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Temporal and depthwise distribution of microorganisms, enzymes activities and soil respiration in potato field soil under different agricultural systems in north-eastern hill region of India

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Synopsis: Temporal and depthwise distribution of fungi and bacteria, enzymes (dehydrogenase, urease, phosphatase), CO_2 evolution and various physico-chemical characteristics of soil have been measured in the three soil systems for two crop cycles of potato.

Keywords: Bacteria, dehydrogenase, fungi, phosphatase, soil respiration, urease.

INTRODUCTION

Soil is a complex system wherein chemical, physical and biochemical factors are held in a dynamic equilibrium. Population dynamics of soil microorganisms is largely regulated by soil characteristics. In agricultural soils, ploughing, tillage, application of fertilizers and biocides and type of cultivation affect the microorganisms (LARSON *et al.*, 1981). Soil microflora exert considerable influence on the soil fertility and plant growth. During recent years more emphasis is laid on the functional attributes of the microorganisms in the ecosystem. These are generally determined by the estimation of the rate of various biochemical processes involving microbial enzymes (OADES & JENKINSON, 1979 ; WEST *et al.*, 1986). Enzymes accumulated in soil have biological significance as they participate in the cycling of elements and thus play a very important role in the initial phase of the decomposition of

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organic residue (KISS *et al.*, 1975). Dehydrogenase, urease and phosphatase estimation provide an index of microbial activity and they also give a measure of oxidative reductive reactions, rate of urea degradation and of phosphate regeneration in the soil (SKUJINS, 1976; FRANKENBERGER, 1983; TREVORS, 1984). Soil respiration is another index of microbial activity (CHANEY *et al.*, 1978). Measurements of enzyme activity in conjunction with soil respiration and microbial number provide the most reliable index of mocrobial activity in soil (CASIDA, 1977). Soil microbial activity may be influenced by numerous factors which fluctuate to varying degrees in the same soil. Temperature, pH, moisture content, organic carbon and mineral concentration are important factors regulating the microbial activity (TREVORS, 1984; TIWARI *et al.*, 1987). A perusal of literature reveals that our knowledge on the ecology of soil microorganisms is largely based on research in forest and grassland soil (WIDDEN, 1979; CLARKE & CHRISTENSEN, 1981). Agricultural soils have received less attention (BARUAH & MISHRA, 1984; TIWARI *et al.*, 1989; INSAM *et al.*, 1989).

The purpose of this study was to assess over a two crop cycle some soil properties that affect the populations and the activity of microorganisms in three different agricultural practices.

I. – STUDY AREA, SOIL AND CLIMATE

The study was carried out at Upper Shillong (altitude 1,706-1,730 m, latitude 25°34″ N and longitude 91°56″ E) in East Khasi Hills district of Meghalaya, India. The hills of Meghalaya are made up largely of pre-cambrian rocks acutely folded and steeply dipping, with an overturned fringe of mesozoic and tertiary sediments. The rock distribution in the plateau reveals that the core of plateau is an ancient mass of gneiss much intruded by a coarse granite, sandstones, limestones and conglametrates with subordinate clays superimposed over these also occur in the Shillong plateau. The soils of study site is red sandy loam of laterite (oxisols) and acidic in nature.

The south west monsoon and north east winter winds influence the climate of area. The climate of study area can be divided into four marked seasons - (i) the monsoon season of heavy rainfall (May-September) due to south west monsoon (ii) a transitional period of low rainfall (October and November) due to retreating monsoon (iii) a winter season (December-February) with scattered low rainfall and (iv) a windy dry summer (March-April). The annual rainfall during study period was 1,570 mm. The average minimum and maximum temperature of study site was 1.0°C and 23°C respectively. Percentage relatively humidity varied between 40.0% and 92.0% (*Fig.* 1).

