0.12 (10.35)	_	_	0.29 (10.55)	_
M. mucedo	_	0.13 (5.66)	_	_	0.04 (1.98)	_	0.33 (21.43)
Pythium intermedium	0.46 (29.37)	0.27 (11.32)	0.08 (6.90)	0.84 (43.76)	0.09 (3.90)	1.29 (47.42)	0.58 (33.33)
Aspergillus flavus	_	_	_	_	0.04 (1.98)	_	_
Fusarium merismoides	_	0.13 (5.66)	0.04 (3.45)	_	0.13 (5.89)	_	_
F. oxysporum	_	_	_	_	0.51 (23.60)	0.10 (3.50)	_
Humicola grisea	_	0.09 (3.77)	_	_	0.51 (23.60)	0.10 (3.50)	_
Penicillium brevicompactum	_	_	0.28 (24.15)	_	0.13 (5.89)	_	_
P. canescens	_	_	_	0.12 (6.25)	_	_	_
P. chrysogenum	_	0.27 (11.32)	_	_	_	_	_
P. janthinellum	_	0.04 (1.87)	_	_	0.09 (3.9)	_	_
P. restrictum	_	_	_	_	_	0.05 (1.77)	_
P. waksmanii	_	_	0.48 (44.86)	_	0.17 (7.87)	_	_
Trichoderma harzianum	_	_	_	_	_	0.14 (5.27)	0.58 (33.33)
T. koningii	_	_	_	0.04 (2.08)	0.43 (19.66)	0.10 (3.50)	_
T. viride	0.71 (45.40)	_	0.08 (6.90)	0.16 (8.33)	_	_	_
Verticillium albo-atrum	0.29 (18.72)	0.04 (1.88)	_	_	_	_	_
White sterile mycelia	0.08 (5.32)	1.38 (58.51)	0.08 (6.90)	0.76 (39.58)	0.04 (1.98)	0.67 (24.59)	0.21 (11.91)

Table 7: Monthly variation of fungal population (per gram dry soil x 10^2) in the maize field casts at Upper Shillong during the sampling period (1995). Values in the parentheses are percentage relative abundance.

	Months						
Fungi	April	May	June	July	August	September	October
Mucor hiemalis	0.04 (1.94)	_	_	0.04 (2.86)	_	0.22 (12.20)	_
M. mucedo	_	_	0.04 (1.96)	_	0.05 (1.52)	_	_
Pythium intermedium	0.04 (1.94)	0.04 (2.65)	0.25 (13.73)	0.79 (54.58)	1.49 (50.00)	1.04 (58.54)	0.79 (63.33)
Fusarium merismoides	_	0.79 (44.99)	_	0.54 (37.14)	_	0.26 (14.63)	_
F. oxysporum				0.04 (2.86)	1.26 (42.42)	0.09 (4.88)	_
F. poae	_	2.93 (5.00)	0.21 (9.80)	_	_	_	_
Humicola grisea	_	0.08 (5.26)	_	_	_	_	_
Penicillium brevicompactum	_	0.29 (18.42)	_	_	_	_	_
P. canescens	_	_	0.50 (23.53)	_	_	0.04 (2.43)	_
P. chrysogenum	_	_	_	0.04 (2.86)	_	_	_
P. nigricans	_	_	0.13 (5.88)	_	_	_	_
Penicillium sp.	_	_	0.25 (11.77)	_	_	_	_
Trichoderma harzianum	_	_	_	_	0.09 (3.03)	_	0.25 (20.00)
T. koningii	0.125 (5.88)	_	_	_	_	0.04 (2.44)	_
T. viride	1.63 (76.47)	_	_	_	0.09 (3.03)	0.09 (4.88)	_
Verticillium albo-atrum	0.21 (9.83)	_	_	_	_	_	_
White sterile mycelia	0.08 (3.94)	0.29 (18.42)	0.08 (1.96)	_	_	_	0.21 (16.67)
Yellow sterile Mycelia	_	0.08 (5.26)	0.67 (31.37)	_	_	_	_

Table 8: Monthly variation of fungal population (per gram dry soil x 10^2) from fore-gut of earthworms collected from Upper Shillong during the sampling period (1995). Values in the parentheses are percentage relative abundance.

			Months				
Fungi	April	May	June	July	August	September	October
Mucor hiemalis	-	0.33 (9.09)	-	0.33 (12.49)	1.33 (30.76)	-	-
M. mucedo	-	-	-	1.00 (37.5)	-	-	-
Pythium intermedium	-	-	1.00 (33.33)	1.00 (37.50)	-	-	3.67 (100)
Fusarium merismoides	-	0.33 (9.09)	-	0.33 (12.49)	-	-	-
Penicillium brevicompactum	0.67 (11.12)	1.00 (27.28)	-	-	-	0.33 (1.96)	-
P. canescens	5.00 (83.33)	1.33 (36.36)	0.33 (11.11)	-	-	16.00 (94.12)	-
P. javanicum	-	-	-	-	1.33 (30.78)	-	-
P. restrictum	-	-	1.33 (44.45)	-	-	-	-
P. waksmanii	-	-	0.33 (11.11)	-	-	-	-
Trichoderma koningii	-	-	-	1.00 (23.09)	-	-	-
T. viride	-	-	-	-	0.07 (3.92)	-	-
White sterile mycelia	-	0.67 (18.18)	-	-	0.67 (15.41)	-	-
Yellow sterile mycelia	0.33 (5.55)	-	-	-	-	-	-

Table 9: Monthly variation of fungal population (per gram dry soil x 10^2) from the mid-gut of earthworms collected from Upper Shillong during the sampling period (1995). Values in the parentheses are percentage relative abundance.

Fungi	Months						
	April	May	June	July	August	September	October
Mortierella gamsii	–	–	–	–	–	0.33 (2.83)	–
M. parvispora	–	–	–	–	0.33 (5.26)	–	–
Pythium intermedium	–	–	1.00 (60.48)	0.33 (33.33)	–	–	4.67 (77.78)
Rhizopus stolonifer	–	–	–	0.33 (33.33)	3.00 (47.36)	–	–
Penicillium brevicompactum	6.67 (60.61)	0.33 (11.11)	–	–	0.33 (5.26)	–	–
P. canescens	3.00 (27.27)	1.33 (44.45)	0.33 (19.96)	–	–	11.33 (97.17)	–
P. jensenii	–	0.33 (11.11)	–	–	–	–	–
P. waksmanii	–	–	0.33 (19.96)	–	–	–	–
Trichoderma harzianum	–	–	–	–	–	–	0.13 (22.22)
T. pseudokoningii	–	–	–	0.33 (33.33)	–	–	–
White sterile mycelia	0.67 (6.06)	1.00 (33.33)	–	–	2.67 (42.12)	–	–
Yellow sterile mycelia	0.67 (6.06)	–	–	–	–	–	–

Table 10: Monthly variation of fungal population (per gram dry soil x 10^2) from hind-gut of earthworms collected from Upper Shillong during the sampling period (1995). Values in the parentheses are percentage relative abundance.

Fungi	April	May	Months June	July	August	September	October
Mucor hiemalis	_	0.33 (9.09)	_	0.33 (12.49)	1.33 (30.78)	_	_
M. mucedo	_	_	_	1.00 (37.5)	_	_	_
Pythium intermedium	_	_	1.00 (33.33)	1.00 (37.5)	_	_	3.67 (100)
Fusarium merismoides	_	0.33 (9.09)	_	0.33 (12.49)	_	_	_
Penicillium brevicompactum	0.67 (11.12)	1.00 (27.28)	_	_	_	0.33 (1.96)	_
P. canescens	5.00 (83.33)	1.33 (36.36)	0.33 (11.11)	_	_	16.00 (94.12)	_
P. javanicum	_	_	_	_	1.33 (30.78)	_	_
P. restrictum	_	_	1.33 (44.45)	_	_	_	_
P. waksmanii	_	_	0.33 (11.11)	_	_	_	_
Trichoderma koningii	_	_	_	1.00 (23.09)	_	_	_
White sterile Mycelia	_	0.67 (18.18)	_	_	0.67 (15.41)	_	_
Yellow sterile Mycelia	0.33 (5.55)	_	_	_	_	_	_

Table 11: Monthly variation of fungal population (per gram dry soil x 10^2) in the maize field soil at Mawlai during the sampling period (1996). Values in the parentheses are percentage relative abundance.

	Months						
Fungi	April	May	June	July	August	September	October
Aspergillus wentii	–	–	–	–	–	0.07 (0.97)	–
Mucor mucedo	–	–	0.18 (6.44)	–	–	–	–
M. racemosus	–	–	–	0.15 (4.84)	0.95 (20.18)	–	0.04 (9.43)
Rhizopus oryzae	–	–	–	0.25 (8.08)	–	–	–
Fusarium merismoides	0.30 (26.7)	0.18 (3.35)	0.73 (25.80)	1.30 (41.94)	0.65 (13.76)	–	0.07 (15.09)
F. sporotrichioides	0.07 (6.7)	–	–	–	1.04 (22.02)	–	–
Pythium chrysogenum	–	–	–	–	–	1.77 (26.22)	0.10 (7.55)
P. intermedium	0.15 (13.20)	0.91 (15.00)	1.06 (37.12)	1.40 (45.14)	1.82 (38.54)	2.81 (41.74)	0.08 (16.98)
Rhizoctonia sp.	–	–	–	–	–	0.13 (1.95)	–
Trichoderma harzianum	–	–	–	–	0.09 (1.84)	–	–
T. viride	–	0.32 (5.82)	–	–	0.17 (3.66)	1.05 (12.61)	0.01 (1.89)
White sterile mycelia	–	0.55 (20.00)	–	–	–	0.78 (14.56)	–
Yellow sterile Mycelia	–	–	–	–	–	0.13 (1.95)	0.02 (3.77)

Table 12: Monthly variation of fungal population (per gram dry soil x 10^2) in the maize field casts at Mawlai during the sampling period (1996). Values in the parentheses are percentage relative abundance.

Fungi	April	May	Months June	July	August	September	October
Absidia cylindrospora	–	–	–	–	0.33 (10.20)	–	–
Mucor circinelloides	–	–	–	–	0.38 (5.12)	–	–
M. hiemalis	–	–	0.55 (14.76)	0.06 (1.30)	0.33 (7.14)	–	0.04 (1.62)
M. mucedo	–	–	0.13 (3.41)	–	–	–	0.22 (8.22)
M. racemosus					0.48 (10.20)	–	–
Pythium intermedium	–	0.65 (16.67)	1.23 (32.97)	1.21 (38.95)	1.15 (38.78)	0.91 (21.74)	0.66 (24.59)
Rhizopus oryzae	–	0.61 (15.57)	–	–	0.48 (10.20)	–	–
Fusarium merismoides	–	0.52 (13.33)	–	1.99 (47.37)	0.05 (1.01)	–	–
F. oxysporum	0.67 (30.77)	–	–	–	–	–	–
F. poae	–	–	–	–	–	–	0.26 (9.84)
Penicillium brevicompactum	0.04 (1.27)	0.04 (1.10)	0.64 (17.05)	–	–	–	–
P. canescens	1.54 (56.42)	1.13 (28.90)	0.23 (7.94)	–	–	–	–
P. waksmanii	–	–	0.34 (9.10)	–	–	–	–
Pseudoeurotium sp.	–	–	–	–	–	2.55 (60.87)	1.49 (55.73)
Rhizoctonia sp.	–	–	–	–	0.62 (13.28)	–	–
Trichoderma koningii	0.32 (11.54)	0.78 (20.00)	0.17 (4.53)	0.66 (15.79)	–	–	–
Verticillium albo-atrum	–	0.17 (4.43)	–	–	–	–	–
White sterile mycelia	–	–	0.38 (10.24)	–	0.19 (4.07)	0.73 (17.39)	–
Yellow sterile mycelia	–	–	–	0.28 (6.59)	–	–	–

Table 13: Monthly variation of fungal population (per gram dry soil x 10^2) in the fore-gut of earthworms collected from Mawlai during the sampling period (1996). Values in the parentheses are percentage relative abundance.

Fungi	Months						
	April	May	June	July	August	September	October
Absidia cylindrospora	0.19 (3.64)	0.95 (14.42)	0.12 (1.87)	–	–	–	–
Mucor circinelloides	–	3.68 (59.80)	–	–	–	–	–
M. hiemalis	–	–	2.30 (37.40)	–	1.42 (35.96)	0.19 (3.64)	0.32 (4.87)
M. mucedo	–		–	–	–	–	0.51 (7.64)
M. racemosus	–	1.39 (21.18)	–	2.57 (6.47)	–	–	0.09 (1.39)
Pythium intermedium	1.33 (25.48)	2.11 (32.21)	–	1.64 (41.54)	–	–	1.39 (20.83)
Fusarium merismoides	2.05 (39.20)	–	–	–	–	1.57 (30.00)	0.46 (6.94)
F. oxysporum	–	–	–	1.23 (31.18)	–	–	–
F. poae	–	–	–	–	2.09 (52.81)	–	0.37 (5.56)
Penicillium canescens	1.56 (29.89)	–	–	–	–	–	–
P. chrysogenum	–	–	–	0.51 (12.98)	–	1.33 (25.45)	–
P. frequentans	–	–	0.06 (0.93)	–	–	–	–
P. janthinellum		2.06 (31.35)	–	–	–	–	–
Paecilomyces sp.	–	0.06 (0.84)	–	–	–	–	–
Pseudoeurotium sp.	–	–	–	0.10 (2.61)	–	–	1.81 (27.03)
Trichoderma harzianum	–	–	–	–	0.44 (11.20)	–	–
T. koningii	–	–	–	0.10 (2.61)	–	–	–
Verticillium albo-atrum	–	–	–	0.10 (2.61)	–	–	1.71 (25.69)
Yellow sterile mycelia	0.09 (1.80)	–	–	–	–	0.10 (1.82)	–

Table 14: Monthly variation of fungal population (per gram dry soil x 10^2) from the mid-gut of earthworms collected from Mawlai during the sampling period (1996). Values in the parentheses are percentage relative abundance.

Fungi	April	May	Months June	July	August	September	October
Absidia cylindrospora	0.14 (3.62)	1.22 (16.53)	0.40 (9.20)	_	_	_	_
Mucor circinell-oides	_	_	0.75 (17.10)	_	_	_	0.23 (2.28)
M. hiemalis	_	_	3.05 (69,75)	0.05 (1.01)	1.87 (47.37)	0.15 (3.67)	_
M. mucedo	_	_	_	.	_	1.47 (37.26)	0.32 (3.13)
M. racemosus	_	1.00 (13.53)	_	0.15 (3.05)	_	_	0.93 (9.08)
Doratomyces stemonitis	_	_	_	0.15 (3.05)	_	_	_
Rhizopus oryzae	_	_	_	0.11 (2.06)	_	_	1.57 (15.44)
Pythium intermedium	0.72 (18.07)	1.61 (21.82)	_	1.29 (25.60)	_	1.62 (40.98)	1.57 (15.44)
Fusarium merismoides	_	_	_	_	1.47 (37.35)	_	_
F. oxysporum	_	_	_	0.83 (16.34)	0.18 (4.49)	_	_
F. sporotrichioi -des	_	_	_	0.98 (19.4)	_	_	1.45 (14.25)
Penicillium canescens	1.47 (37.24)	_	_	_	0.27 (6.77)	_	1.10 (10.74)
P. chrysogenum	_	_	_	0.51 (10.20)	_	0.72 (18.09)	_
P. frequentans	_	_	0.17 (3.94)	_	_	_	_
P. janthinellum	_	3.56 (48.12)	_	_	_	_	1.63 (16.00)
Pseudoeurotium sp.	_	_	0.16 (4.03)	_	_	_	1.39 (13.63)
White sterile mycelia	1.62 (40.96)	_	_	0.97 (19.29)	_	_	_

Table 15: Monthly variation of fungal population (per gram dry soil x 10^2) in the hind-gut of earthworms collected from Mawlai during the sampling period (1996). Values in the parentheses are percentage relative abundance.

Fungi	April	May	June	July	August	September	October
			Months				
Absidia cylindrospora		1.17 (18.75)	0.35 (5.36)	_	_	_	_
M. hiemalis		_	0.63 (9.83)	0.15 (6.00)	3.02 (93.14)	0.33 (13.73)	0.19 (3.97)
M. mucedo		_	0.52 (20.55)	_	0.53 (6.86)	_	0.19 (3.77)
M. racemosus		1.78 (28.58)		0.26 (10.02)	_	_	_
Rhizomucor pusillus		0.06 (0.88)	_	_	_	_	_
Pythium intermedium		1.06 (16.96)	1.44 (22.31)	1.08 (42.00)	_	0.86 (35.29)	2.87 (58.49)
Fusarium merismoides		_	0.63 (9.83)	_	_	1.00 (41.18)	0.97 (19.82)
F. oxysporum		_	_	0.46 (18.00)	_	_	_
F. sporotrichioides		_	_	0.26 (10.02)	_	_	_
Penicillium brevicompactum		_	0.23 (3.56)	_	_	_	_
P. canescens		_	0.63 (8.04)	_	_	_	_
P. chrysogenum		_	_	0.05 (1.97)	_	0.24 (9.80)	_
P. frequentans		_	1.26 (19.64)	_	_	_	_
P. janthinellum		2.22 (35.71)	_	_	_	_	_
Pseudoeurotium sp.		_	_	0.26 (10.02)	_	_	0.60 (12.26)
Yellow sterile mycelia		_	_	0.05 (1.97)	_	_	0.09 (1.89)

Table 16: Monthly variation of fungal population (per gram dry soil x 10^2) in the maize field soil at Upper Shillong during the sampling period (1996). Values in the parentheses are percentage relative abundance.

Fungi	Months						
	April	May	June	July	August	September	October
Cunninghamella elegans	0.22 (20.00)	0.26 (6.60)	_	_	_	_	_
Mucor circinelloides	_	_	1.79 (40.20)	_	_	_	1.323 (14.11)
M. hiemalis	0.22 (20.00)	_	_	0.62 (15.79)	_	0.22 (3.35)	_
M. mucedo	_	_	_	_	_	_	0.822 (18.49)
M.racemosus	_	_	_	0.52 (13.39)	1.08 (16.43)	0.06 (2.52)	0.62 (0.66)
Pythium intermedium	_	0.35 (8.80)	1.84 (41.31)	1.33 (34.02)	3.51 (53.57)	2.52 (37.81)	3.19 (3.40)
Rhizopus oryzae	0.41 (13.30)	1.57 (39.56)	_	_	_	_	_
Fusarium merismoides	0.18 (16.70)	0.22 (5.54)	_	1.28 (32.82)	_	_	1.06 (11.34)
F. oxysporum	0.18 (16.70)	_	_	_	_	_	_
F. sporotrichioides	_	_	_	_	1.45 (22.13)	_	_
Penicillium sp.	_	_	_	_	_	_	1.94 (20.66)
P. canescens	_	1.09 (27.43)	_	_	_	_	_
P. chrysogenum	_	_	_	_	_	0.62 (9.25)	1.88 (20.00)
Pseudoeurotium sp.	_	_	_	_	_	1.68 (21.86)	1.00 (4.00)
Rhizoctonia sp.	_	_	_	0.16 (3.99)	_	_	_
Trichoderma koningii	_	0.48 (12.10)	_	_	_	_	_
T. polysporum	0.04 (3.30)	_	_	_	_	_	1.26 (1.34)
T. viride	0.11 (10.00)	_	_	_	0.09 (1.44)	_	_
Verticillium albo-atrum	_	_	_	_	0.23 (3.58)	_	_
White sterile mycelia	_	_	_	_	0.19 (2.85)	1.96 (25.21)	0.56 (4.00)
Yellow sterile mycelia	_	_	0.82 (18.49)	_	_	_	0.19 (2.00)

Table 17: Monthly variation of fungal population (per gram dry soil x 10^2) in the maize field casts at Upper Shillong during the sampling period (1996). Values in the parentheses are percentage relative abundance.

Fungi	Months						
	April	May	June	July	August	September	October
Absidia cylindrospora	_	_	0.30 (8.33)	_	_	_	_
Cunninghamella elegans	_	_	_	1.48 (37.50)	_	_	_
Mucor circinell-oides	_	0.09 (3.14)	_	_	_	_	_
M. hiemalis	0.28 (18.20)	_	1.58 (43.04)	_	0.56 (13.04)	_	_
M. racemosus	_	0.26 (9.37)	_	_	0.71 (16.30)	0.50 (9.89)	0.42 (0.13)
Pythium intermedium	0.07 (4.56)	0.56 (20.29)	0.20 (5.58)	0.58 (14.76)	0.21 (48.91)	4.45 (87.93)	1.15 (24.12)
Rhizopus oryzae	_	0.22 (7.83)	_	1.12 (28.40)	_	_	_
R. pusillus	_	_	_	_	0.38 (8.71)	_	_
Eupenicillium brefeldianum	0.04 (21.25)	_	_	_	_	_	_
Fusarium merismoides	0.07 (4.56)	0.22 (7.82)	_	0.49 (12.52)	0.33 (7.60)	_	0.13 (0.34)
F. oxysporum	0.92 (59.06)	_	_	_	_	_	_
Penicillium brevicompactum	0.11 (6.81)	_	0.20 (5.55)	_	_	_	_
P. canescens	_	0.30 (10.92)	_	_	_	_	_
P. chrysogenum	_	_	_	_	_	_	1.30 (28.58)
P. frequentans	0.07 (4.56)	_	_	_	_	_	_
P. waksmanii	_	_	_	_	0.14 (3.26)	_	_
Pseudoeurotium sp.	_	_	_	_	_	0.11 (2.18)	0.60 (12.51)
Rhizoctonia sp.	_	_	_	0.18 (5.69)	_	_	_
Trichoderma koningii	_	0.61 (21.89)	1.33 (37.5)	_	_	_	_
T. viride	_	_	_	_	0.10 (2.18)	_	_
Verticillium albo-atrum	_	0.52 (18.74)	_	_	_	_	0.77 (2.06)
White sterile mycelia	_	_	_	_	_	_	0.68 (1.83)
Yellow sterile mycelia	_	_	_	0.04 (1.13)	_	_	0.42 (0.88)

Table 18: Monthly variation of fungal population (per gram dry soil x 10^2) in the fore-gut of the earthworms collected from Upper Shillong during the sampling period (1996). Values in the parentheses are percentage relative abundance.