II. – MATERIALS AND METHODS

K. Jyoti variety of potato developed by Central Potato Research Institute, Shimla, India was grown in the month of August each year and average yield was approximately 20 $t.h^{-1}$. Soil samples were collected from potato fields under 3 different agricultural systems. In one type farmers adapt slash and burn type of shifting cultivation mostly on the hillocks (slope land). The second type is done on bench terraces, built on hill slopes. Between the hillocks some plain land are found and on these lands permanent type of cultivation is done and it is known as valley land. Sampling was done at 10 days interval for two crop cycles from 10th September, 1985 to 20th November, 1985 and 10th September, 1986 to 20th November, 1986. Soil samples were collected from three depths (0-10, 10-20, and 20-30 cm). The data in tables and on figures correspond to mean of three replicate analysis of a mixed sample collected from five random sites in each field. The soil samples were brought to the laboratory

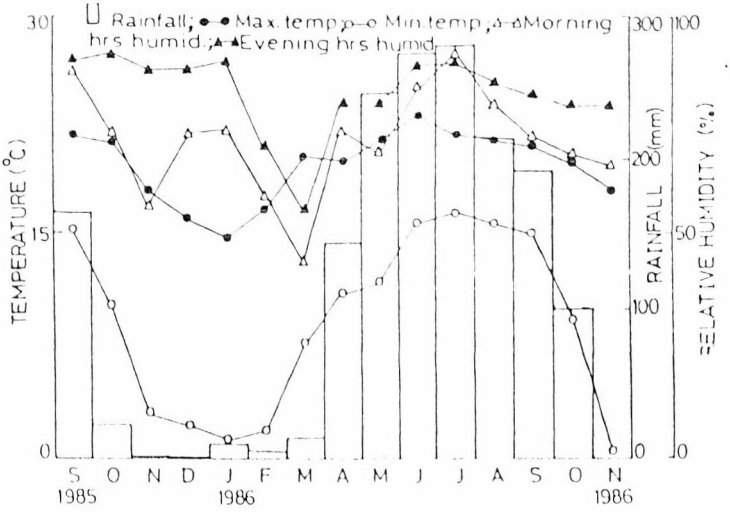


FIG. 1. – Monthly variation in rainfall, minimum temperature, maximum temperature and percentage relative humidity of the study area during the study period.

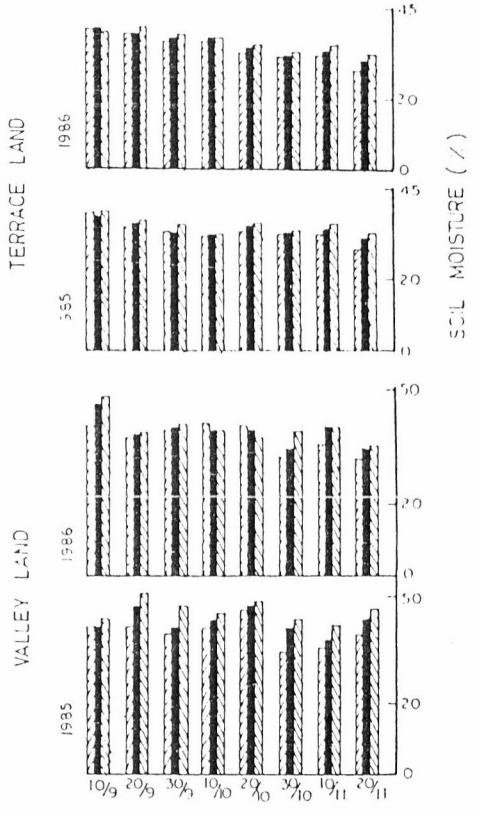
and all the estimations concerning the microbial population and activity were carried out within 24 hours after collection.

Organic carbon, total nitrogen, available phosphorus and exchangeable potassium were determined by the WALKLEY & BLACK'S (1934) method, semi-micro Kjeldahl method (ALLEN, 1974), sulphomolybdic acid method (JACKSON, 1973) and flame photometer method respectively. The pH was measured in a soil and water mixture (1 : 5) using an electrical pH meter. Moisture content was assessed by oven dry method at 105°C.