Fungi	Months						
	April	May	June	July	August	September	October
Mortierella gamsii	_	_	_	_	_	0.33 (5.88)	_
M. parvispora	_	_	_	_	1.00 (27.13)	_	_
Mucor hiemalis	_	_	_	_	1.00 (27.13)	_	_
Rhizopus stolonifer	_	_	_	0.33 (11.11)	_	_	_
Pythium intermedium	_	_	0.33 (16.67)	1.00 (33.33)	_	_	2.00 (37.50)
Fusarium merismoides	_	_	_	_	0.67 (18.18)	_	_
Penicillium brevicompactum	2.00 (50.00)	0.33 (8.33)	_	_	_	_	_
P. canescens	1.00 (25.00)	1.00 (25.00)	_	0.33 (11.11)	_	5.33 (94.12)	_
P. frequentans	1.00 (25.00)	0.33 (8.33)	_	_	_	_	_
P. irregulare	_	_	_	1.33 (44.45)	_	_	_
P. jensenii	_	_	0.33 (16.67)	_	_	_	_
P. restrictum	_	_	0.33 (16.67)	_	_	_	_
P. waksmanii	_	_	1.00 (50.00)	_	_	_	_
Trichoderma harzianum	_	_	_	_	_	_	2.33 (43.75)
T. koningii	_	_	_	_	0.667 (18.11)	_	_
White sterile mycelia	_	2.00 (50.00)	_	_	0.33 (8.95)	_	1.00 (18.75)
Yellow sterile mycelia	_	0.33 (8.83)	_	_	_	_	_

Table 19: Monthly variation of fungal population (per gram dry soil x 10^2) in the mid-gut ‹ earthworms collected from Upper Shillong during the sampling period (1996). Values : the parentheses are percentage relative abundance.

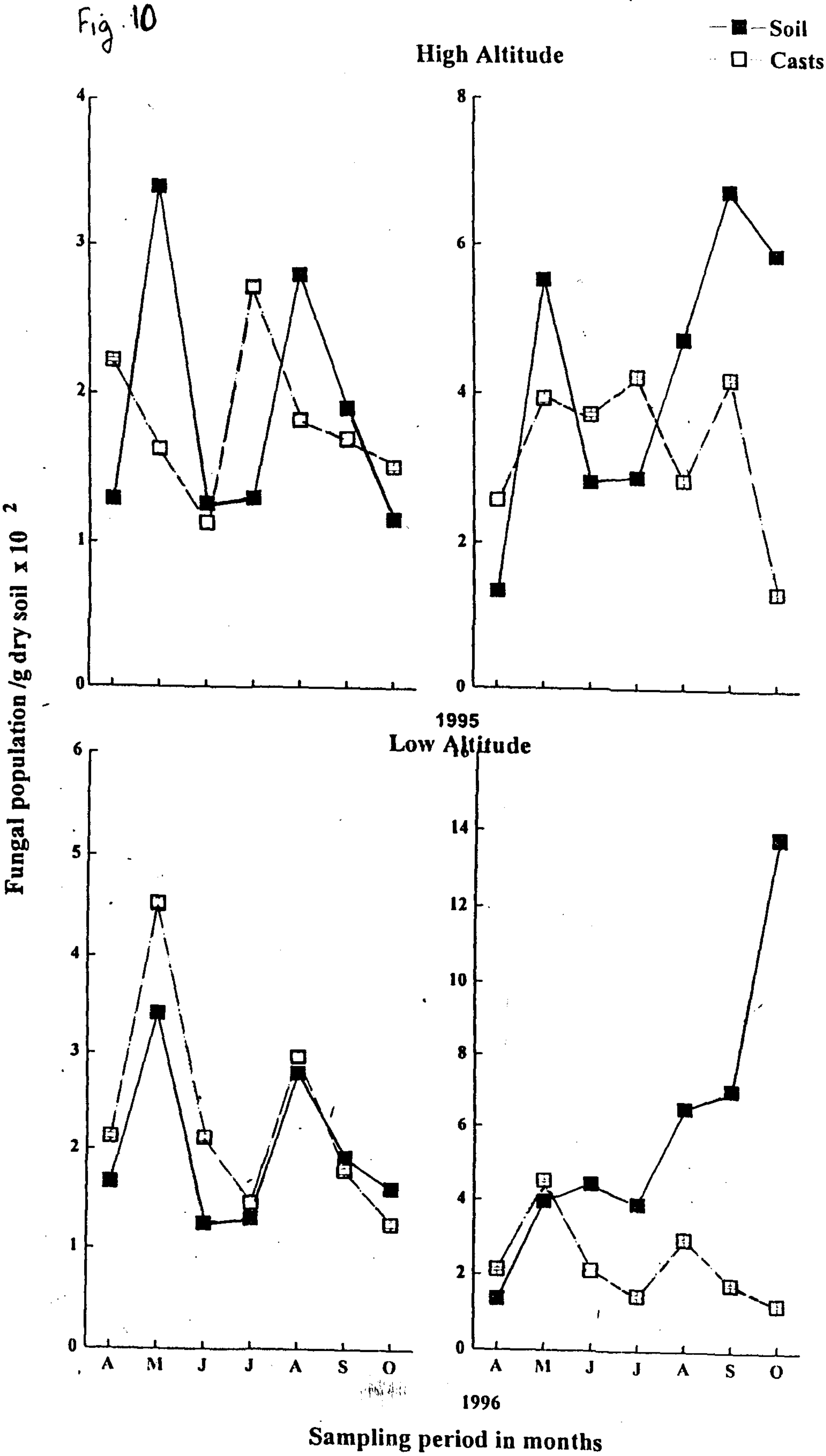
	Months						
Fungi	April	May	June	July	August	September	October
Mucor circinelloides	_	1.22 (19.77)	_	_	0.62 (15.65)	0.05 (1.04)	_
M. mucedo	_	1.17 (18.87)	_	_	2.38 (60.27)	0.05 (1.04)	_
M. racemosus	_	_	_	0.22 (4.11)	_	0.05 (1.04)	0.30 (6.12)
Rhizopus oryzae	0.22 (3.23)	_	0.17 (3.45)	_	_	_	_
Rhizomucor pusillus	1.36 (20.43)	_	_	_	4.71 (1.19)	_	_
Pythium intermedium	_	0.20 (3.23)	1.89 (39.07)	2.47 (47.42)	_	2.19 (47.92)	1.62 (33.67)
Aspergillus niger	1.23 (18.48)	0.11 (0.89)	_	_	_	_	_
Eupenicillium brefeldianum	_	0.17 (2.70)	_	_	_	_	_
Fusarium merismoides	_	0.56 (8.97)	2.78 (57.48)	2.53 (48.47)	_	_	1.72 (35.72)
Penicillium brevicompactum	1.48 (22.23)	0.78 (12.08)	_	_	_	_	_
P. canescens	0.24 (3.63)	_	_	_	0.14 (3.62)	_	_
P. chrysogenum	1.25 (18.78)	_	_	_	_	_	0.20 (4.08)
P. frequentans	_	1.32 (21.40)	_	_	0.57 (14.46)	_	_
P. jensenii	_	_	_	_	4.71 (1.19)	_	_
Pseudoeurotium sp.	0.35 (5.26)	_	_	_	_	1.62 (35.42)	0.74 (15.31)
Rhizoctonia sp.	0.53 (7.96)	0.44 (7.11)	_	_	_	_	_
Trichoderma koningii	_	0.22 (3.50)	_	_	_	_	_
T. viride	_	_	_	_	0.15 (3.62)	_	_
Verticillium albo-atrum	_	0.11 (1.80)	_	_	_	_	0.25 (5.10)
White sterile mycelia	_	_	_	_	_	0.62 (13.54)	_

Table 20 : Monthly variation of fungal population (per gram dry soil x 10^2) in the hind-gut (earthworms collected from Upper Shillong during the sampling period (1996). Values i the parentheses are percentage relative abundance.

Fungi	Months. April	May	June	July	August	September	October
Absidia cylindrospora	0.58 (12.19)	–	0.28 (5.16)	–	–	–	–
Mucor circinelloides		1.06 (19.18)	–	–	1.43 (31.25)	–	–
M. hiemalis	0.54 (11.44)	–	–	–	0.10 (2.10)	–	–
M. mucedo	0.23 (4.85)	1.11 (20.22)	–	–	–	–	–
M. racemosus	–	0.95 (17.18)	–	0.16 (4.11)	–	–	0.15 (3.75)
Rhizopus oryzae	0.58 (12.19)	–	0.33 (6.19)	–	–	–	–
Rhizomucor pusillus	–	–	–	–	2.33 (51.03)	–	–
Pythium intermedium	–	0.67 (12.12)	2.06 (38.14)	1.94 (49.32)	–	2.38 (54.95)	1.77 (45.00)
Eupenicillium brefeldianum	0.72 (15.26)	0.11 (2.03)	–	–	–	–	–
Fusarium merismoides	–	0.89 (16.15)	2.72 (50.51)	1.83 (46.57)	–	–	1.52 (38.75)
Penicillium brevicompactum	0.85 (18.01)	0.72 (13.12)	–	–	–	–	–
P. canescens	–	–	–	–	0.47 (1.03)	–	–
P. frequentans	–	–	–	–	0.14 (6.25)	–	–
Pseudoeurotium sp.	–	–	–	–	–	0.81 (18.68)	0.49 (12.50)
Rhizoctonia sp.	–	–	–	–	–	0.10 (2.20)	–
Trichoderma viride	–	–	–	–	0.38 (8.34)	–	–
White sterile mycelia	0.61 (13.03)	–	–	–	–	1.00 (23.08)	–
Yellow sterile mycelia	0.61 (13.03)	–	–	–	–	0.05 (1.20)	–

Fig.10 Fungal population in the soil and the casts of both the fields during the sampling period

Fig. 10



Soil
Casts
High Altitude
Low Altitude
1995
1996
Fungal population /g dry soil x 10 2
A M J J A S O
A M J J A S O
Sampling period in months

Table 21: List of fungi isolated from soil, casts, gut contents of earthworm *Amynthas corticis* (Kinberg) collected from Mawlai and Upper Shillong during the study period (1995-1996).

Fungi	Soil		Fore-gut		Mid-gut		Hind-gut		Casts	
	M	US.	M	US	M	US	M	US	M	US
Absidia cylindrospora	+	-	+	+	+	-	+	+	+	+
Mortierella candellabrum	-	-	+	-	+	-	-	-	-	-
M. elongata	-	-	-	-	+	-	-	-	-	-
M. gamsii	-	-	-	+	+	+	-	-	-	-
M. minutissima	+	-	-	-	-	-	-	-	+	-
M. parvispora	+	-	+	+	+	+	+	-	+	-
Mucor circinelloides	-	-	+	-	+	+	-	+	+	+
M. hiemalis	-	+	+	+	+	-	+	+	+	+
M. mucedo	+	+	+	+	+	+	+	+	+	+
M. racemosus	+	+	+	+	+	+	+	+	+	+
Rhizopus oryzae	+	+	-	+	+	+	-	+	+	+
R. stolonifer	+	-	-	+	-	+	-	-	-	-
Rhizomucor pusillus	-	-	-	+	+	+	+	+	-	+
Pythium intermedium	+	+	+	+	+	+	+	+	+	+
P. irregulare	-	-	-	+	-	-	-	-	-	-
Aspergillus flavus	-	+	-	-	-	-	-	-	-	-
A. fumigatus	-	-	-	-	+	-	-	-	-	-
A. niger	-	-	-	-	-	+	-	-	-	-
A. wentii	+	-	+	-	-	-	-	-	-	-
Cladosporium cladosporoides	+	-	-	-	-	-	-	-	-	-
Cunninghamella elegans	+	+	+	-	+	-	+	-	+	+
Doratomyces stemonitis	-	-	-	-	+	-	-	-	+	-
Eupenicillium brefeldianum	-	-	-	-	+	+	-	+	-	+
Fusarium merismoides	+	+	+	+	+	+	+	+	+	+
F. oxysporum	+	+	+	-	+	-	+	-	+	+
F. poae	+	-	+	-	-	-	-	-	-	+
F. proliferatum	-	+	-	-	-	-	+	-	-	-
F. redolens	+	-	-	-	-	-	-	-	-	-
F. semitectum	+	-	-	-	-	-	-	-	-	-
F. sporotrichioides	+	+	+	-	+	-	+	-	-	-
Humicola grisea	-	+	-	-	-	-	-	-	-	+
Paecilomyces sp.	-	-	+	-	-	-	-	-	-	-
Penicillium brevicompactum	+	+	-	+	+	+	+	+	+	+
P. canescens	-	+	+	+	+	+	+	+	+	+
P. chrysogenum	+	+	+	+	+	+	+	-	+	+
P. daleae	-	-	-	-	+	-	-	-	-	-
P. frequentans	+	-	+	+	+	+	+	+	-	+
P. janthinellum	-	+	+	-	+	-	+	-	-	-
P. javanicum	-	-	-	-	-	+	-	+	-	-
P. jensenii	-	-	-	+	-	+	-	-	-	-
P. irregulare	-	-	-	+	-	-	-	-	-	-
P. nigricans	-	-	-	+	-	-	-	-	-	-
P. polysporum	-	+	-	-	-	-	-	-	-	-
Penicillium sp.	-	+	-	+	-	-	-	-	-	-
P. restrictum	-	+	-	+	-	-	-	+	-	-
P. waksmanii	-	+	-	+	-	+	-	+	+	+
Pseudoeurotium sp.	-	+	+	+	+	+	+	+	+	+
Rhizoctonia sp.	+	+	-	-	-	+	-	+	+	+
Trichoderma harzianum	+	+	+	+	+	+	-	-	-	+
T. koningii	+	+	+	+	+	+	+	+	+	+
T. pseudokoningii	+	-	-	-	-	+	-	-	-	-
T. viride	+	+	+	-	+	+	+	+	+	+
Verticillium albo-atrum	-	+	+	+	+	+	+	-	+	+
White sterile mycelia	+	+	+	+	+	+	+	+	+	+
Yellow sterile mycelia	+	+	+	+	+	+	+	+	+	+

+ = Present ; - = Absent

fungal population was observed to be maximum in the month of May in both the cropping seasons. Whereas, in the case of the casts, at low altitude, the fungal population was observed to is maximum in the month of July in the first cropping season and in the months of July and September in the second cropping season.

At high altitude, (Table A) the fungal population shows a positive correlation with moisture content of the casts ($P<0.10$) and also with the organic carbon of the soil ($P<0.05$).

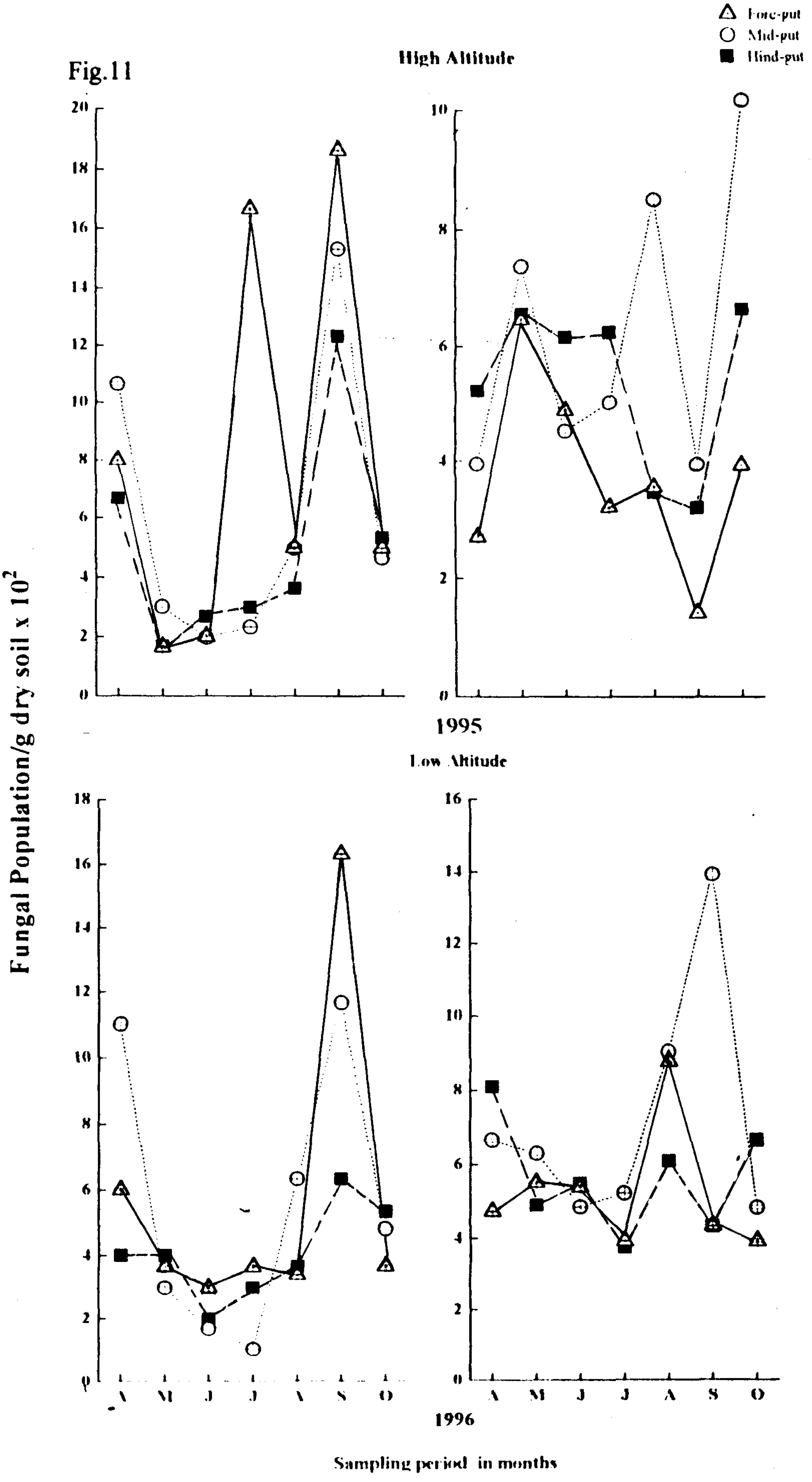
At low altitude, fungal population shows a positive correlation with p^H of the casts ($P<0.01$) and organic carbon of the soil ($P<0.10$).

Altogether, 26 fungal species (Table 21) could be isolated from the soil at low altitude, of which 7 belonged to Phycomycetes, 17 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 4 genera and 7species, Fungi Imperfecti was represented by 7 genera and 17species. A total of 28 fungal species could be isolated from soil at high altitude, of which 5 belonged to Phycomycetes, 21 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 2 genera and Fungi Imperfecti was represented by 5 species and 10 genera and 21 species.

A total of 24 fungal species (Table 21) could be isolated from the casts of the earthworms collected from low altitude, of which 8 belonged to Phycomycetes, 14 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 4 genera and 8 species and Fungi Imperfecti was represented by 8 genera and 14 species. Whereas, 26 fungal species could be isolated from the casts of the earthworms from high altitude, of which 6 belongs to Phycomycetes, 18 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 3 genera and 6 species and Fungi Imperfecti was represented by 10 genera and 18 species.

Fig.11 : Fungal population in the fore-gut, mid-gut and hind-gut of earthworms collected from both the fields during the sampling period.

Fig.11



Fore-gut
Mid-gut
Hind-gut
High Altitude
1995
Low Altitude
1996
Fungal Population/g dry soil x 10^2
A M J J A S O
Sampling period in months

Fungal population in the foregut, midgut and hindgut of the earthworm *Amynthas corticis*:

The fungal population in the foregut, midgut and hindgut was observed to be higher in earthworms collected from low altitude than from high altitude (fig.11) The fungal population in the earthworm at low altitude ranged between 1.67-12.33/g dry soil x 10^2 in the foregut, between 1.96-15.33/g dry soil x 10^2 in the midgut and between 1.66-19.33/g dry soil x 10^2 in the hindgut. In the case of the gut contents of earthworms collected from high altitude, the fungal population ranged between 1.99-8.10/g dry soil x 10^2 in the foregut, between 1.02-13.28/g dry soil x 10^2 in the midgut and between 2.69-16.33/g dry soil x 10^2 in the hindgut.

The maximum fungal population was recorded in the month of September from the foregut, midgut and hindgut in the first cropping season, at both altitudes, whereas, in the second cropping season the peaks were observed in the month of April, August and May in the foregut, midgut and hindgut respectively, only at high altitude and at low altitude the highest fungal population was observed in the month of May from the foregut and hindgut and in the month of October from the midgut. The fungal population followed a trend of hindgut > midgut> foregut.

A total of 25 fungal species (Table 21) could be isolated from foregut of the earthworms collected from low altitude, of which 7 belonged to Phycomycetes, 16 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 3 genera and 7 species and Fungi Imperfecti was represented by 9 genera and 16 species. Whereas, 28 fungal species could be isolated from foregut of the earthworms from high altitude, of which 10 belonged to Phycomycetes, 16 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 5 genera and 10 species and Fungi Imperfecti was represented by 6 genera and 17 species.

A total of 30 fungal species (Table 21) could be isolated from midgut of the earthworms from low altitude, of which 11 belonged to Phycomycetes, 17 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 5 genera and 11 species and Fungi Imperfecti was represented by 9 genera and 17 species. Whereas, 27 fungal species could be isolated from midgut of the earthworms from high altitude, of which 8 belonged to Phycomycetes, 17 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 4 genera and 8 species and Fungi Imperfecti was represented by 8 genera and 17 species.

A total of 23 fungal species (Table 21) could be isolated from hindgut of the earthworms from low altitude, of which 6 belonged to Phycomycetes, 15 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 3 genera and 6 species and Fungi Imperfecti was represented by 7 genera and 15 species. Whereas, 22 fungal species could be isolated from hindgut of the earthworms from high altitude, of which 7 belonged to Phycomycetes, 13 to Fungi Imperfecti and 2 to Mycelia Sterilia. The class Phycomycetes was represented by 4 genera and 7 species and Fungi Imperfecti was represented by 7 genera and 13 species.

Table 21 shows the list of fungi isolated from the soil, casts and gut contents of the earthworm *Amynthas gracilis* (Kinberg). Almost similar fungal species were isolated throughout the study period but there was difference in the fungal species composition in soil, casts and the earthworm gut. A few species were however restricted to each study site. *Mucor circinelloides*, *M. hiemalis*, *Aspergillus flavus*, *Fusarium proliferatum*, *Humicola grisea*, *Penicillium canescens*, *P. janthinellum*, *P. polysporum*, *P. restrictum*, *P. waksmanii*, *Pseudoeurotium* sp., *Verticillium albo-atrum,* could be isolated only from the soil at high altitude.

Absidia cylindrospora Mortierella minutissima, M. parvispora, R. stolonifer, Cladosporium cladosporoides, F. poae, F. redolens, F. semitectum, P. frequentans, Trichoderma pseudokoningii could be isolated only from the soil at low altitude.

Rhizopus storlonifer, Pythium irregulare, Aspergillus niger, Eupenicillium brefeldianum, P. javanicum, P. jensenii, P. waksmanii, Rhizoctonia sp. and T. *pseudokoningii* could be isolated only from the gut contents of earthworms from high altitude.

M. candelabrum, M. elongata, Aspergillus fumigatus, A. wentii, C. elegans, D. stemonitis, F. javanicum, F. oxysporum, F. poae, F. sporotrichioides, Paecilomyces sp. and *P. proliferatum* could be isolated only from the gut contents of earthworms from low altitude.

E. brefeldianum, F. poae, P. frequentans, H. grisea, T. harzianum, could be isolated only from the casts of earthworms from high altitude.

M. minutissima, M. parvispora and D. stemonitis could be isolated only from the casts of earthworms from low altitude.

The dominant fungi isolated from the soil, earthworm gut contents and the casts from samples collected from high altitude (Upper Shillong) are:

Soil: *Rhizopus oryzae, Pythium intermedium, Fusarium merismoides, Trichoderma viride* and white sterile mycelia.

Foregut: *Mucor hiemalis, Mortierella parvispora, P. intermedium, F. merismoides, Penicillium brevicompactum, P. waksmanii* and white sterile mycelia.

Midgut: *Rhizopus stolonifer, P. intermedium, F. merismoides, P. brevicompactum, P. canescens, P. waksmanii, Trichoderma pseudokoningii* and white sterile mycelia.

Hindgut: *Mucor mucedo, Rhizomucor pusillus, P. intermedium, F. merismoides, P. brevicompactum, P. canescens, P. restrictum,* and *T. pseudokoningii.*

Casts: *M. hiemalis, P. intermedium, F. merismoides, F. oxysporum,* and *Trichoderma koningii.*

The dominant fungi isolated from the soil, earthworm gut contents and the casts from samples collected from low altitude (Mawlai) are:

Soil: *M. hiemalis, P. intermedium, F. merismoides, F. semitectum, F. sporotrichioides* and *P. waksmanii.*

Foregut: *M. hiemalis, P. intermedium, F. oxysporum, Fusarium* sp., *Paecilomyces* sp., and yellow sterile mycelia.

Midgut: *M. hiemalis, M. mucedo, P. intermedium* and white sterile mycelia.

Hindgut: *M. hiemalis, P. intermedium, F. merismoides, P. canescens, P. janthinellum T. viride,* and white sterile mycelia.

Casts: *P. intermedium, F. merismoides, P. canescens, P. waksmanii* and *T. viride.*

Dispersal of fungi by earthworms:

Table 22 shows the p^H and moisture content of soil from burrows and the surrounding soil.

p^H of the burrow soil was found to be higher than the surrounding soil. The p^H ranged between 5.37-5.99 in the burrow soil, whereas, it ranged between 5.26-5.82 in the surrounding soil.

The percentage moisture content was higher in the burrow soil than the surrounding soil. The percentage moisture content ranged between 18.8-25.5% in the burrow soil, whereas, it ranged between 8.7-24.7% in the surrounding soil.

Table 21 : pH and moisture content of the soil collected from burrows and the surrounding soil.

Days	Burrow soil		Surrounding soil	
	pH	M.C.(%)	pH	M.C.(%)
1	5.45	21.2	5.33	20.3
15	5.37	19.4	5.26	16.6
30	5.78	21.4	5.81	8.7
45	5.86	25.5	5.82	24.7
60	5.99	18.8	5.79	15.1

Table 23: Variation of fungal population (per gram dry soil x 10^2) in the burrow soil during the sampling period of 15 days interval. Values in the parentheses are percentage relative abundance.

	Days				
Fungi	1	15	30	45	60
Cunninghamella elegans	5.11 (23.35)	_	_	_	_
Mucor circinelloides	2.92 (1.65)	_	_	_	_
M. hiemalis	1.26 (5.00)	7.09 (16.05)	_	_	_
M. mucedo		2.91 (6.59)	8.34 (15.04)	_	5.89 (20.27)
Pythium intermedium	_	5.00 (11.32)	1.25 (2.26)	29.66 (52.75)	12.17 (41.87)
Rhizopus oryzae	0.42 (1.70)	_	_	1.77 (3.14)	_
Fusarium merismoides	2.92 (11.65)	_	_	9.30 (11.03)	10.99 (37.82)
Penicillium canescens	1.26 (5.00)	_	_	_	_
P. chrysogenum	2.51 (10.00)	_	_	11.51 (22.04)	_
P. frequentans	2.51 (10.00)	_	48.84 (82.70)	_	_
P. waksmanii	_	17.50 (39.63)	_	_	_
Trichoderma koningii	_	11.66 (26.41)	_	_	_
White sterile mycelia	10.45 (41.65)	_	_	5.76 (10.24)	_
Yellow sterile mycelia	_	_	_	4.43 (0.80)	_

Table 24 : Variation of fungal population (per gram dry soil x 10^2) in the surrounding soil during the sampling period of 15 days interval. Values in the parentheses are percentage relative abundance.

Fungi	Days 1	15	30	45	60
Cunninghamella elegans	–	0.41 (0.94)	–	–	–
Mucor hiemalis	5.41 (24.06)	2.09 (4.77)	–	–	8.62 (15.80)
M. mucedo	–	1.25 (3.80)	2.97 (5.07)	2.69 (5.71)	0.41 (1.30)
M. racemosus	–	1.66 (3.80)	–	–	–
Pythium intermedium	2.91 (12.94)	17.09 (39.06)	2.54 (4.35)	29.98 (63.80)	12.73 (40.78)
Rhizopus oryzae	3.75 (9.80)	–	–	–	–
Fusarium merismoides	12.09 (53.72)	–	–	14.32 (30.49)	–
F. oxysporum	–	–	–	–	4.52 (14.49)
Penicillium canescens	–	–	–	–	4.11 (13.19)
P. chrysogenum	–	–	–	–	0.41 (13.19)
P. frequentans	–	–	46.22 (78.98)	–	–
P. janthinellum	–	10.41 (23.80)	–	–	–
P. waksmanii	–	7.50 (16.20)	0.85 (1.45)	–	–
Trichoderma koningii	–	3.34 (7.63)	5.94 (10.15)	–	0.41 (1.30)

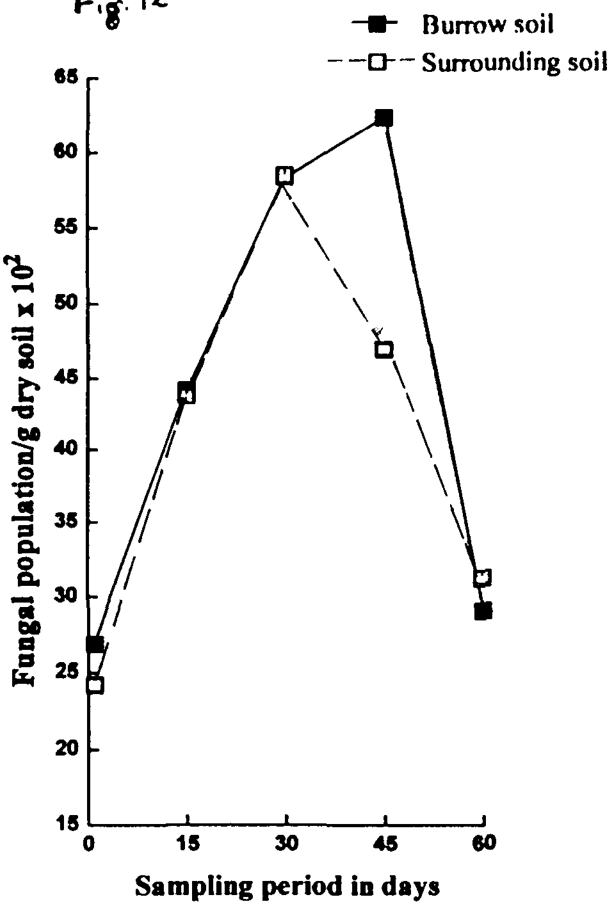
Table 25 : List of fungi isolated from burrow soil and the surrounding soil.

Fungi	Burrow soil	Surrounding soil
Cunninghamella elegans	+	+
Mucor circinelloides	+	-
M. hiemalis	+	+
M. mucedo	+	+
M. racemosus	-	+
Rhizopus oryzae	+	+
Pythium intermedium	+	+
Fusarium merismoides	+	+
F. oxysporum	-	+
Penicillium canescens	+	+
P. chrysogenum	+	+
P. frequentans	+	+
P. janthinellum	+	+
P. waksmanii	-	+
Trichoderma koningii	+	+
White sterile mycelia	+	-
Yellow sterile mycelia	+	-

+ = Present , - = Absent

Fig.12 : Fungal population in the burrow soil and the surrounding soil during the sampling period.

Fig. 12



Burrow soil
Surrounding soil
65
60
55
50
45
40
35
30
25
20
15
0
15
30
45
60
Fungal population/g dry soil x 10^2
Sampling period in days

The fungal population was slightly higher in the burrow soil than in the surrounding soil. (Fig. 12) The fungal population ranged between 29.05-62.43/g dry soil x 10^2 in the burrow soil and between 24.16-58.52/g dry soil x 10^2 in the surrounding soil. The maximum fungal population was recorded at 45 days of sampling in the burrow soil, whereas, maximum fungal population was recorded at 30 days of sampling in the surrounding soil. Tables 23 and 24 shows the variation in fungal population/g dry soil x 10^2 and its corresponding relative abundance in the burrow soil and the surrounding soil respectively.

Table 25 shows the list of fungi isolated from the burrow soil and the surrounding soil. Altogether, 14 fungal species were isolated from the burrow soil, of which, 4 belonged to Phycomycetes, 8 to Fungi Imperfecti and 2 to Mycelia sterilia. The class Phycomycetes is represented by 3 genera and 5 species and Fungi Imperfecti is represented by 4 genera and 7 species. From the surrounding soil also 14 fungal species were isolated, of which 4 belonged to Phycomycetes and 10 to Fungi Imperfecti. The class Phycomycetes is represented by 3 genera and 5 species and Fungi Imperfecti is represented by 4 genera and 9 species. Qualitatively, there was not much difference in the fungal flora isolated from the burrow soil and the surrounding soil. Most of the species were found to be common in both the soil types. However, *M. racemosus*, *F. oxysporum* and *P. janthinellum* could be isolated only from the surrounding soil, whereas, *M. circinelloides*, white sterile mycelia and yellow sterile mycelia could be isolated only from the burrow soil.

Effect of earthworms on the growth of maize in pots:

Plates 3.1, 3.3, 3.5 and 3.7 shows the growth of maize in Control pots (where no earthworms were added) after 20, 30, 40, 50 days respectively. Plates 3.2,3.4,3.6 and 3.8 show the growth of maize in pots treated with earthworms after 20, 30, 40, 50 days respectively. Not much difference was observed on the growth of stems and leaves of maize

Plate3.1: Growth of maize in control pots after 20 days interval

Plate3.2. Growth of maize in treated pots after 20 days interval

Plate3.3: Growth of maize in control pots after 30 days interval

Plate3.4: Growth of maize in treated pots after 30 days interval

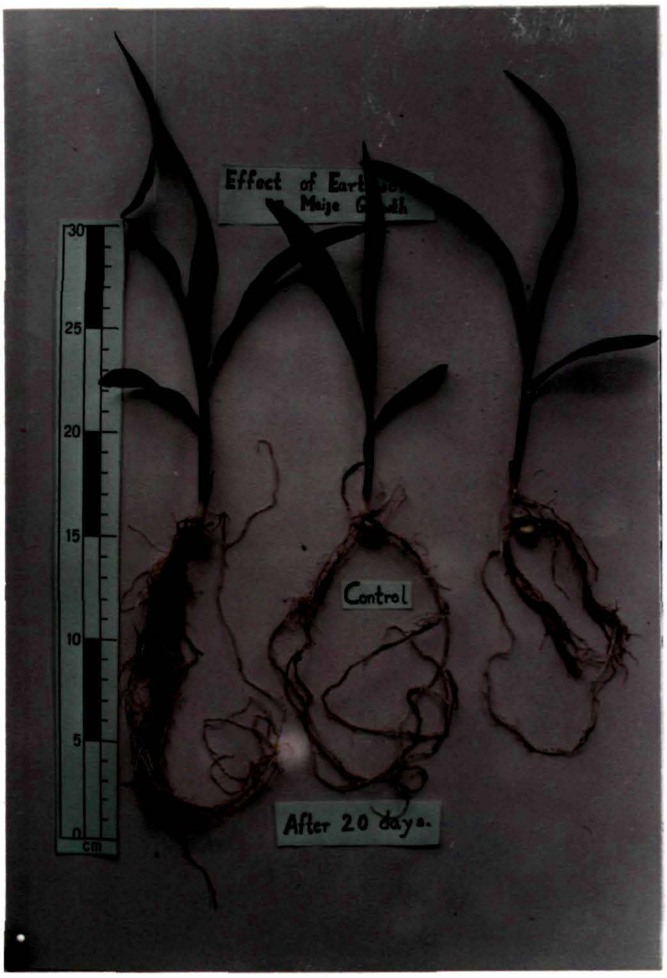


Plate 3.1

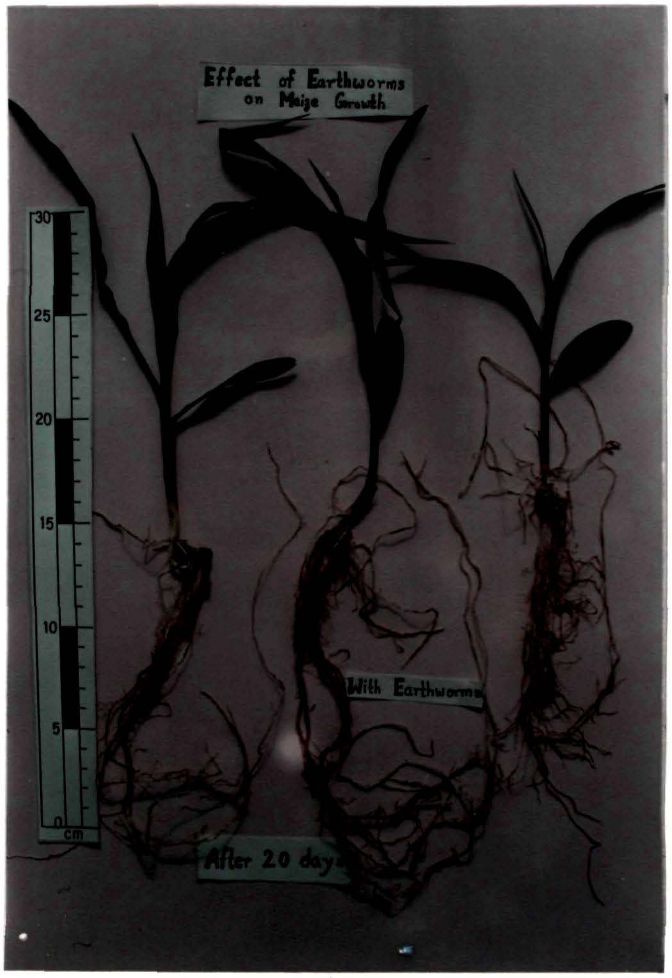


Plate 3.2.

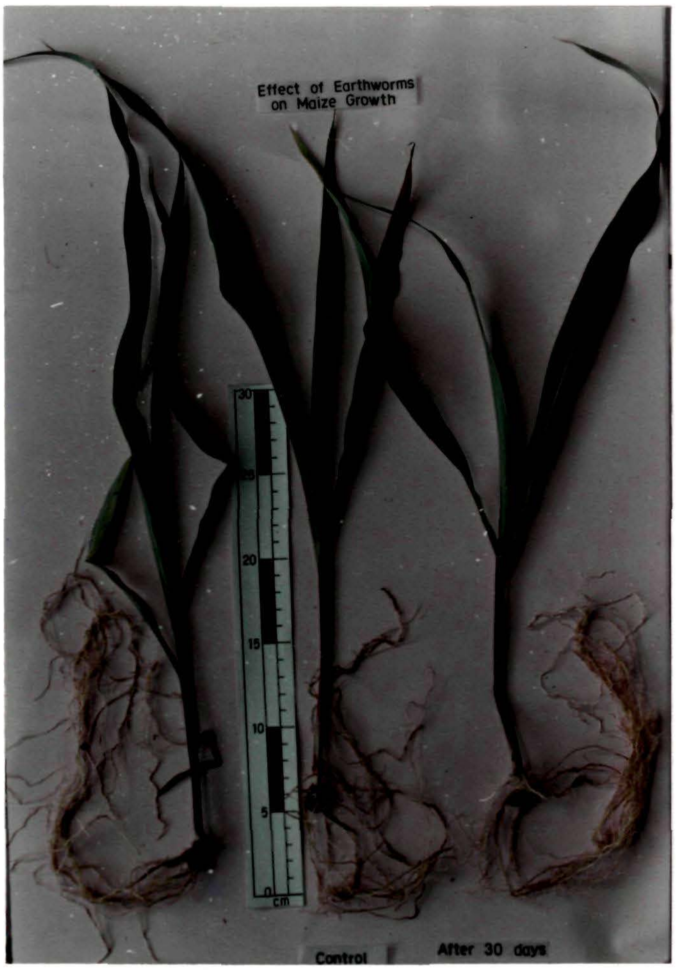


Plate 3.3.

Plate 3.4.

Plate3.5: Growth of maize in control pots after 40 days interval

Plate3.6: Growth of maize in treated pots after 40 days interval

Plate3.7: Growth of maize in control pots after 50 days interval

Plate3.8: Growth of maize in treated pots after 50 days interval

Plate 3.5.

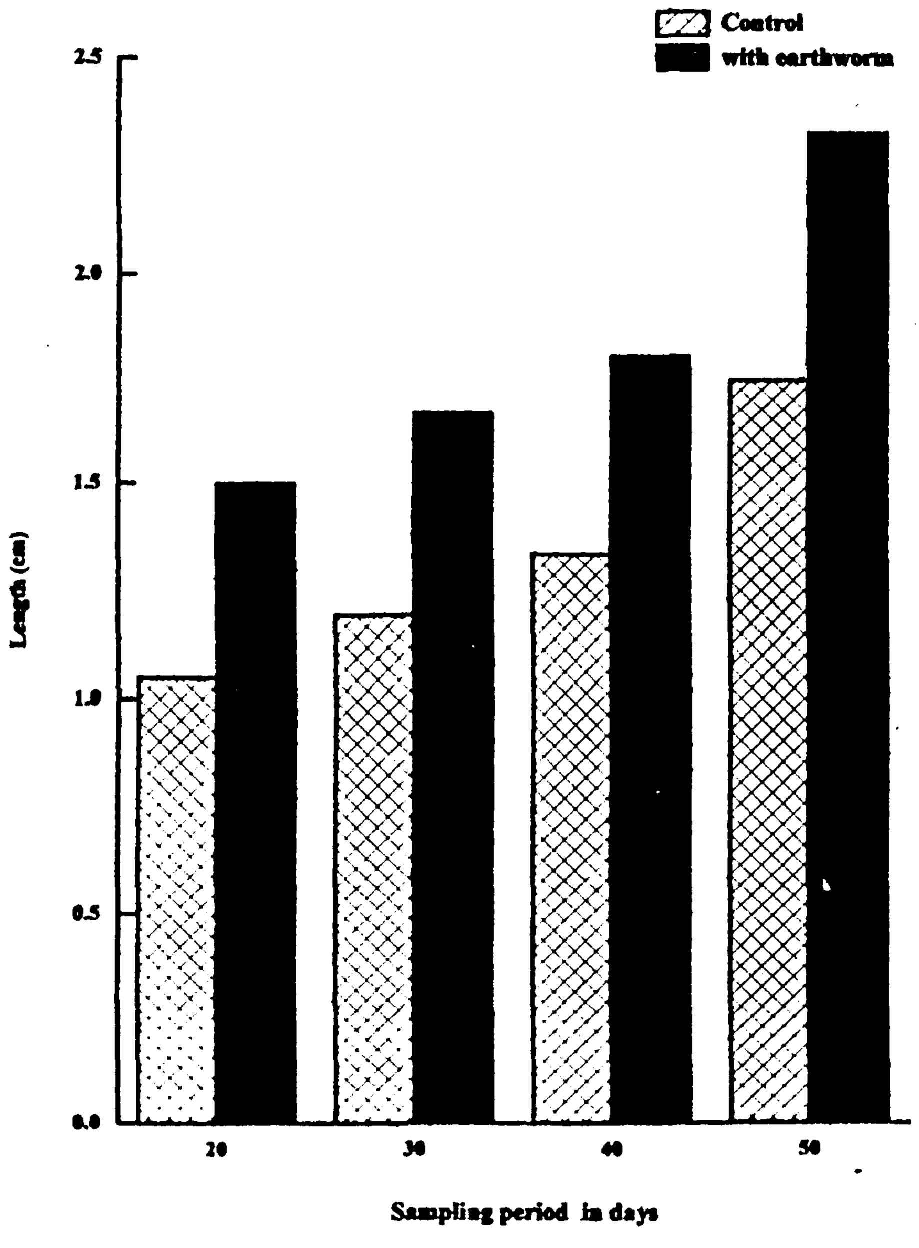
Plate 3.6

Plate 3.7.

Plate 3.8.