WARCUP'S (1950) soil plate method was used to assess fungal populations developing on Martin's rose bengal agar medium (JOHNSON & CURL, 1972). The inoculated agar plates were incubated at 25°C and colonies were counted after 5 days. Dilution plates were used to estimate bacterial populations on nutrient agar medium (JOHNSON & CURL, 1972). The Petriplates were incubated at 30°C, and colonies were counted after 24 hours. Dehydrogenase activity of soil was determined by 2, 3, 5 triphenyl tetrazolium chloride (T.T.C.) reduction technique as suggested by CASIDA (1977). Urease activity was estimated by the method of MCGARITY & MYERS (1967). Ammonia released as a result of urease activity was assessed by indophenol blue method. The optical density of blue coloured solution was measured at 630 nm. Phosphatase activity was measured by the method of TABATABAI & BREMNER (1969) using *p*-nitrophenyl phosphate as substrate. Soil respiration was measured by estimating release of CO_2 during a 24 hours incubation at room temperature by absorption and titration method (MACFADYEN, 1970). 1 Kg of soil was placed into glass jar and a beaker of 100 ml capacity containing 50 ml of 0.1 N KOH solution was placed inside the jar then sealed and made air tight. Suitable control jar with equal volume of sterilized sand were also used for the substraction of the atmospheric CO_2. After 24 hours incubation at room temperature the amount of CO_2 fixed by KOH solution was measured by titrimetric method using 0.1 N HCl as titrant and phenolphthlein as an indicator.

III. – RESULTS

Moisture content of soil was higher in valley soils than the fields on hillocks. Maximum amount of moisture content was recorded in valley land (50.50%) at the depth of 20-30 cm and minimum (10.10%) was in hill slope soil at 0-10 cm



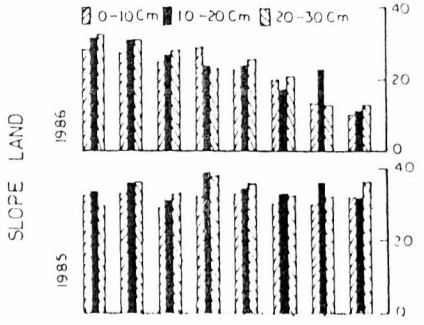


FIG. 2. — Variation in moisture content of potato field soil under different agricultural practices

depth. In valley soil pH ranged between 4.0 to 5.22, while in terrace land between 4.0 to 5.28 and in slope land from 3.64 to 5.64. No marked temporal variation in pH was observed. Organic carbon, total nitrogen and available phosphorus showed maximum in valley soil followed by terrace soil and the minimum was recorded in slope soil. Upper layer (0-10 cm) of soil contained higher percentage of carbon, nitrogen and phosphorus which decreased along soil depth. In all the three practices organic carbon was higher at the sowing and harvesting period (*Fig.* 4). In slope soil phosphorus content was nearly half of the valley soil. Higher values of nitrogen and phosphorus were obtained during the month of October and a decline was observed during the following period. Maximum potassium content was found in terrace soil followed by slope soil and valley soil. There was no marked variation in potassium among the three depths (0-10, 10-20 and 20-30 cm) in all the three systems.

Temporal and depthwise variation in the population of fungi and bacteria in different agricultural practices are given in Figure 8 and 9. The number of fungal propagules per gram of dry soil was maximum in valley soil and minimum in hill slope soil. Maximum number of bacteria per gram of dry soil was in terrace soil which was followed by the valley and hill slope soil. In depthwise studies the