Fig. 13: whole plant length during growth of maize in laboratory condition

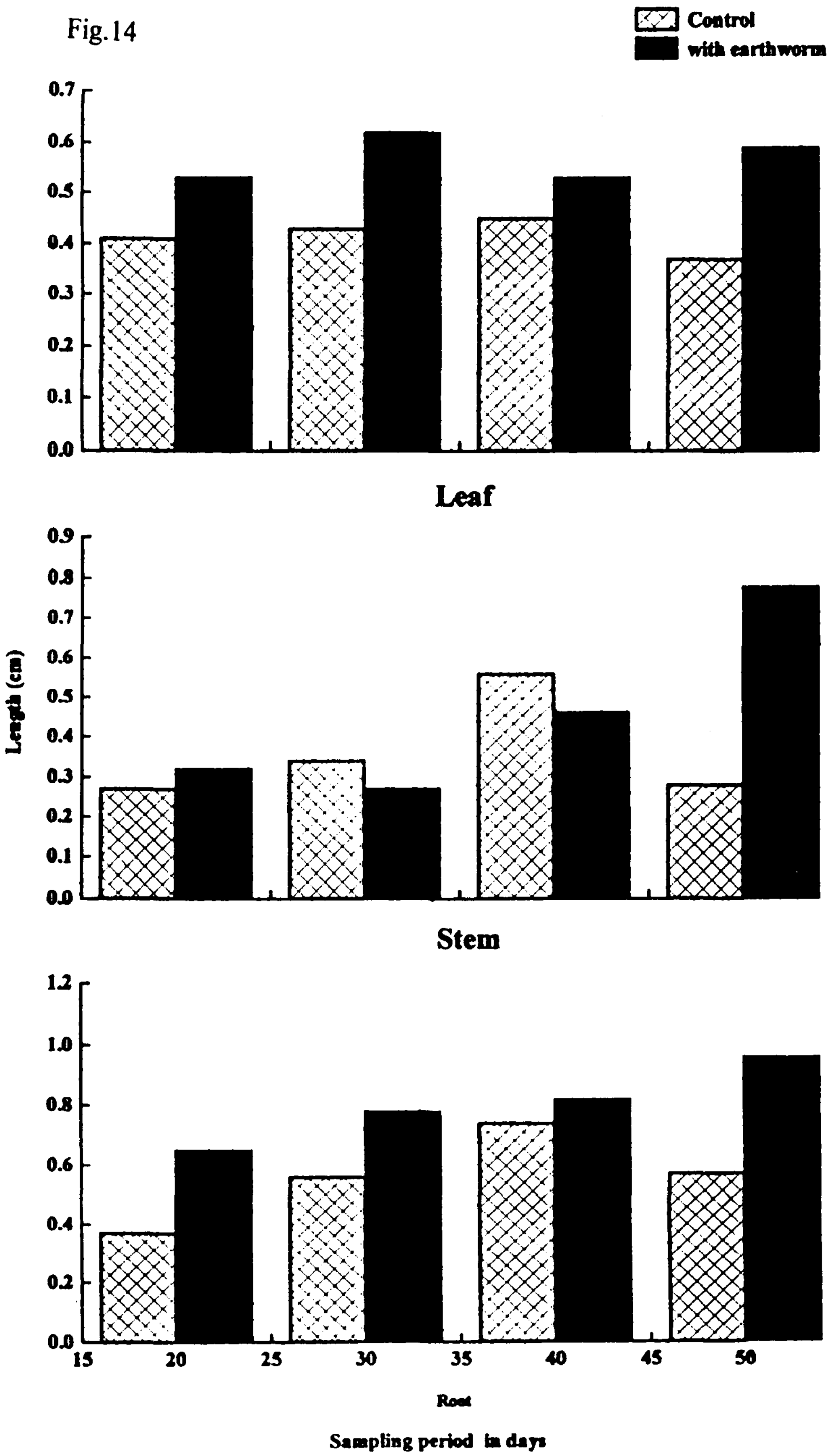
Fig.13



Control
with earthworm
2.5
2.0
1.5
1.0
0.5
0.0
Length (cm)
20
30
40
50
Sampling period in days

Fig. 14 : Root, stem and leaf length during growth of maize in laboratory condition

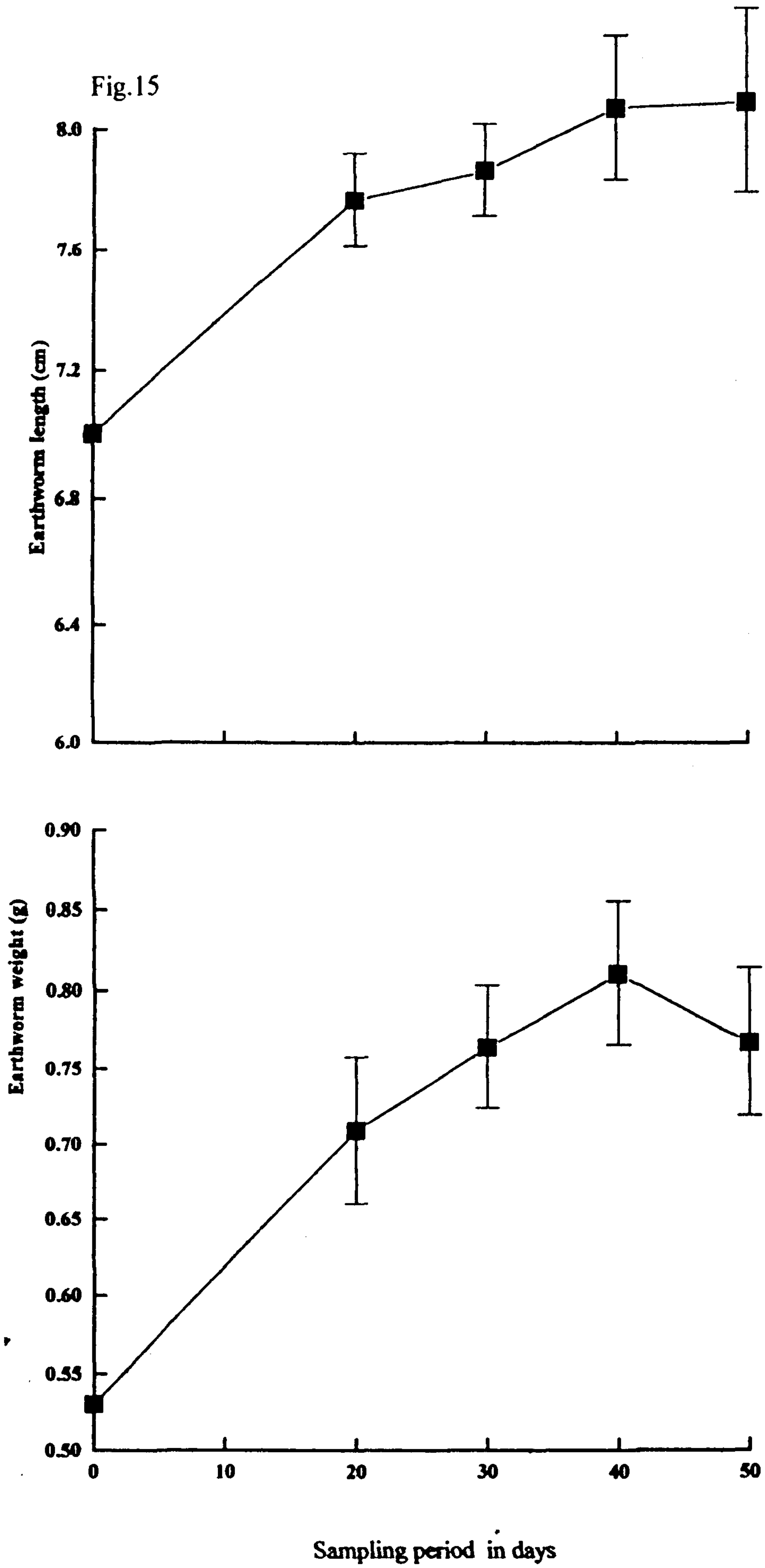
Fig.14



Control
with earthworm
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Leaf
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Length (cm)
Stem
1.2
1.0
0.8
0.6
0.4
0.2
0.0
15
20
25
30
35
40
45
50
Root
Sampling period in days

Fig.15 : Earthworm length and weight during growth of maize in laboratory condition.

Fig.15



8.0
7.6
7.2
6.8
6.4
6.0
Earthworm length (cm)
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
Earthworm weight (g)
0
10
20
30
40
50
Sampling period in days

between control plants and treated plants. A marked difference was however, observed in the growth of roots between the control plants and the treated plants. More root growth was observed when earthworms were added to the treated plants. With the increase in the number of days there was a decrease in the number of earthworms. This decrease in the number of earthworms affected the growth of maize roots as observed in Plate 5.8. Fig. 13 shows the whole plant length of maize in untreated and treated pots. With the increase in the number of days an increase in the growth of maize was observed. Plants treated with earthworms showed more growth in length as compared to the untreated plants. Fig. 14 shows roots, stems and leaves length during growth of maize. When stems, roots and leaves were taken as separate identity, an increase in the length of roots, stems and leaves was observed to be more in treated plants than that of the untreated plants. Fig. 15 shows earthworm length and weight during growth of maize. An increase in the length was observed with increase in the number of days. Gain in weight was observed as sampling period increases from 10-40 days followed by a decrease in weight towards the end of the sampling period.

Decomposition of maize litter by earthworms in laboratory condition:

p^H:

Fig. 16 shows the p^H values in the control (untreated) and the treated pots. The p^H in control pots ranged between 5.14-6.76 in Control Root (CR), between 6.23-6.68 in Control Stem (CS) and between 6.02-6.82 in Control Leaves (CL). Whereas, in the pots treated with earthworms, the soil p^H ranged between 6.12-6.60 in pots where root litter was added (ER), between 6.00-6.87 in pots where stem litter was added (ES) and between 6.00-6.67 in pots where leaf litter was added (EL). The p^H of the casts ranged between 6.13-6.89 in pots

Fig 16: p^{H} of soil and the casts during decomposition period.

Fig.16

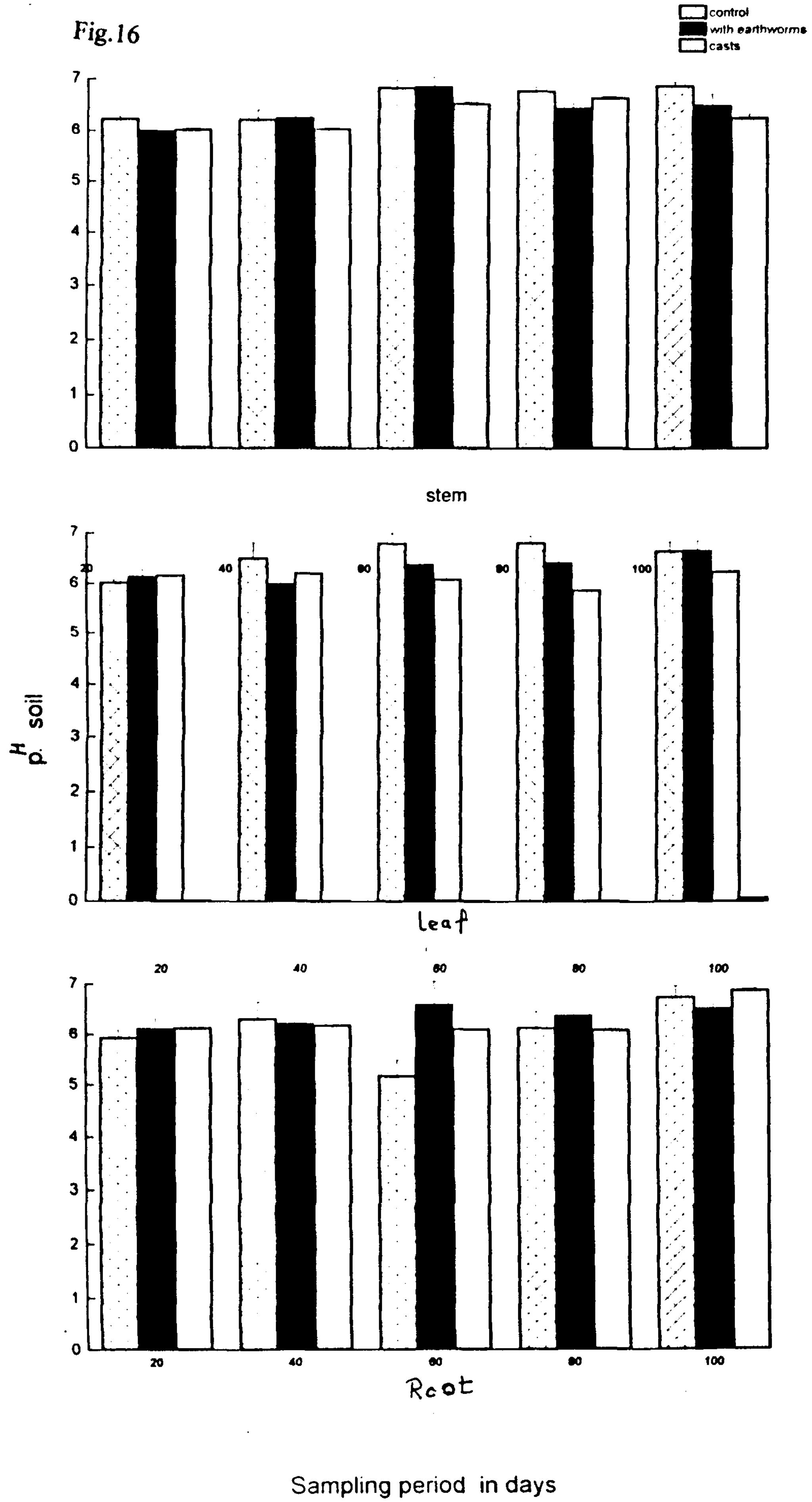
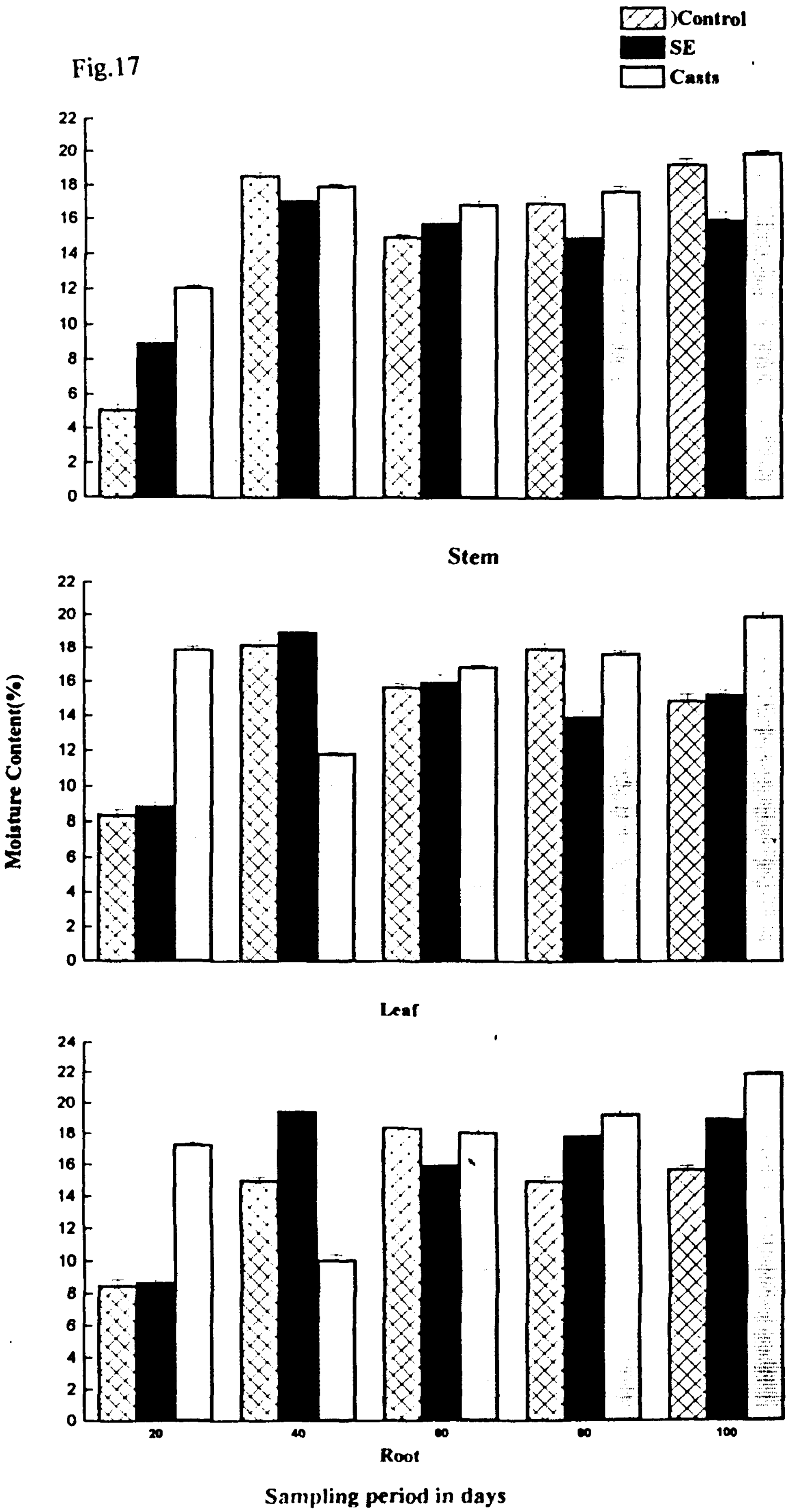

control
with earthworms
casts
0
1
2
3
4
5
6
7
stem
20
40
60
80
100
p. H soil
leaf
Root
Sampling period in days

Fig. 17: Moisture content (%) of soil and casts during the decomposition period.

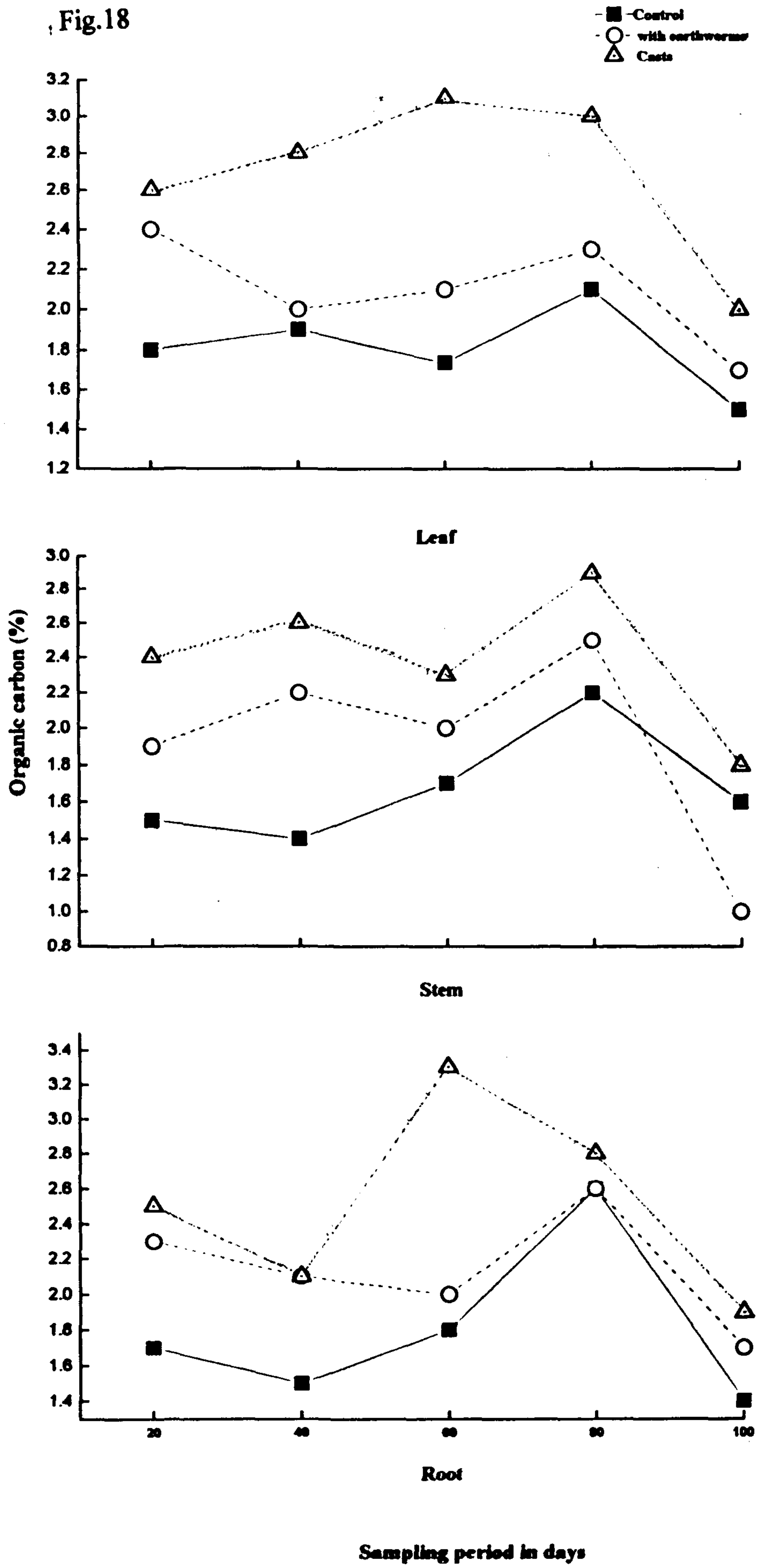
Fig.17



)Control
SE
Casts
Stem
Leaf
Root
Moisture Content(%)
Sampling period in days
20
40
60
80
100

Fig. 18: Organic carbon in control, soil treated with earthworms and casts during decomposition in laboratory condition.

Fig.18


Control
with earthworms
Casts
Leaf
Stem
Root
Organic carbon (%)
20
40
60
80
100
Sampling period in days

where root litter was added (ER); between 6.03-6.66 in pots where stem litter was added (ES) and between 5.88-6.25 in pots where leaf litter was added (EL).

Moisture content:

Fig. 17 shows the percentage moisture content in the control (untreated) and the treated pots. The percentage moisture content in control pots ranged between 8.5-18.4% in CR, between 8.4-18.2% in CS and between 5.1-19.3% in CL. In the pots treated with earthworms, the percentage moisture content of the soil ranged between 8.71-19.5% in ER, between 8.89-19.0% in ES and between 8.96-17.1% in EL. The percentage moisture content of the casts ranged between 10.1-22% in ER, between 12.1-20.0% in ES and between 11.9-20.0% in EL.

An increase in the percentage moisture content of treated soil than the untreated soil was observed throughout the study period. Higher percentage moisture content was recorded in the casts than that in the soil.

Organic carbon:

Fig. 18 shows the percentage organic carbon in the control (untreated) and the treated pots. The percentage organic carbon in control pots ranged between 1.4-2.6% in CR, between 1.4-2.2% in CS and between 1.5-2.1% in CL. In the pots treated with earthworms, the percentage organic carbon of the soil ranged between 1.7-2.6% in ER, between 1.0-2.5% in ES and between 1.7-2.4% in EL. The percentage organic carbon of the casts ranged between 1.9-3.3% in ER, between 1.8-2.9% in ES and between 2.0-3.1% in EL.

Throughout the study period the percentage organic carbon was found to be maximum after 80 days in all the cases except in the casts collected from pots treated with root litter and the earthworms (ER) which showed its maximum percentage after 60 days. The percentage organic carbon in soil collected from the treated pots was higher than the

Fig.19: CO_2 evolution of soil and casts during the decomposition period.

Fig. 19

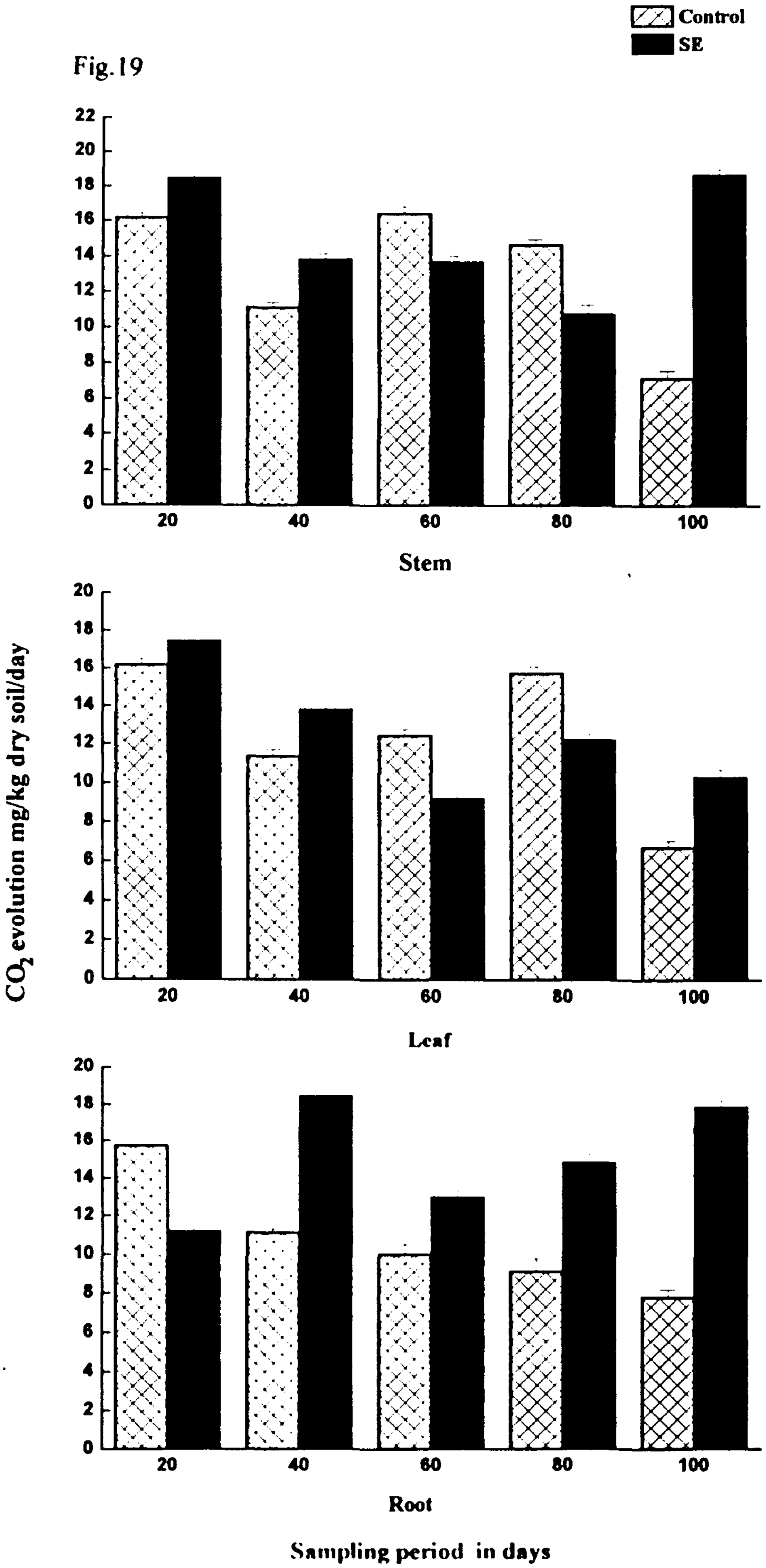
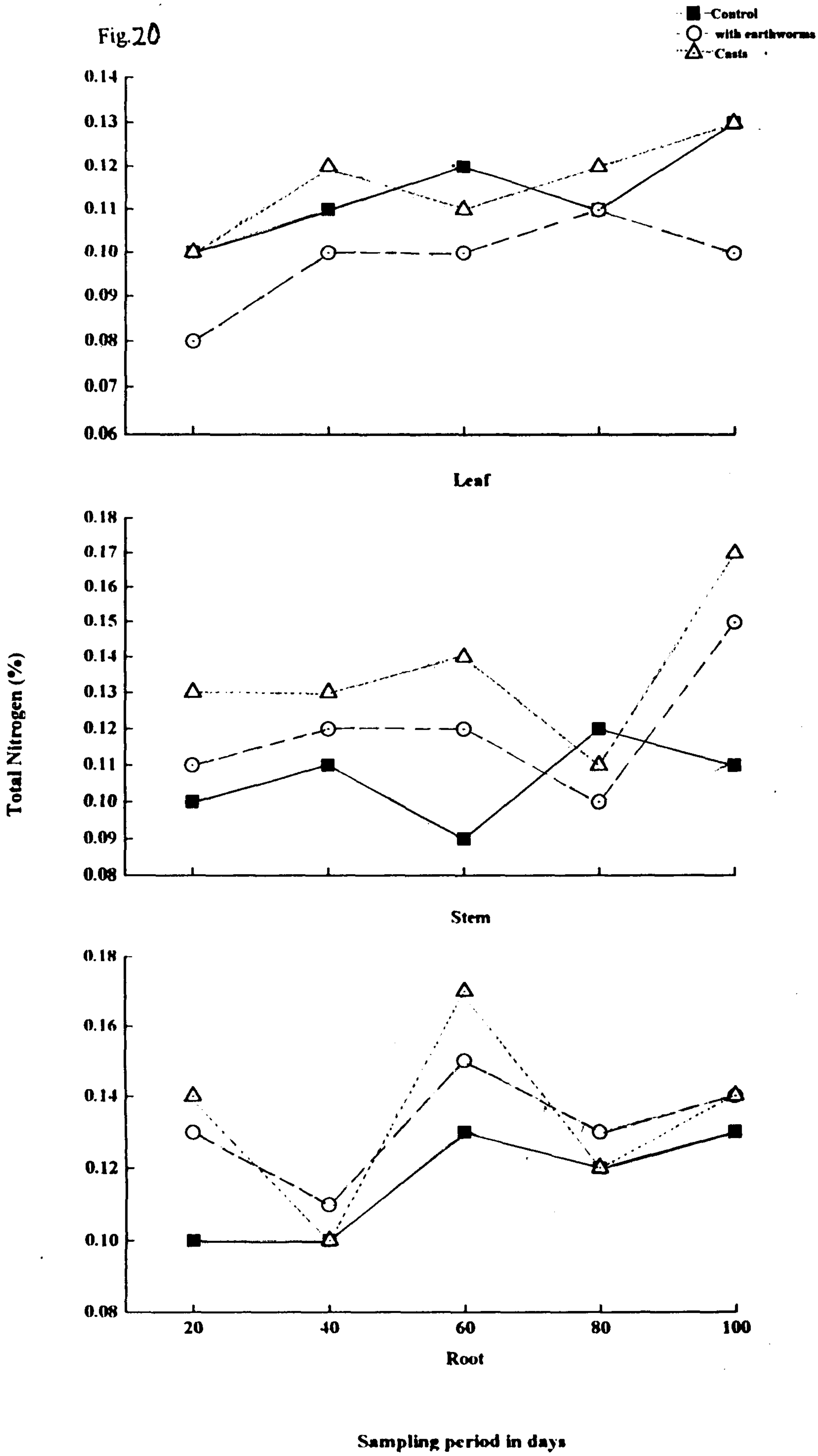

Control
SE
22
20
18
16
14
12
10
8
6
4
2
0
20
40
60
80
100
Stem
Leaf
Root
CO_2 evolution mg/kg dry soil/day
Sampling period in days

Fig. 20: Total nitrogen in control, soil treated with earthworms and casts during decomposition in laboratory condition.

Fig.20



Control
with earthworms
Casts
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
Leaf
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
Stem
Total Nitrogen (%)
0.18
0.16
0.14
0.12
0.10
0.08
20
40
60
80
100
Root
Sampling period in days

untreated pots. Likewise the percentage organic carbon in casts was higher than that of the soil.

Carbon di-oxide evolution:

Fig. 19 shows the carbon di-oxide evolution mg/kg dry soil/day in the control (untreated) and the treated pots. The carbon di-oxide evolution in control pots ranged between 7.83-15.75 mg/kg dry soil/day in CR, between 7.17-16.45 mg/kg dry soil/day in CS and between 6.73-16.19 mg/kg dry soil/day in CL. In the pots treated with earthworms, the soil carbon di-oxide evolution ranged between 11.2-18.46 mg/kg dry soil/day in ER, between 10.76-18.63 mg/kg dry soil/day in ES and between 9.22-17.45 mg/kg dry soil/day in EL. Throughout the study period, the carbon di-oxide evolution was higher in the presence of earthworms.

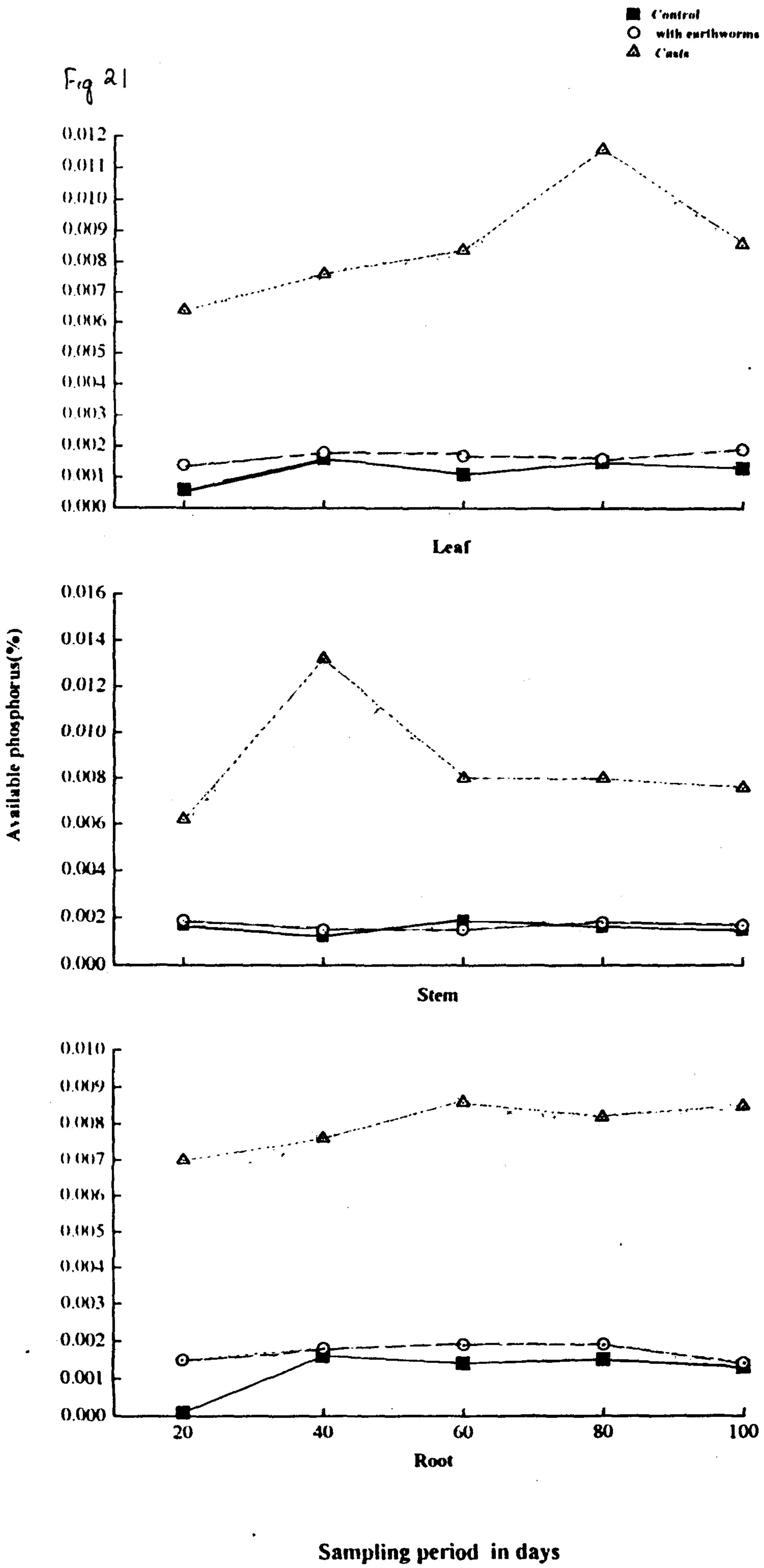
Total nitrogen:

Fig. 20 shows the percentage total nitrogen in the control (untreated) and the treated pots. The percentage total nitrogen in control pots ranged between 0.10-0.13% in CR, between 0.09-0.12% in CS and between 0.10-0.13% in CL. In the pots treated with earthworms, the percentage total nitrogen of the soil ranged between 0.11-0.15% in ER, between 0.10-0.50% in ES and between 0.08-0.11% in EL. The percentage total nitrogen of the casts ranged between 0.10-0.17% in ER, between 0.11-0.17% in ES and between 0.10-0.13% in EL.

In pots where root litter was added, higher total nitrogen was recorded in the treated soil and the casts than the untreated soil. Highest total nitrogen was observed in the treated soil where root litter was added than the other treated soils. Peak period was observed after 60 days interval in soil from ER followed by a slight decrease after 80 days interval. Thereafter, an increase in the total nitrogen at the end of the experiment was observed. Total

Fig.21: Available phosphorus in control, soil treated with earthworms and casts during decomposition in laboratory condition.

Fig 21



Control
with earthworms
Casts
Available phosphorus(%)
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Leaf
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Stem
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
20
40
60
80
100
Root
Sampling period in days

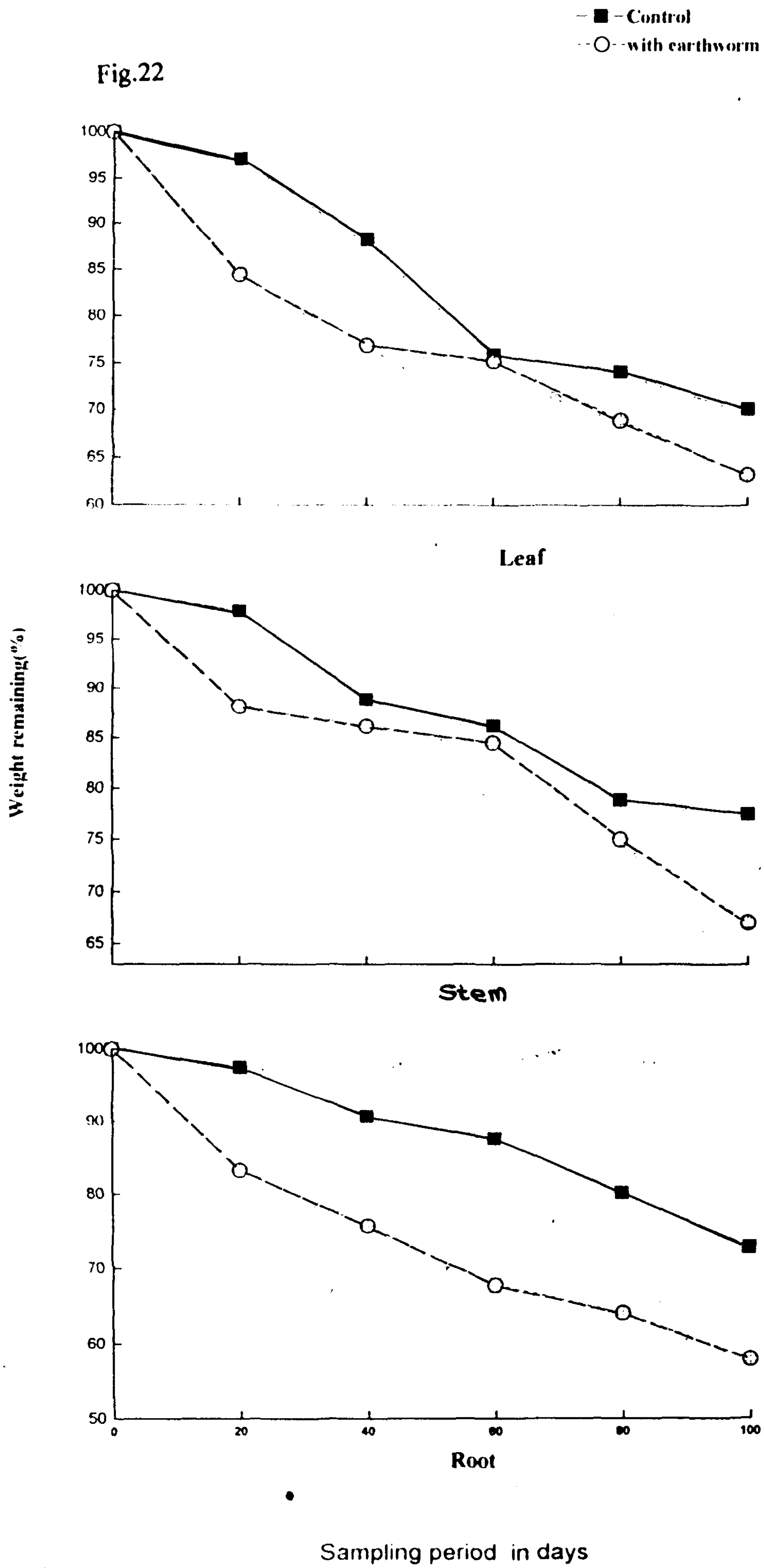
nitrogen in casts in ER also followed the same trend as that of the treated soil. In CR the total nitrogen was minimum at the initial stage whereas a gradual increase in the total nitrogen was observed in the latter stage. Peak periods were observed at 60 and 100 days interval. However, maximum total nitrogen was observed in the casts than that of the treated soil. In treated pots having stem as litter (ES), the maximum total nitrogen was observed at the end of the experiment i.e., after 100 days. Similar results were observed in the casts and the untreated soil. Minimum total nitrogen was recorded in untreated pots, with a higher value in the treated pots and the highest values in the casts. In treated pots where leaf litter was added (EL), the total nitrogen was higher in the treated pots than the untreated pots. The highest total nitrogen was observed at the end of the experiment i.e., after 100 days in treated soil and the casts. Whereas, the total nitrogen in untreated soil was maximum after 80 days interval. Overall percentage of total nitrogen was observed to be fluctuating throughout the study period. An increase in the total nitrogen was observed towards the end of the experiment in all the three types of treated pots. Whereas, a decrease in total nitrogen was observed in the untreated pots where stem and leaf litter were added respectively.

Available phosphorus:

Fig. 21 shows the percentage available phosphorus in the control (untreated) and the treated pots. The percentage available phosphorus in control pots ranged between 0.0001-0.0016% in CR, between 0.0012-0.0019% in CS and between 0.0006-0.0016% in CL. In the pots treated with earthworms, the percentage available phosphorus of the soil ranged between 0.0014-0.0019% in ER, between 0.0015-0.0019% in ES and between 0.0014-0.0019% in EL. The percentage available phosphorus of the casts ranged between 0.007-0.0086% in ER, between 0.006-0.0132% in ES and between 0.0064-0.0116% in EL.

Fig 22: Percentage weight remaining of maize litter during decomposition period

Fig.22



Control
with earthworm
Weight remaining(%)
Leaf
Stem
Root
0
20
40
60
80
100
Sampling period in days

Not much difference was observed in the available phosphorus in the treated soil and the untreated soil in all the three types of litter but a marked difference was observed in the available phosphorus in the casts in all the three types of treated soil. Highest available phosphorus was observed in the casts. Peak period of available phosphorus in the casts collected from ER was observed after 60 days interval followed by a slight decline after 80 days interval. In the casts collected from ES the available phosphorus showed a peak period after 40 days interval followed by a decline towards the end of the study period. Whereas, in the casts collected from ER the available phosphorus showed a steady increase from the beginning of the sampling period with its peak period after 80 days interval followed by a decrease after 100 days interval.