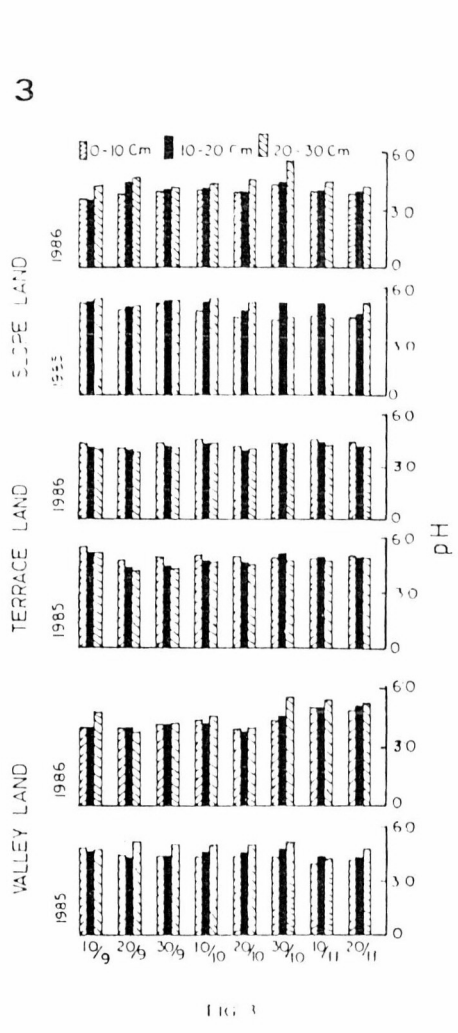


FIG. 3

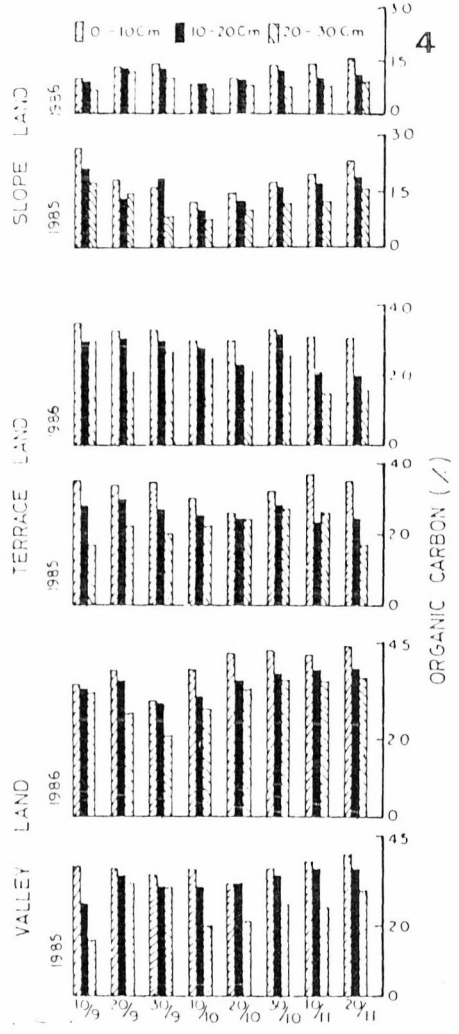


FIG. 4

FIG. 3. – Variation in pH of potato field soil under different agricultral practices.

FIG. 4. – Variation in organic carbon of potato field soil under different agricultural practices.

number of fungi and bacteria was always highest in surface soil (0-10 cm) and it decreased along depth. In all the three agricultural systems highest number of microorganisms were found in the month of October, which was followed by a sharp decline.

Enzyme activities of all three systems for two crop cycles are shown in Figure 10, 11, and 12. Enzyme activities varied in all the three systems. Maximum of enzymes activities (dehydrogenase, urease, phosphatase) were noted in valley soil which was followed by terrace and hill slope soil. In all the three agricultural

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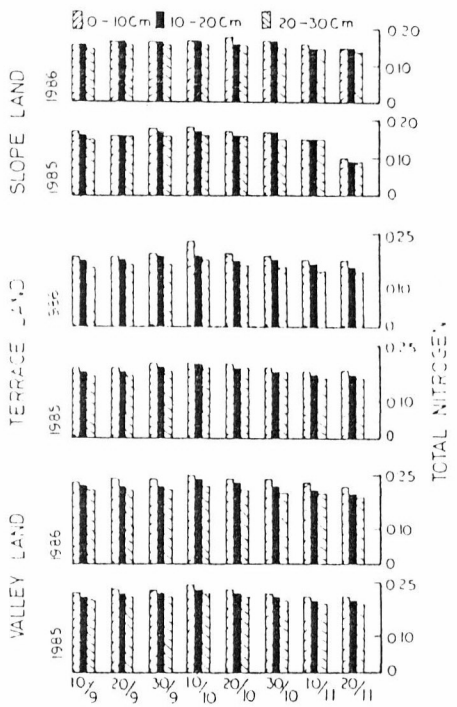

FIG 5

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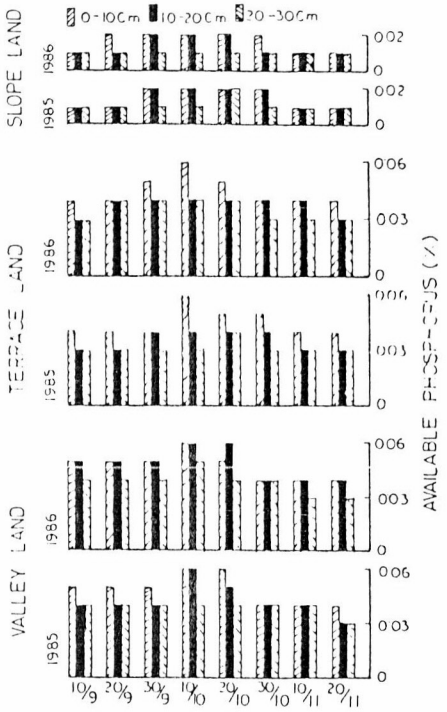


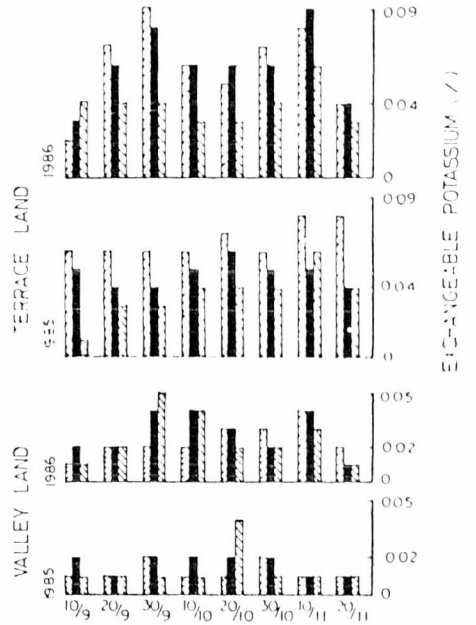
FIG. 6

FIG. 5. — Variation in total nitrogen of potato field soil under different agricultural practices.

FIG. 6. — Variation in available phosphorus of potato field soil under different agricultural practices.

practices highest activities were recorded in surface layer (0-10 cm) soil and as depth increased the activity decreased. In valley soil dehydrogenase activity ranged from 10.0 to 83.8 μg TPF g^{-1} dry soil while in hill slope soil ranged between 17.6 and 52.6 μg TPF g^{-1} dry soil. Urease activity in valley soil ranged between 26.9 and 137.8 μg NH_4^+ g^{-1} dry soil and in hill slope soil ranged from 20.8 to 94.9 μg NH_4^+ dry soil. Maximum phosphatase activity in valley soil ranged between 263.3 and 295 μg *p*-nitrophenol g^{-1} dry soil and minimum in hill slope soil ranged from 244.6 to 291.0 μg *p*-nitrophenol g^{-1} dry soil. The output of CO_2 in relation to total organic carbon in valley land ranged from 0.93 to 4.41 mg CO_2 g^{-1} soil organic C while in hill slope land it ranged between 2.40 and 9.89 mg CO_2 g^{-1} soil organic C. Except dehydrogenase activity during both years (1985-86) distribution pattern of enzyme activities and CO_2 evolution was similar in all the three agricultural systems.

To assess the relationship among enzymatic activities, microorganisms and soil properties, correlation, co-efficients were analysed (Tab. I). Dehydrogenase activity was significantly correlated with organic C ($r = 0.57^{***}$, 0.53^{***}), total nitrogen



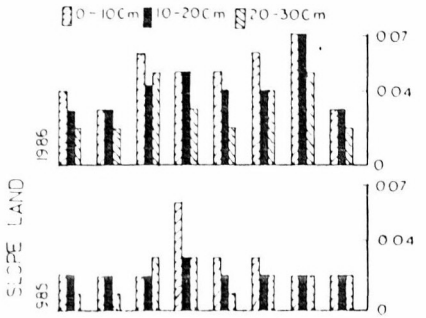


FIG. 7. — Variation in exchangeable potassium of potato field soil under different agricultural practices

($r = 0.51^{***}$, 0.30^{*}), available phosphorus ($r = 0.29^{*}$, 0.62^{***}), exchangeable potassium ($r = 0.66^{***}$, 0.56^{***}) and phosphatase activity ($r = 0.36^{*}$, 0.58^{***}) in valley and terrace soil. Urease activity was significantly correlated with total N, phosphorus and fungal population in all the three systems and with CO_2 in terrace and slope soil only. Phosphatase activity significantly correlated with organic C, total N, available phosphorus and fungal population in all the three practices, while with soil respiration in terrace and hill slope soil only. Soil respiration significantly correlated with moisture content, total nitrogen, available phosphorus, fungal population and some enzyme activities.