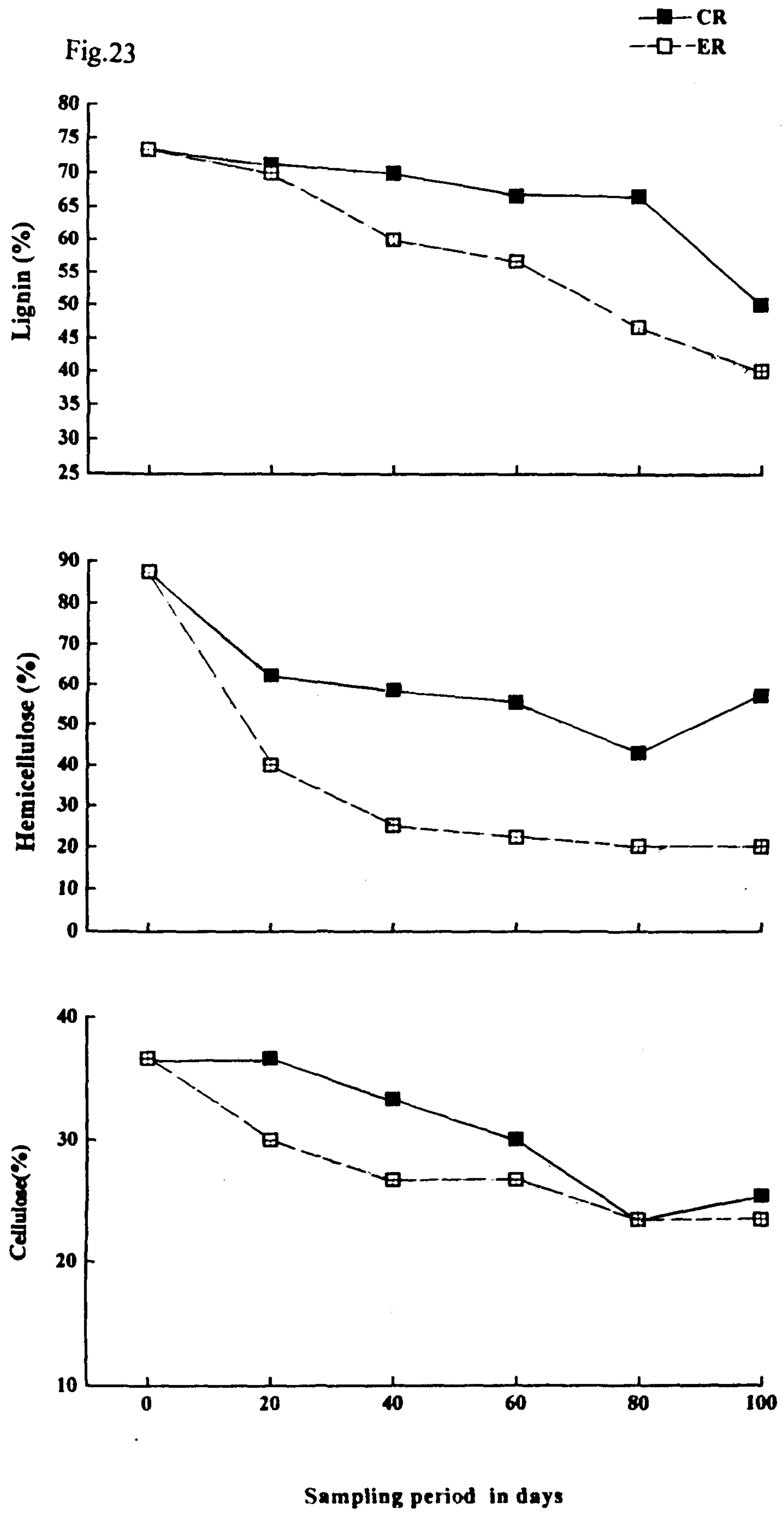
Percentage weight remaining of maize litter in treated and untreated pots:

Fig. 22 shows the percentage weight remaining of maize litter in the control (untreated) and the treated pots. The percentage weight remaining of maize litter in control pots ranged between 70.1-97.1% in CR, between 77.5-97.9% in CS and between 72.8-97.4% in CL. In the pots treated with earthworms, the soil percentage weight remaining of maize litter ranged between 63.8-84.4% in ER, between 75.0-88.1% in ES and between 57.9-83.1% in EL.

A gradual decrease in the weight of maize litter was observed in both the treated and the untreated pots in all the three types of litter. However, the percentage weight remaining was more in the untreated pots than the treated pots in all the three types of litter. Decrease in the amount of litter was the highest in the pots where root litter was added in the untreated pots, whereas, in the treated pots the highest decrease of litter was observed in the pots where leaf litter was added. Weight loss of litter in the untreated pots followed a trend

Fig.23: Percentage cellulose, hemicellulose and lignin in decomposing maize root in laboratory condition

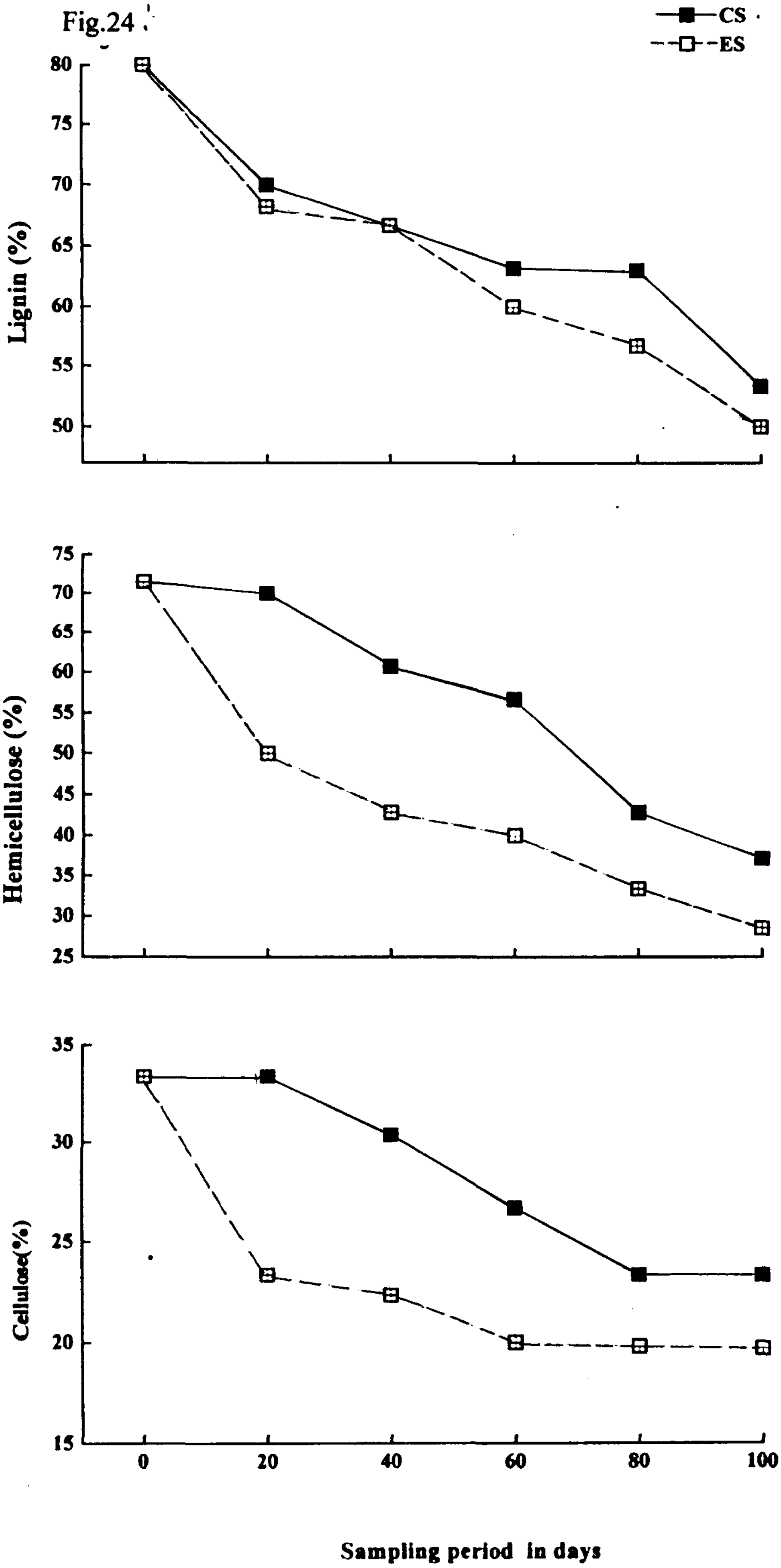
Fig.23



CR
ER
80
75
70
65
60
55
50
45
40
35
30
25
Lignin (%)
90
80
70
60
50
40
30
20
10
0
Hemicellulose (%)
40
30
20
10
Cellulose(%)
0
20
40
60
80
100
Sampling period in days

Fig.24: Percentage cellulose, hemicellulose and lignin in decomposing maize stem in laboratory condition

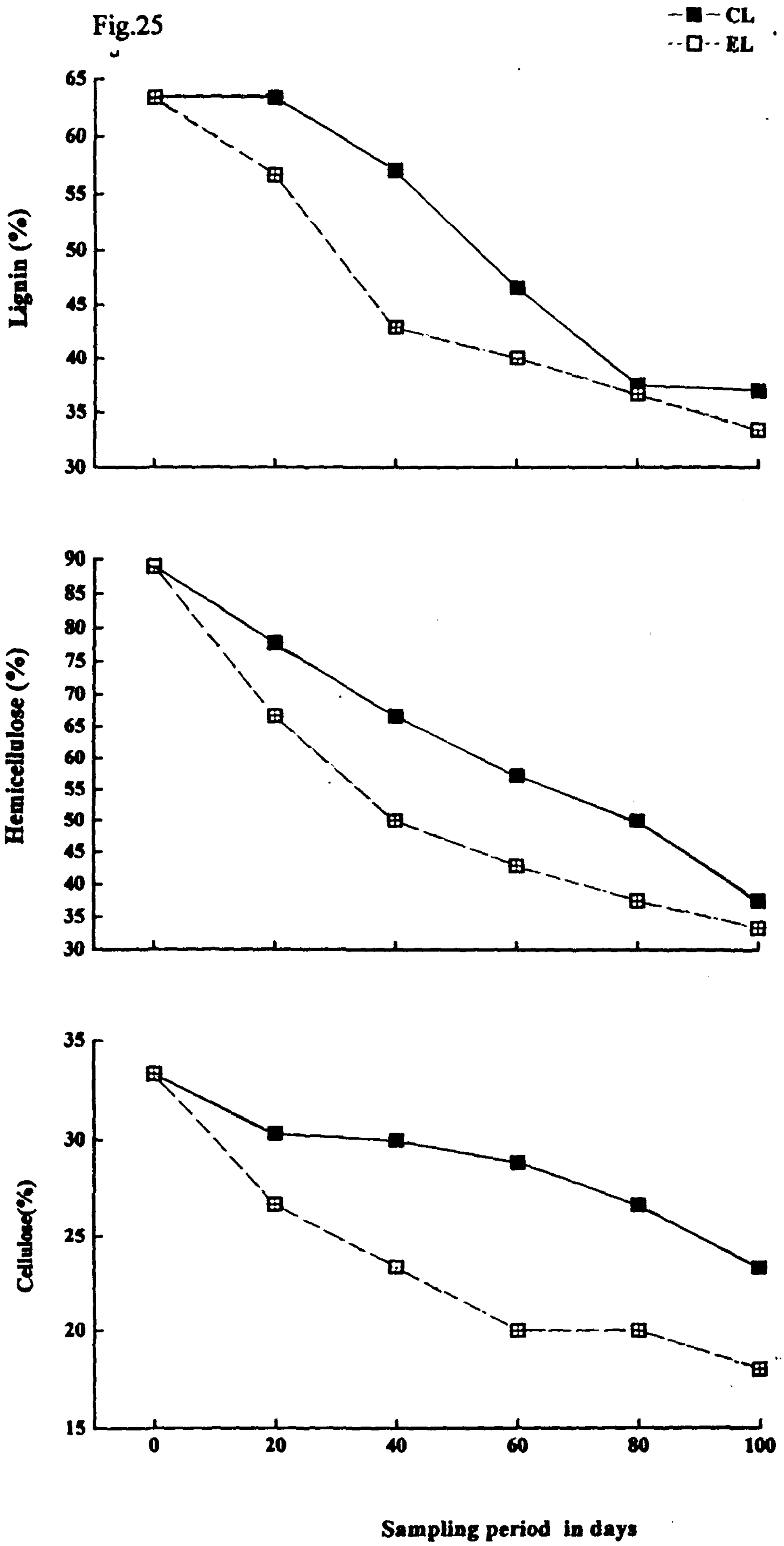
Fig.24



CS
ES
80
75
70
65
60
55
50
Lignin (%)
75
70
65
60
55
50
45
40
35
30
25
Hemicellulose (%)
35
30
25
20
15
Cellulose(%)
0
20
40
60
80
100
Sampling period in days

Fig.25: Percentage cellulose, hemicellulose and lignin in decomposing maize leaf in laboratory condition

Fig.25


CL
EL
Lignin (%)
65
60
55
50
45
40
35
30
Hemicellulose (%)
90
85
80
75
70
65
60
55
50
45
40
35
30
Cellulose(%)
35
30
25
20
15
0
20
40
60
80
100
Sampling period in days

CR>CL>CS and in the treated pots weight loss followed a trend EL>ER>ES. Decrease in the amount of litter in the treated pots ER and ES were gradual throughout the study period except at the end of the study period where the loss of weight was lesser than after 80 days interval.

Percentage cellulose, hemicellulose and lignin in litter during decomposition:

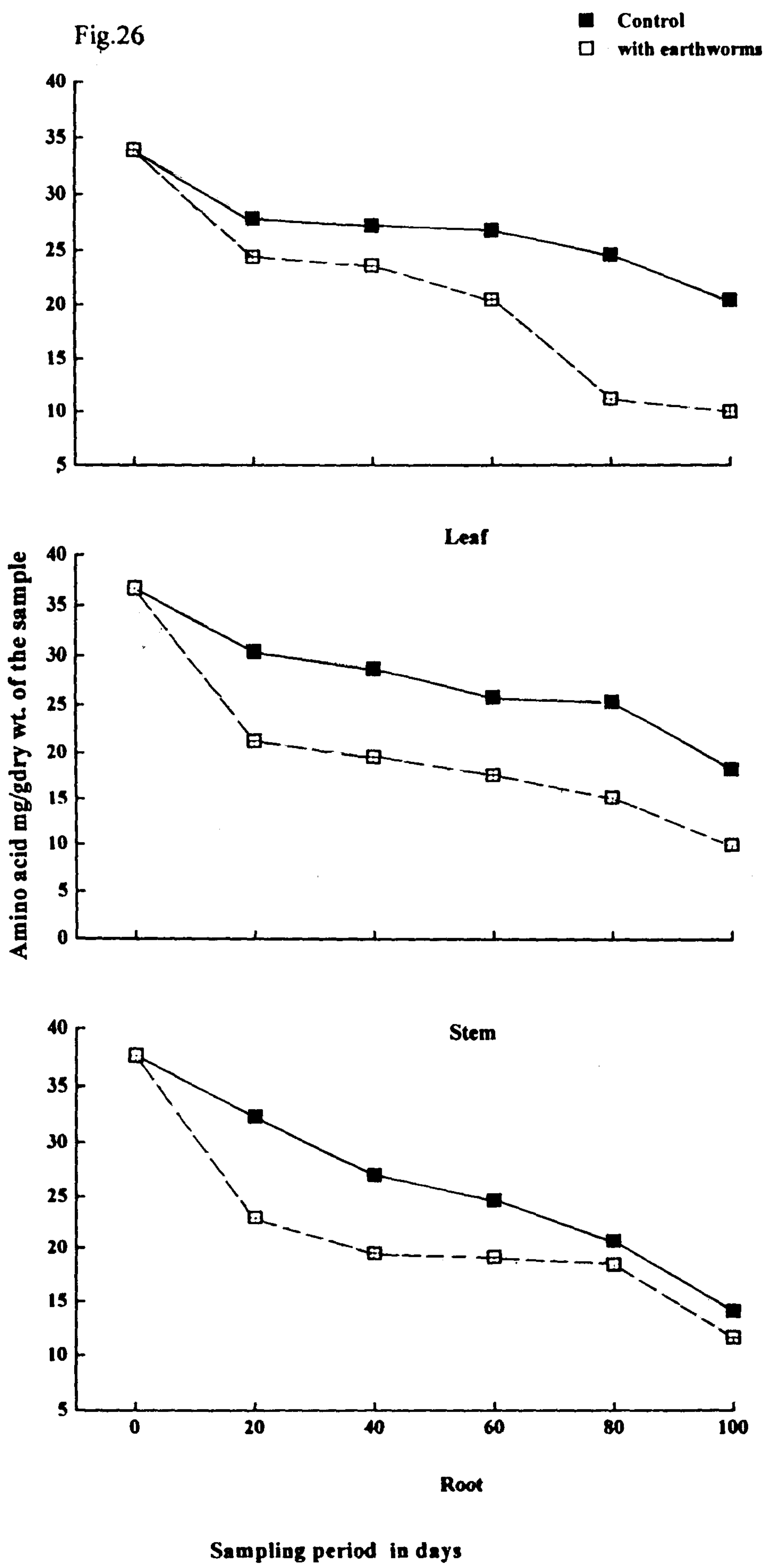
Fig. 23 shows the percentage cellulose, hemicellulose and lignin during the decomposition period in the pots where root litter was added. The percentage cellulose ranged between 27.33-36.67% in CR, between 23.33-30.00% in ER, the percentage hemicellulose ranged between 47.86-62.50% in CR, between 20.00-40.00% in ER and the percentage lignin ranged between 50.00-71.23% in CR, between 40.00-70.00% in ER. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease in the percentage cellulose, hemicellulose and lignin was observed in both the untreated and treated pots.

Fig. 24 shows the percentage cellulose, hemicellulose and lignin during the decomposition period in the pots where stem litter was added. The percentage cellulose ranged between 23.33-33.33% in CS, between 19.72-23.33% in ES, the percentage hemicellulose ranged between 37.14-70.00% in CS, between 28.57-50.00% in ES and the percentage lignin ranged between 53.33-70.00% in CS, between 50.00-68.23% in ES. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease in the percentage cellulose, hemicellulose and lignin was observed in both the untreated and treated pots.

Fig. 25 shows the percentage cellulose, hemicellulose and lignin during the decomposition period in the pots where leaf litter was added. The percentage cellulose ranged between 23.33-30.33% in CL, between 18.00-26.67% in EL, the percentage hemice-

Fig.26: Amino acid of the sample in decomposing maize root, stem and leaf in laboratory condition

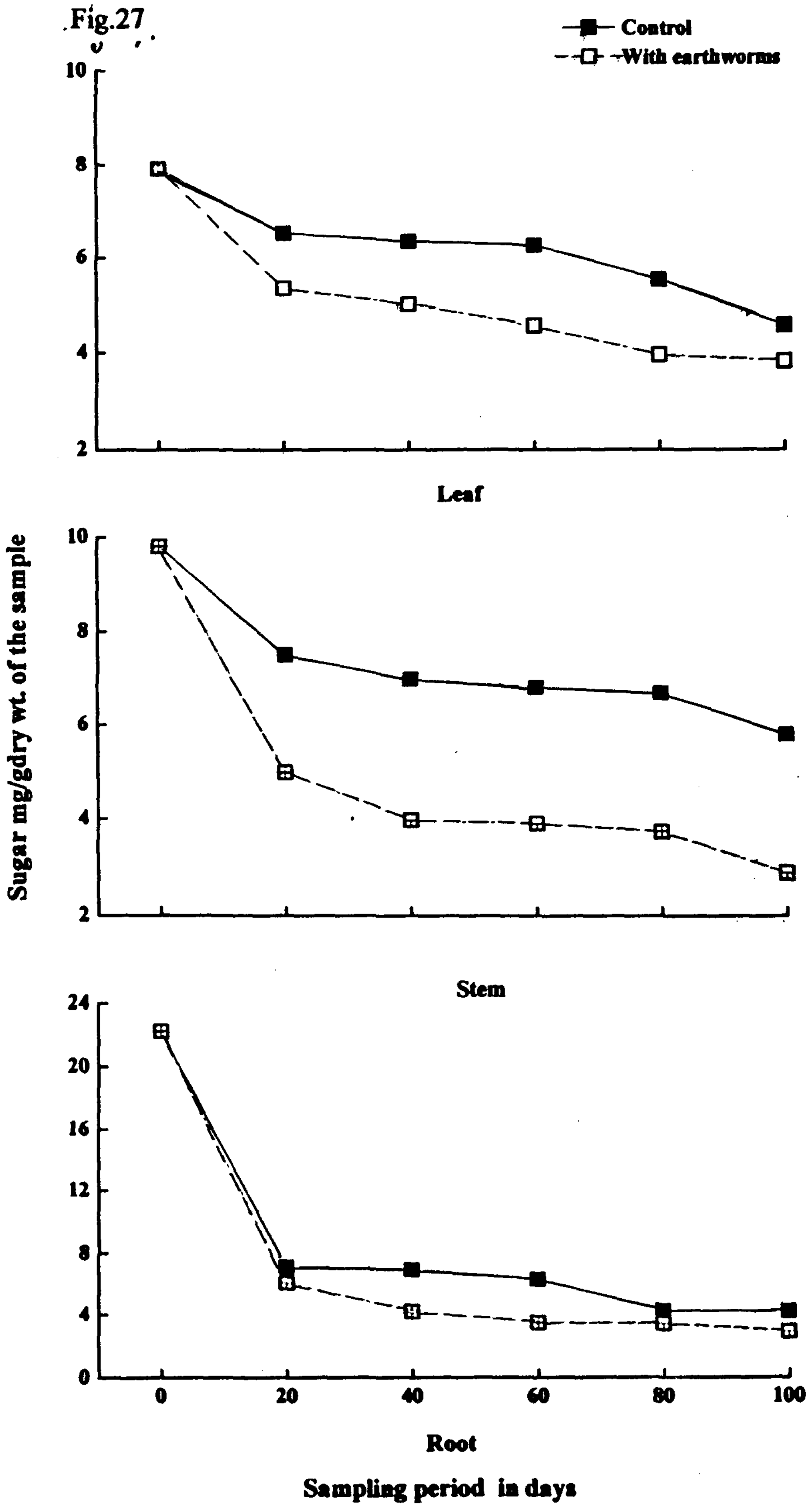
Fig.26



Control
with earthworms
Amino acid mg/gdry wt. of the sample
Leaf
Stem
Root
0
20
40
60
80
100
Sampling period in days

Fig 22: Sugar of the sample in decomposing maize root, stem and leaf in laboratory condition

Fig.27


Control
With earthworms
10
8
6
4
2
Leaf
10
8
6
4
2
Sugar mg/gdry wt. of the sample
Stem
24
20
16
12
8
4
0
0
20
40
60
80
100
Root
Sampling period in days

llulose ranged between 37.50-77.78% in CL, between 33.36-66.67% in EL and the percentage lignin ranged between 37.00-63.333% in CL, between 33.36-56.67% in EL. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease was recorded in the percentage cellulose, hemicellulose and lignin was observed in both the untreated and treated pots. The percentage weight loss of cellulose followed a trend CR>CS=CL in the untreated pots, whereas, it followed a trend EL>ES>ER in the treated pots. The percentage weight loss of hemicellulose followed a trend CR>CS>CL in the untreated pots, whereas, it followed a trend ER >ES> EL in the treated pots. And the percentage weight loss of lignin followed a trend CL>CR>CS in the untreated pots, whereas, it followed a trend EL>ER>ES in the treated pots.

In the untreated pots having root litter (CR), the percentage weight loss of cellulose was the highest, followed by lignin and the least by hemicellulose. Whereas, in the treated pots (ER), the percentage weight loss of hemicellulose was the highest, followed by cellulose and the least by lignin. In the untreated pots having stem litter (CS), the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. Whereas, in the treated pots (ES) the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. In the untreated pots having leaf litter (CL), the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. Whereas, in the treated pots (EL) the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin.

Amino acid and the sugar in litter during decomposition:

Fig. 26, 27 shows the amount of total amino acid and the sugar in maize litter during decomposition in the control (untreated) and the treated pots. The amino acid ranged between 14.17-32.37mg/g dry wt. of the sample in CR and in ER between 11.7-23.07mg/g dry wt. of the sample. Amino acid ranged between 18.33-30.43mg/g dry wt. of the sample in CS and in ES between 10.00-21.27mg/g dry wt. of the sample. The amino acid ranged between 20.47-27.83mg/g dry wt. of the sample in CL and in EL between 10.00-24.40mg/g dry wt. of the sample. Decrease in the amino acid was more in the treated pots than the untreated pots. At the initial stage the decrease in the amino acid was rapid followed by a slower rate in all the three types of litter. The decrease in the amino acid was more in stem litter followed by leaf litter and the least in the root litter.

The amount of sugar ranged between 4.18-7.09mg/g dry wt. of the sample in CR and in ER between 2.91-6.04mg/g dry wt. of the sample. . The amount of sugar ranged between 5.78-7.51mg/g dry wt. of the sample in CS and in ES between 2.87-4.96mg/g dry wt. of the sample. The amount of sugar ranged between 4.53-6.51mg/g dry wt. of the sample in CL and in EL between 3.8-5.33mg/g dry wt. of the sample. Decrease in the amount of sugar was more in the treated pots than the untreated pots. A sharp decline in the amount of sugar was observed in the initial stage of the experiment followed by a slow decline after 20 days interval in both the untreated and in the treated pots where stem and root litter were added. However a gradual decline in the amount of sugar was observed where leaf litter was added. The weight loss of sugar in the untreated pots was highest in pots incorporated with root litter, followed by leaf litter and the least in pots having stem litter. Whereas, in the treated pots there was not much difference in the weight loss of sugar in the pots having root or stem litter. But the weight loss of sugar in the pots having leaf litter was lesser than in the pots having either stem or root litter

DISCUSSION

Physico-chemical characteristics of the soil and the casts:

Soil temperature:

Variation in the soil temperature of high and low altitudes is in conformation with the altitude of the two sites respectively, where the temperature of the soil is affected by the altitude of the land, slope and also by the climate of the particular place. A difference in the maximum soil temperature of the two fields during the two cropping seasons corresponds to the difference in the atmospheric temperature during the study period.

Moisture content:

Higher moisture content in soil at low altitude than that of high altitude may be due to the availability of more water at low lying areas, whereas, at high altitude water runoff is very high leading to less water retention capacity of the soil. A difference in the moisture content of the soil and the casts observed during the two cropping seasons where there was lower moisture content in the casts than that of the soil in the first cropping season and higher moisture content in the casts than that of the soil in the second cropping season, may be due to the age of the casts during sampling (Scheu, 1987a) where field collected casts were of unspecified age.

p^H :

p^H of the soil and the casts was found to be acidic at both the sites. Higher p^H values in the casts than in the soil are in consistent to those reports of Lunt and Jacobson (1944); Lee (1985); Mulongoy and Bedoret (1989); Dkhar and Mishra (1992) and Dkhar (2000). Higher p^H values in the casts may be due to the neutralisation of the soil by the secretions from the intesti-nine and by ammonia, which is excreted into the gut by the earthworms

(Edwards and Lofty, 1972a) or may also be due to the action of the calciferous glands in the worm pharynx when the soil is being ingested (Lee, 1985). Prento (1979) suggested that increase in p^H during gut transit is related to the mucus production and to the activity of the morren glands which secretes large amount of $CaCo_3$ spherules.

Organic carbon:

Higher values of organic carbon in the soils of low altitude than of high altitude may be due to the difference in the physical, chemical and biological properties of the soil. Higher value of organic carbon in the casts from low altitude than of high altitude is due to the cumulative effects of the difference in the physico-chemical characteristics of the soil as well as the activity and interaction of the earthworm species with the soil, microbes and plant organic matter as it passes through the gut. Higher organic carbon in the casts than that of the soil is due to the enrichment of organic carbon in the casts through the ingestion of plant and microbial residues by the earthworms and the production of large quantities of mucopolysaccharides by the earthworms during digestion (Bhandari, *et al.* 1967; Lee, 1985 and Schrader and Zhang, 1997). The higher organic carbon content in the casts is ascribed to the fact that earthworms may select soil fractions enriched in organic compounds (Blair *et. al.* 1994). Lee (1985) suggested that the enrichment of organic carbon in casts as compared to the surrounding soil was due to ingestion of plant and microbial residues and large quantities of mucopolysaccharides produced by the worm during digestion. Deka (1981) noted lowest level of organic matter during the period from June-August followed by a subsequent period of almost uniform level of organic matter.

Total nitrogen:

Higher concentration in the total nitrogen in the casts than in the soil may be due to the excretion of urine in the gut (Dash and Patra, 1979) in the form of ammonia and urea

Laverack, 1963) and also due to the presence of plant tissues in the casts which have passed through the gut with little chemical change (Lee, !983). Higher concentration of total nitrogen in the casts is in concurrence with the works of Lunt and Jacobson (1944); Graff (1971); Aldag and Graff (1975); Syers *et al.* (1979); and Lavelle *et al.* (1992) who also reported higher nitrogen content in the casts than that of the surrounding soil. However, Needham (1957) suggested that very little nitrogen is excreted in the faeces of earthworm.

Available phosphorus:

Higher values of available phosphorus in the soil and casts collected from low altitude is due to the greater microbial activity and release of soluble phosphate and may be because of suitable temperature at low altitude than at high altitude. Higher values of available phosphorus in the casts than in the surrounding soil may be due to increase in p^H of the casts which was responsible for higher solubility of nutrients in casts (Barley, 1961) or probably due to enhanced microbial activity in the casts (Sharpley and Syers, 1977). Another possible reason could be that the gut passage might have altered the P-sorption capacities of the soil (Lopez-Hernandez *et. al.* 1993). Mackay *et al.* (1982,1983) showed an increase in the availability of phosphorus from ground phosphate rock, which was intimately mixed with soil in earthworm casts during digestion. Maximum concentration of available phosphorus in the soil during the month of September and August at high and low altitude respectively in the first cropping season and in the months of April and July at high and low altitude respectively in the second cropping season suggested that this maybe due to the greater microbial activity and release of soluble phosphate because of suitable temperature in the respective fields (Dkhar, 1983). Higher values of available phosphorus in the casts in the month of September and August at high and low altitude respectively in the first cropping season and in the months of August and July at high and low altitude respectively in the second cropping season maybe due to the greater microbial activity in thc casts.

Carbon di-oxide evolution:

Higher carbon di-oxide evolution in soils at low altitude than that at high altitude reflects the favourable effect of soil moisture (Tesarova and Glosser, 1976; Gupta and Singh, 1981 and Dkhar, 1983) and temperature on the microbial activity (Witkamp, 1966b; Anderson, 1973; Gupta and Singh, 1981 and Dkhar, 1983). Dkhar and Mishra (1987) reported a significant correlation between carbon di-oxide evolution, microbial population and fungal biomass in the soils of Jhum, terrace and valley agricultural systems.

It is seen that the earthworm casts contain more organic carbon, total nitrogen and available phosphorus than the parent soil from which the soil is derived. The above results are in conformation with the reports of Wasawo and Visser (1959) and De Vleeschauwer and Lal 1981).

Earthworm population:

Earthworm population was higher in soils of low altitude than that of high altitude, this may be due to the more favourable conditions of the soil at low altitude. Soil at low altitude had a higher nutrient content than soil at high altitude. Soil at low altitude also had a favourable temperature and moisture content for the growth of the earthworm populations. Variation in the earthworm population observed at both the study sites could be attributed to the earthworm species, soil type and altitude (Guild, 1952a and Murchie, 1958a). Reddy and Pasha (1993) suggested that seasonal population structure is significantly influenced by the seasonal patterns in rainfall, soil temperature, p^H, phosphorus, organic carbon, nitrogen and potassium. They further suggested that the physical factors of the soil were collectively more effective in causing the seasonal variation in their population size than the chemical factors. Mishra and Ramakrishnan (1988) reported a monthly fluctuation in the population of earthworms and attributed this fluctuation to be related to soil temperature, moisture and litter fall pattern. Guild (1951) suggested that earthworm activity was limited to certain seasons. Moisture and temperature are regarded as important factors affecting earthworms (Evans and Guild 1947c; Gerard, 1967; Edwards and Lofty, 1977; Dash and Senapati, 1980; Sahu and Senapati, 1986; Reddy, 1987 and Bhaduria and Ramakrishnan, 1989). The findings are in contrast to that in Pine forests as reported by Dkhar (2000) where the earthworm population was higher at high altitude than at low altitude. Maximum earthworm population in the month of August at both the study sites and at both the cropping seasons is in agreement with the reports of Lavelle and Fragoso (1992) who reported that peak activity was observed during hot wet season in humid tropics when availability of moisture and temperature is more. Mishra and Ramakrishnan (1988) reported a monthly fluctuation in the population of earthworms and attributed this fluctuation to be related to soil temperature, moisture and litter fall pattern.

Population size was significantly correlated with soil moisture, temperature and organic carbon is in agreement with the reports of Bhadauria and Ramakrishnan (1989).

Fungal population in the soil and the casts of the two maize fields and the gut of the earthworms *Amynthas gracilis* (Kinberg):

Higher fungal population at low altitude than at high altitude is in concurrence with the reports of Dkhar and Mishra (1987, 1992). Fungal population was observed to be higher in the casts than in the soil of low altitude during the first cropping season is in agreement with the reports of Dash *et. al.* (1979); Mulongoy and Bedoret, (1989) and Tiwari and Mishra, (1993) who reported higher fungal population in the casts than the surrounding soil.

Fungal population was however observed to be higher in the soil than in the casts at high altitude in the first cropping season, as well as in the second cropping season at both the study sites. Low fungal populations in the casts than that of the soil is due to the lower moisture content of the casts than that of the soil in both the fields. The fungal population is more related to moisture content and organic carbon is in agreement with the reports of Behera *et. al.* (1991) and Tiwari and Sharma (1998). Fungal population is more related to soil moisture content than any other environmental factors (Tiwari *et. al.* 1987, 1989 and 1991). Higher fungal population in the soil in the month of May and October at high altitude in the first and second cropping season respectively and higher fungal population in the soil at low altitude in the month of May and September in the first and second cropping season respectively may be due to the prevailing climatic conditions and availability of substrate which are added to the soil after harvest which favour the growth of the microbes, availability of substrates during these months appear to favour the growth and development of the soil microbes (Wright and Bohlen, 1961; and Christensen and Whittingham, 1965). Waksman, 1927 considered organic matter, soil p^H, moisture, temperature, aeration and nature of the crop grown to be responsible for the distribution and abundance of microbes in soil. Higher fungal populations in the casts in the month of May at high altitude in both the second cropping seasons and at low altitude in the month of July in the first cropping season and in the months of July and September in the second cropping season maybe due to the favourable temperature and moisture in these months which favour the growth of the microorganisms. Went (1963) reported little or no difference between microfloral population of earthworm casts and soil. Higher fungal population in the gut of the earthworms collected from low altitude than from high altitude is due to the favourable climatic conditions and the availability of nutrients in the soil for the growth of the microorganisms and also due to the activity of the different species of earthworms associated with the respective fields. Ghilarov (1963) reported that increase in the number of microorganisms in the earthworm gut and casts were twice than that observed in the surrounding soil. The fungal population was highest in the hindgut, lower in the midgut and the least in the foregut; this trend maybe attributed to the stimulation of fungal species during passage through gut. This is in agreement with the works of Kritufek *et al.*, (1992) who reported that the number of fungi increased during passage through the gut of *Lumbricus rubellus*. The increase in the fungal population from the foregut to the midgut and to the hindgut maybe attributed to the stimulation of the fungal species during passage through the gut which is contrary to the report of Dkhar and Mishra (1991) who reported maximum fungal population in the foregut and minimum in the hindgut.

Almost similar fungal species were isolated throughout the study period in both the fields and in both the cropping seasons but a few were restricted to each study site. Qualitatively and quantitatively there was not much difference in the fungal species of the soil, gut content and casts of earthworms. Edwards and Fletcher (1988) reported that a wide range of microorganisms including bacteria, algae, protozoa, actinomycetes, fungi and even nematodes are found commonly throughout the length of the earthworm gut. There was an increase in the fungal species from soil to gut content and a decrease in the fungal species then followed from gut content to casts. Fungal species followed a trend soil <gut content>casts. Similar fungal composition may be due to the similarity in the type of crops grown. Slight variation in the fungal flora could be due to the corresponding variation in the environmental factors *viz.* temperature, soil p^H, moisture, organic carbon (Mishra, 1966; Mishra and Kanaujia, 1972 and Dkhar and Mishra, 1986). Fungal population is more related to soil moisture than any other environmental factors. Higher fungal population and species richness obtained during the summer season may be attributed to favourable temperature and moisture conditions (Kilbertus *et. al.* 1979 and Tiwari *et. al.* 1992).

A decrease in the number of fungal species observed from soil to hindgut to casts maybe due to the fact that probably some of the fungal species were either killed during passage or fungal mycelia and spores got digested as they passes through the gut (Dash *et al.* 1979). Moody *et. al.* (1996) found that the effect of passage through the earthworm gut on the viability of spores of saprophytic fungi was found to vary depending upon the fungal and earthworm species. They further reported that *Trichoderma* sp. and *Mucor hiemalis* significantly increase in the spore germination after gut transit. Went (1963) reported that the microfloral population of casts soil is larger than that of the surrounding soil. However, some of the microorganisms that are taken in with the soil are killed during their progress through the earthworm gut. Some of the fungal species were present throughout the gut canal as well as in the soil and casts, this may be due to the fact that various fungal spores have thick-walled or wrinkled coats (Dash *et. al.* 1979) or are resistant to breakdown by intestinal enzymes of the earthworms (Strignova et. *al.* 1989) thus leading to their survival during passage through the alimentary canal (Harinikumar *et. al.* 1991; Redell and Spain, 1991 and Harinikumar and Bhagyaraj, 1994). The survival of the fungal spores and mycelia such as of *Aspergillus* and *Penicillium* maybe attributed to their antibiotic producing capacity and are not readily killed but excreted as casts (Alexopoulos, 1973; Ravasz *et. al.* 1986; Kristufek et. *al.* 1992 and Reddy and Grisham, 1998). Increase in the fungal population in the gut than that of soil and casts may also be due to large amount of mucus that the earthworms secrete into their gut which may be assimilated by the microbial community in the gut (Barois and Lavelle, 1986 and Sheu, 1991). The reduction of the number of species from the different region of the gut passage occurs probably due to the digestion of fungal spores (Dash *et. al.* 1979). The variations in the mycoflora in the different regions of the gut suggests that some of the fungi which are in dormancy gets broken down while passing through the gut and multiplied in the gut and casts (Dash *et. al.* 1979; Bhattacharya and Chakrabarty, 1986, Ghosh *et. al.* 1989 and Reddy and Grisham, 1998). Tiwari *et. al.* (1990) suggested that suggested that there existed a gradient with regard to the digestive capability of different regions of the gut of earthworms for utilisation of microfungi as food. Comparative richness of mycoflora in the gut than in the casts may also be due to the dehydrated condition of the casts.

Dispersal of fungi by earthworms and the fungal population in the burrow soil and the surrounding soil:

High p^H in the burrow soil than in the surrounding soil is due to the release of urine mainly in the form of ammonia and urea onto the burrow wall and the production of epidermal mucus which is rich in mucopolysaccharides and proteins that can bind soil particles together into the burrow making it smooth and compact and at the same time altering the p^H of the soil.

Percentage moisture content of the burrow soil is higher than the surrounding soil this may be due to the production of mucus by the body wall of the earthworm onto the burrow soil (Edwards, *et al.* (1995), and may also be attributed to the opening up of the soil for better infiltration of water (Lee, 1985). Roth and Joschko (1991) suggested that the larger soil burrowing earthworms create biopores, macropores in the soil that allow for downward drainage of water and improved aeration and also reduce runoff of water. Daniel and Anderson (1992) reported that earthworm activity is accompanied by increased number of water stable aggregates: mineral soil particles clumped into rather resistant, larger structures and altered microbial biomass.

Similar fungal species were isolated throughout the study period, but a few species were restricted to each study site. Slight variation in the fungal flora could be due to the corresponding variation in the p^H and moisture content (Dkhar and Mishra, 1986 and Ranee and Dkhar, 1998). Higher fungal population and species richness in the burrow may be due to the presence of mucus compounds secreted by the earthworms, which may stimulate microbial activity and act as energy substrates for microorganisms (Barois and Lavelle,1986; Scheu, 1991 and Edwards and Bohlen, 1996). Hutchinson and Kamel (1956) reported that the rate of spread of the fungi through the soil was much greater when worms were present.

Pythium intermedium, Fusarium merismoides and *Penicillium frequentans* were found to be dominant in both the soils. *Mucor racemosus, Fusarium oxysporum* and *Penicillium janthinellum* could be isolated only from the burrows, this could be attributed to the stimulation of the dominant fungi for growth due to the presence of the mucous compounds on the burrow wall (Barois and Lavelle, 1986). Presence of *Pythium* and *Fusarium* in the burrow wall as well as in the soil indicates that the earthworms as they pass through the burrow dispersed these fungi. This is in agreement with the reports of Baweja (1939) and Khambatta and Bhatt (1957). Edwards and Fletcher (1988) reported the dispersal of spores of harmful fungi such as *Pythium* and *Fusarium* through the soil. Brown (1995) suggested that by feeding, burrowing and casting activity earthworms influenced the dispersal of microorganisms throughout the soil. Toyota and Kimura (1994) found that the earthworm *Pheretima* sp. dispersed the soil borne plant pathogen *Fusarium oxysporum* in the topsoil but decreased the total propagules of this pathogen. Stephens *et. al.* (1994a,b) reported that *A. trapezoides* enhanced the rate of dispersal of *Rhizoctonia meliloti* as well as the levels of root nodulation in infected alfalfa plants. Hoffman and Purdy (1964) reported that teleospores produced by *Telletia controversa*, a pathogen causing dwarf bunt could pass through the earthworm gut without harm.

Earthworms and growth of maize plants:

Slightly more growth in length of the maize plants observed in treated pots than plants grown in untreated pots may be due to the influence of earthworms on maize plants. These influences may be due to the production of some plant growth promoting substances (Gavilov, 1963 and Nielson, 1965) or may be due to the production of substances having hormonal effects (Springett and Syers, 1979; Graff and Makeschin, 1980; Tomati et al. 1983; Tomati et al. 1988 and Edwards and Burrows, 1988). Spain *et. al.* (1992) found that the growth of *Panicum maximum* increased significantly in the presence of earthworms.

Edwards and Lofty, (1978) reported significant improved root and shoot growth of cereals in response to the earthworm inoculations. Lavelle (1992) reported an increase in crop growth and yields significantly in ten out of 20 cropping cycles, when earthworm species were inoculated into several low-chemical input farming systems at La Mancha, Mexico and Yurimaguas, Peru.

Increase in the growth of roots in pots treated with earthworms as compared to the control pots probably resulted from roots following earthworm burrows as they penetrated the soil as they are known to grow preferentially along burrows and cracks in soil and have been shown to proliferate around the casts of some earthworm species (Springett and Syers, 1979). Or may be by some stimulation of root growth due to the enrichment in available plant nutrients of casts and the mucus compounds deposited on the burrow wall making it a favourable environment for root growth (Edwards and Lofty, 1980). They also reported significant increases in total weight of roots of barley in plots inoculated with earthworms. Parle (1963a) reported that plant nutrients occur in higher concentrations in fresh earthworm casts and around the lining of the burrows than in the bulk soil. Tomati *et. al.* 1988 reported that earthworms can increase the total uptake of nutrients by plants by increasing the amounts of available nutrients in soil, and by secreting compounds in their casts that act like plant hormones and stimulate plant growth. There were no significant differences in the growth of the stems and the leaves. James and Seastedt (1986) reported a positive effect of earthworms on root growth of big bluestem. Zaller and Arnone III, (1999) reported that earthworm activity had no effect on the aboveground biomass production of the plant community or of any plant functional type. Hopp and Slater (1948,1949) reported that earthworms increased yields of millet, lima beans, soybeans and hay and concluded that adding live worms increased more yields than adding dead ones.

Decrease in earthworm numbers may be due to death, or on account of their running away from the pots have shown to affect the growth of the roots of maize plants at the end of the experimental period. Increase in weight of the earthworms from the start of the experiment to near the end of the experiment may be attributed to the exudates secreted by the plants, which favoured for the growth of the earthworms. Decrease in the weight of the earthworms at the end of the experiment may be due to senescence of the earthworm introduced into the pots.

Decomposition of maize by earthworms:

p^H of the soil and the casts :

Not much difference was recorded between the p^H of the control soils and the treated soils. A slight increase in the p^H of the casts in pots treated with roots (ER) litter was observed but in pots treated with leaf (EL) litter and with stem (ES) litter respectively there was a decrease in the p^H of the casts as compared to that of the soil. Increase in the p^H of the casts in ER may be due to more activity of the earthworm and the more palatability of the root litter compared to the stem and leaf litter. Mulongoy and Bedoret, (1989) also reported higher p^H values in casts than the surrounding soil.

Moisture content of the soil and the casts:

Increase in the moisture content of the treated soil may be due to the release of urine and mucous into the soil by the earthworms. Increase in the moisture content of the casts may also be due to the release of some urine into the gut of the earthworms and also due to the secretion of mucus by the earthworms which gets mixed intimately with the soil as it passes through the gut, and later excreted in the form of casts with higher moisture content as compared to the soil.

Differences in the moisture content of the casts in the field condition may be largely due to the age of the casts, where casts of undeterminably age was collected from the fields, whereas, fresh casts were collected from the pots which makes it less dehydrated than the casts collected from the field condition.

Organic carbon in the soil and the casts during decomposition:

Highest percentage of organic carbon was observed in the casts as compared to the soil in the presence of earthworms in all the three types of litter. The percentage of organic carbon was observed to be higher in soil treated with earthworms than the untreated soil in all the three types of litter. Higher percentage of organic carbon in the casts may be due to the enrichment of organic carbon through the ingestion of plant and microbial residues by earthworms and may be due to the production of large quantities of mucopolysaccharides during digestion (Lee, 1985). Ferriere and Bouche (1985) suggested that a considerable portion of the entire carbon content turnover was due to mucus secretion secreted by the earthworm.

Mulongoy and Bedoret (1989) reported higher organic carbon in the casts than in the surrounding soil. Higher percentage of organic carbon in soil treated with earthworms than the control soil may be due to the increase in the mineralization of C from the pool of particulate organic matter in the soil (Parmelee *et al.,* 1990). Highest percentage of organic carbon in the casts collected from ER maybe due to more activity of the earthworms when root litter was added followed by lesser percentage of organic carbon in the casts collected from EL and the least percentage of organic carbon was observed in the casts collected from ES. This shows that the earthworm activity was highest when root litter was added followed by the leaf litter and the least by the stem litter.

Carbon di-oxide evolution:

Higher carbon di-oxide evolution was observed in treated pots than the untreated pots this may be due to the effects of earthworms on soil respiration (Haimi and Einbork, 1992; Bohlen and Edwards, 1995; Wessells *et. al.* 1997; and Schindler Wessels *et al.* 1997). Lee (1985) reported that earthworm respiration is often the major portion of faunal respiration, it usually is 5–6% of the total energy flow in the terrestrial ecosystems. Hendrix *et. al.* (1987) reported that earthworms were responsible for about 30% of the total heterotrophic soil respiration, Not much difference was noted in the carbon di-oxide evolution between the treated pots where root and stem litter was incorporated. Lower carbon di-oxide evolution was observed in treated pots where leaf litter was incorporated. Haimi and Huhta (1990) observed that earthworm *L. rubellus* respiration accounted for 21-32% of the increase in CO_2 evolution. Haimi and Boucelham (1991) in a laboratory study reported that *L. rubellus* had a positive effect on CO_2 evolution during the period when the worms were present.

Coleman and Crossley (1996) reported that earthworm respiration accounted for 71g-carbon/m^2/ season. Bohlen and Edwards (1995) reported that earthworms increased soil respiration rates during the first 15 days of incubation by 1.24 to 2.42 folds. Ruz-Jerez *et. al.* (1992) observed that earthworms increased CO_2 evolution after the addition of clover and grass by 1.35 and 1.25 fold.

Total nitrogen in the soil and in the casts during decomposition:

Highest total nitrogen observed in casts collected from ER, ES and EL may be due to the direct contribution of urine and mucus secretion by the wall of the gut into the gut and intimately mixing of the secretions with the gut contents have led to higher concentrations of nitrogen in the casts. Aldag and Graff (1975) and Mulongoy and Bedoret (1989) reported higher values of total nitrogen in casts than in the parent soil. Increase in the total nitrogen in soil at the end of the experimental period preceded by lower total nitrogen maybe due to the contribution of nitrogen into the pool through the death of the earthworms in the treated soil (Christensen, 1988 and Lee1985). Less total nitrogen was observed in the treated soil (EL) than the untreated soil may be attributed to low activity of the earthworms in the pots where leaf litter was added and may have lead to the decrease in the total nitrogen, this could also be due to the loss of soluble nitrogen through leaching.

Available Phosphorus in the soil and in the casts during decomposition:

Higher values in available phosphorus in the casts than the treated soil may be due to the increase in the p^H of the casts (Barley, 1961) or probably due to the enhanced microbial activity in the casts. Increase in the available phosphorus in the soil treated with earthworms than the control soil may be due to the contribution of small quantities of phosphorus in the form of liquid wastes excreted by earthworms (Bahl, 1947). Fardeau (1981) reported higher values of phosphorus in casts of Pontoscolex *corethrurus* than in non-ingested control soil.

Percentage weight remaining:

Higher weight loss was observed in pots treated with earthworms than the untreated pots in all the three types of litter. Higher weight loss in the presence of earthworms may be due to the capability of the earthworms to consume the leaves, stems and root materials. Cortez and Bouche (1998) reported that anecic earthworms make litters more palatable by a particular type of behaviour. They reported that during the first stage of decomposition the litters were ploughed in by earthworm casts involving both an increase of microbial activity and preliminary microbial litter decomposition. Edwards and Bohlen 1996) reported that earthworms can consume large amounts of litter, and the amount they ingest seem to depend more on the total amount of suitable organic matter available than on other factors. Cortez *et. al.* (1989) reported relatively large increase in decomposition of plant litter on the soil by addition of earthworms. Curry and Byrne (1992) using wheat straw as litter found that the decomposition rate of straw was increased by 26-47% as compared to the straw from which earthworms were excluded. There was a gradual decrease in the weight of litter as the experiment proceeds. Decrease in the amount of litter followed a trend CR>CL>CS in the untreated pots and in the treated pots the decrease followed a trend EL>ER>ES. The highest weight loss of litter in the treated pots where leaf litter was added, followed by the root litter and the least by the stem litter may be due to the ability of the earthworms to consume the softer parts of the leaves, veins and ribs (Edwards and Heath, 1963) or may be due to the more palatable nature of the leaves as compared to the roots and the stems. Dickschen and Tropp (1987) reported that depending on temperature and litter quality, the earthworm *Lumbricus rubellus* assimilates 30-70% of leaf litter. On the other hand, Crossley *et al.* (1971) using cesium tracer reported much lower assimilation efficiencies (12-29%) for a number of earthworms. The difference in the decomposition of the maize residues may be due to the effect of quality as defined by their chemical composition *viz.* C-to-N ratio, lignin and polyphenol contents. Moisture and temperature have fundamental effects on plant residue decomposition as they control decomposer activity (Tian *et al.* 1993).

Percentage cellulose, hemicellulose and lignin in litter during decomposition:

Higher percentage weight loss of cellulose, hemicellulose and lignin in the treated pots than the untreated pots in all the three types of litter may be due to the action of cellulase enzyme produced in the earthworm gut or may also be due to the enhanced activity of the microorganisms after passage through the gut. Parle (1963a) reported that most of the cellulase and chitinase enzymes that occur in the alimentary canals of earthworms were secreted by the earthworms and not by the symbiotic microorganisms, as they are in some arthropods. Zhang *et al.* (1993) reported that earthworms have some enzymes capable of decomposing chitin and oligosaccharides, he also suggested that the gut environment itself may promote activities of cellulase and mannase for the tropical earthworm, *Pontoscolex corethrurus*. Scheu (1993a,b) reported that the during the 253 day laboratory incubation, earthworms of the species *Octolasion lacteum* increased the mineralization of labelled lignin for the first ten weeks, but decreased mineralization later in the experiment in four of the five lime stone soils. He also suggested that earthworms increase the mineralization of ^{14}C-labelled lignin, although the extent of the increase depends upon the species of earthworm, length of the incubation period and types of organic matter present.

Total amino acid and sugar:

Decrease in the total amino acid and sugar was more in the treated pots than the untreated pots. At the initial stage, the decrease in the amino acid was rapid followed by a slower rate in all the three types of litter is in agreement with the reports of Mishra and Tiwari (1984) who reported that sugars and amino acid concentration declined very fast during the initial periods of decomposition and became stabilised in the later periods. The decrease in the amino acid was more in stem litter followed by leaf litter and the least in the root litter. Difference in the weight loss of amino acid in the decomposing maize litters may be due to variation in the litter types. A sharp decline in the amount of sugar was observed in the initial stage of the experiment, followed by a slow decline after 20 days interval in both the untreated and in the treated pots is in conformity with the reports of Mishra and Tiwari (1984) who reported that sugars and amino acid concentration declined very fast during the initial periods of decomposition and became stabilised in the later periods. Variation in the weight loss of sugar in the untreated pots and in the treated pots may be due to the difference in the litter types. Loss in weight of total amino acid and sugar may be more related to microbial activity than to the activity of the earthworms although they may contribute to the weight loss by transforming the litter and enhancing the activity of the microbes as they pass through the gut and thus breakdown of the undigested material. Disappearance of sugar and amino acid was faster than cellulose, hemicellulose and the least by lignin in all the three types of litter both in the treated and untreated pots, this is in concurrence with the reports of Sokolov and Karpova (1965) who observed that during decomposition of starch, hemicellulose and amino acids in organic residues decomposed at a faster rate while lignin was the last to decompose. Mishra and Tiwari (1984) reported that sugars and amino acid concentration declined very fast during the initial periods of decomposition and became stabilised in the later periods.

Dkhar and Mishra (1992) reported that the amount of cellulose, hemicellulose and lignin contents of the decomposing maize litters varied with different litter types. They observed maximum amount of lignin in the root followed by the stem and minimum in the leaf. They also observed significant positive correlation between percentage weight remaining and various chemical compounds associated with different types of litter. Berg and Staff (1986) suggested that saprophytic fungi decompose soluble substances and then non-lignified carbohydrates (cellulose and hemicellulose) in the first phase and in the late decomposition phase, primarily lignin and lignified cellulose remained.

SUMMARY

Maize being one of the major staple food crop grown throughout the state, was selected for the present study. And also keeping in view of the type of agricultural practices and altitude, two experimental sites (i) Terrace land agriculture at 5th Mile, Upper Shillong, situated at an altitude of 1725 m and lying between $25^{0}.34''$ N latitude and $91^{0}.52''$ E longitude and (ii) Permanent agriculture at Mawlai, situated at an altitude of 1400 m and lying between $25^{0}.34''$ N latitude and $91^{0}.52''$ E longitude, were selected for the present study.

Samplings of soil, the earthworms and their casts were carried out at the two study sites at monthly intervals for a period of 7 months, starting from the sowing period till harvest, *i.e.*, April to October, being the cropping season of maize. The following investigations were carried out for 2 crop cycles. The surface soil samples (0 -10 cm) were collected randomly from 5 places at each study site. Earthworm casts were collected randomly from the surface of the soil and thoroughly mixed to make a composite sample. Various physico-chemical characteristics such as p^H, moisture content, organic carbon, nitrogen and phosphorus of the samples were analysed. Walkley and Black's (1934) rapid titration method was followed for the determination of organic carbon, Kjeldahl's method was followed for the determination of nitrogen (Jackson, 1973), Molybdenum blue method (Allen, 1974) was followed for the determination of available phosphorus. The carbon di-oxide evolution was measured by absorption and titration method (MacFadyhen, 1970)

Soil temperature, moisture content, organic carbon, nitrogen and phosphorus of the soil were higher at low altitude than at high altitude in both the cropping seasons. A difference in the soil temperature of the two fields during the two cropping seasons corresponds to the difference in the atmospheric temperature during the study period. In the first cropping season, the moisture content of the soil was lower than that of the casts, whereas, in the second cropping season the moisture content of the soil was found to be higher than that of the casts.

The p^H of the soil and the casts was found to be acidic in both the fields with higher values in the casts than the soil. Higher organic carbon observed in the casts than in the soil in both the cropping seasons is due to the enrichment of organic carbon in the casts through the ingestion of plant and microbial residues by the earthworms and the production of large quantities of mucopolysaccharides by the earthworms during digestion or maybe due to the selection of soil fractions enriched in organic compounds by the earthworms.

Total nitrogen was also observed to be higher in the casts than in the soil, in both the cropping seasons in both the fields. Higher concentration in the total nitrogen in the casts than in the soil may be due to the excretion of urine in the gut in the form of ammonia and urea and also due to the presence of plant tissues in the casts which have passed through the gut with little chemical change. Available phosphorus was also observed to be higher in the casts than in the soil, in both the cropping seasons in both the fields.

Carbon di-oxide evolution in the soil was observed to be higher at low altitude than at high altitude in both the cropping seasons. The maximum carbon di-oxide evolution was recorded in the month of July at both the sites in the first cropping season, and in the month of June and July at high and low altitude respectively in the second cropping season. The physico-chemical characteristics of the soil were found to be higher at low altitude than at high altitude. Whereas, the physico-chemical characteristics of the casts was higher than that of the soil at both the altitudes.

The earthworm population was estimated by handpicking method (Edwards and Lofty, 1972) following randomnized-sampling procedure considering 50 sq cm cube. A cube of 50 x 50 x 50 cm was dug up. The earthworm population was observed to be higher in the soil at low altitude than at high altitude (fig.). The earthworms *Amynthas gracilis* (Kinberg) and *Metaphire houletti* (Perrier) were collected from the field at high altitude, whereas, *Amynthas gracilis* (Kinberg) and *Amynthas corticis* (Kinberg) were collected from the field at low altitude.

The soil plate method (Warcup, 1950) using Rose Bengal agar medium (Martin, 1950) was followed for the isolation of fungi. The fungal population was observed to be higher in the soil of low altitude than of soil from high altitude. Fungal population was observed to be higher in the casts than in the soil of low altitude during the first cropping season, whereas, it was observed to be higher in the soil than in the casts at high altitude in the first cropping season and as well as in the second cropping at both low and high altitudes. Altogether, 26 fungal species could be isolated from the soil at low altitude, 28 fungal species could be isolated from soil at high altitude, 24 fungal species could be isolated from the casts of the earthworms collected from low altitude and 26 fungal species could be isolated from the casts of the earthworms from high altitude. The fungal population in the foregut, midgut and hindgut was observed to be higher in earthworms collected from low altitude than from high altitude. The fungal population followed a trend of hindgut> midgut>foregut.

A total of 25 fungal species could be isolated from foregut, 30 fungal species could be isolated from midgut and 23 fungal species could be isolated from hindgut of the earthworms from low altitude. Whereas, 28 fungal species could be isolated from foregut, 27 fungal species could be isolated from midgut of the earthworms and 22 fungal species could be isolated from hindgut of the earthworms from high altitude.

A few species were however restricted to each study site. *Mucor circinelloides, M. hemalis, Aspergillus flavus, Fusarium proliferatum, Humicola grisea, Penicillium canescens, P. janthinellum, P. polysporum, P. restrictum, P. waksmanii, Pseudoeurotium* sp., *Verticillium albo-atrum,* could be isolated only from the soil at high altitude.

Absidia cylindrospora Mortierella minutissima, M. parvispora, R. stolonifer, Cladosporium cladosporoides, F. poae, F. redolens, F. semitectum, P. frequentans, Trichoderma pseudokoningii, could be isolated only from the soil at low altitude.

Rhizopus storlonifer, Pythium irregulare, Aspergillus niger, Eupenicillium brefeldianum, P. javanicum, P. jensenii, P. waksmanii, Rhizoctonia sp. and T. *pseudokoningii* could be isolated only from the gut contents of earthworms from high altitude.

M. candelabrum, M. elongata, Aspergillus fumigatus, A. wentii, C. elegans, D. stemonitis, F. javanicum, F. oxysporum, F. poae, F. sporotrichioides, Paecilomyces sp. and *P. proliferatum* could be isolated only from the gut contents of earthworms from low altitude.

E. brefeldianum, F. poae, P. frequentans, H. grisea, T. harzianum, could be isolated only from the casts of earthworms from high altitude.

M. minutissima, M. parvispora and D. stemonitis could be isolated only from the casts of earthworms from low altitude.

Most of the fungal species isolated were found to be common in soil, casts and the earthworm gut.

p^H and percentage moisture content of the burrow soil were found to be higher than the surrounding soil.

The fungal population was slightly higher in the burrow soil than in the surrounding soil. Altogether, 14 fungal species were isolated both from the burrow soil and the surrounding soil. Qualitatively, there was not much difference in the fungal flora isolated from the burrow soil and the surrounding soil. Most of the species were found to be common in both the soil types. However, *M. racemosus, F. oxysporum* and *P. janthinellum* could be isolated only from the surrounding soil, whereas, *M. circinelloides*, white sterile mycelia and yellow sterile mycelia could be isolated only from the burrow soil.

Not much difference was observed on the growth of stems and leaves of maize between control plants and treated plants. A marked difference was, however, observed in the growth of roots between the control plants and the treated plants. More root growth was observed when earthworms were added to the treated plants. With the increase in the number of days there was a decrease in the number of earthworms, which affected the growth of maize roots. With the increase in the number of days an increase in the growth of maize was observed. Plants treated with earthworms showed more growth in length as compared to the untreated plants. When stems, roots and leaves were taken as a separate identity, an increase in the length of roots, stems and leaves was observed to be more in treated plants than that of the untreated plants. An increase in the length was observed with increase in the number of days. Gain in weight was observed as sampling period increased from 10-40 days followed by a decrease in weight towards the end of the sampling period.

An altered method of Mackay and Kladivko (1985) was followed for the study of the effect of earthworm on the decomposition of maize litter. The physico-chemical characteristics (p^H, moisture content, organic carbon, total nitrogen, available phosphorus and the CO_2 evolution, of the soil samples were determined. Slight increase in the p^H was observed in the soil in the presence of earthworms. Casts p^H was also slightly higher than the soil in the untreated pots. An increase in the percentage moisture content of treated soil than the untreated soil was observed throughout the study period. Higher percentage moisture content was recorded in the casts than that in the soil. Throughout the study period the percentage organic carbon was found to be maximum after 80 days in all the cases except in the casts collected from pots treated with root litter and the earthworms (ER) which showed its maximum percentage after 60 days. The percentage organic carbon in soil collected from the treated pots was higher than the untreated pots and the percentage organic carbon in casts was higher than that of the soil. The carbon di-oxide evolution was higher in the presence of earthworms. In pots where root litter was added, higher total nitrogen was recorded in the treated soil and the casts than the untreated soil. Higher total nitrogen was observed in the treated soil where root litter was added than the other treated soils. Peak period was observed after 60 days interval in soil from ER followed by a slight decrease after 80 days interval. Thereafter, an increase in the total nitrogen at the end of the experiment was observed. Total nitrogen in casts in ER also followed the same trend as that of the treated soil. In CR the total nitrogen was minimum at the initial stage whereas a gradual increase in the total nitrogen was observed in the latter stage. Peak periods were observed at 60 and 100 days interval. However, maximum total nitrogen was observed in the casts than that of the treated soil. In treated pots having stem as litter (ES), the maximum total nitrogen was observed at the end of the experiment i.e., after 100 days. Similar results were observed in the casts and the untreated soil. Minimum total nitrogen was recorded in untreated pots, with a higher value in the treated pots and the highest values in the casts. In treated pots where leaf litter was added (EL), the total nitrogen was higher in the treated pots than the untreated pots. The highest total nitrogen was observed at the end of the experiment i.e., after 100 days in treated soil and the casts. Whereas, the total nitrogen in untreated soil was maximum after 80 days interval. Overall percentage of total nitrogen was observed to be fluctuating throughout the study period. An increase in the total nitrogen was observed towards the end of the experiment in all the three types of treated pots. Whereas, a decrease in total nitrogen was observed in the untreated pots where stem and leaf litter were incorporated separately. Not much difference was observed in the available phosphorus in the treated soil and the untreated soil in all the three types of litter but a marked difference was observed in the available phosphorus in the casts in all the three types of treated soil. Highest available phosphorus was observed in the casts. Peak period of available phosphorus in the casts collected from ER was observed after 60 days interval followed by a slight decline after 80 days interval. In the casts collected from ES the available phosphorus showed a peak period after 40 days interval followed by a decline towards the end of the study period. In the case of the casts collected from ER the available phosphorus showed a steady increase from the beginning of the sampling period with its peak period after 80 days interval followed by a decrease after 100 days interval.

A gradual decrease in the weight of maize litter was observed in both the treated and the untreated pots in all the three types of litter. However, the percentage weight remaining was more in the untreated pots than the treated pots in all the three types of litter. Decrease in the amount of litter was the maximum in the pots where root litter was added in the untreated pots, whereas, in the treated pots the maximum decrease of litter was observed in the pots treated with leaf litter. Weight loss of litter in the untreated pots followed a trend CR>CL>CS and in the treated pots weight loss followed a trend EL>ER>ES. Decrease in the amount of litter in the treated pots ER and ES was gradual throughout the study period except at the end of the study period where the loss of weight was lesser than after 80 days interval. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease in the percentage cellulose, hemicellulose and lignin was observed in both the untreated and treated pots. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease in the percentage cellulose, hemicellulose and lignin was observed in both the untreated and treated pots. The percentage weight loss of cellulose, hemicellulose and lignin was more in the treated pots than the untreated pots. Gradual decrease was recorded in the percentage cellulose, hemicellulose and lignin was in both the untreated and treated pots. The percentage weight loss of cellulose followed a trend CR>CS=CL in the untreated pots, whereas, it followed a trend EL>ES>ER in the treated pots. The percentage weight loss of hemicellulose followed a trend CR>CS>CL in the untreated pots, whereas, it followed a trend ER >ES> EL in the treated pots. And the percentage weight loss of lignin followed a trend CL>CR>CS in the untreated pots, whereas, it followed a trend EL>ER>ES in the treated pots. In the untreated pots having root litter (CR), the percentage weight loss of cellulose was the highest, followed by lignin and the least by hemicellulose. Whereas, in the treated pots (ER) the percentage weight loss of hemicellulose was the highest, followed by cellulose and the least by lignin. In the untreated pots having stem litter (CS), the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. Whereas, in the treated pots (ES) the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. In the untreated pots having leaf litter (CL), the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. In the treated pots (EL) the percentage weight loss of cellulose was the highest, followed by hemicellulose and the least by lignin. Decrease in the amino acid was more in the treated pots than the untreated pots. At the initial stage the decrease in the amino acid was rapid followed by a slower rate in all the three types of litter. The decrease in the amino acid was more in stem litter followed by leaf litter and the least in the root litter. Decrease in the amount of sugar was more in the treated pots than the untreated pots. A sharp decline in the amount of sugar was observed in the initial stage of the experiment followed by a slow decline after 20 days interval in both the untreated and in the treated pots where stem and root litter were added. However, a gradual decline in the amount of sugar was observed where leaf litter was added. The weight loss of sugar in the untreated pots was highest in pots incorporated with root litter, followed by leaf litter and the least in pots having stem litter. Whereas, in the treated pots there was not much difference in the weight loss of sugar in the pots having root or stem litter. But the weight loss of sugar in the pots having leaf litter was lesser than in the pots having either stem or root litter.

From the present study it can be concluded that the presence of earthworms under suitable conditions improves the physico-chemical characteristics of the soil by producing mucus rich in polysaccharides thus enhancing the activity of the fungi in the decomposition of litter. Presence of earthworms during the growth of the maize plant stimulates more root growth, which may ultimately lead to more yields if long term study is carried out in field conditions. The earthworms can increase the total uptake of nutrients by plants by increasing the amounts of available nutrients in soil, and by secreting compounds in their casts that act like plant hormones and stimulate plant growth.

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