IV. – DISCUSSION

The three agricultural systems differ markedly with respect to soil moisture content. The slope soil generally contains less moisture mainly because of heavy run off losses allowing little percolation of water; next comes the terrace where some moisture is retained due to the terracing and bands; the valley soil contains maximum moisture due to constant seepage from the adjoining hillocks and less evapotranspiration losses. These soils experience heavy losses of nutrients and sediments through leaching and run off (Toky & Ramakrishnan, 1981; Mishra & Ramakrishnan, 1983). The labile elements and most of the sediments are lost to the streams while part of the organic carbon gets accumulated in the valley lands. These processes of nutrient loss and accumulation are partly responsible for the drop in the pH in all the soil due to loss of cations. The drop in organic carbon in the slope land and general increase in the organic carbon content of valley land

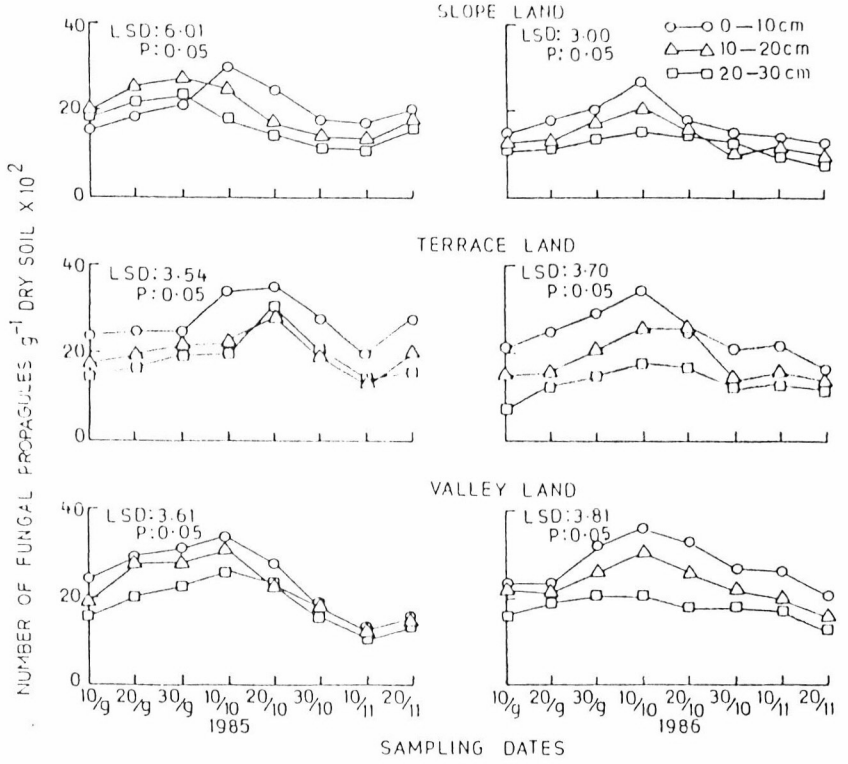


FIG. 8. — Variation in number of fungi (fungal propagules) of potato field soil under different agricultural practices.

soil during the second year of the study may be as a result of the transfer of organic carbon from hill slopes to the valleys along with the run off water (MISHRA & RAMAKRISHNAN, 1983). The organic carbon and total nitrogen contents of soils do not correspond with each other. Neither a loss in total nitrogen is recorded in slope land nor an increase in the total nitrogen is recorded in the valley land soil corresponding to the similar changes in the organic carbon content of these soils. This shows that probably in these soils the inorganic nitrogen particularly NO_3 and NH_4^+, somehow balances the levels of nitrogen in the soil. Further, the relationship between organic carbon and total nitrogen content of sandy laterite soils may not be always a linear one as the rates of nitrogen transformations may be quite rapid (SAXENA & RAMAKRISHNAN, 1986). The decrease in number of microorganisms along depth can be attributed to the less amount of minerals (*Fig.* 4, 5, 6 & 7), low oxygen concentration and increase in concentration of CO_2 in deeper soils. The drop in number of fungi in lower depth could also be attributed to the high moisture content of the deeper soils resulting into reduced aeration of soil (DASTANE *et al.*, 1965). Surface soils usually provided with high organic matter content which in presence of adequate moisture supply is acted upon by the microorganisms to decompose the complex organic residue into simpler forms, hence the number of microorganisms is higher on upper layer of the soil (ACEA & CARBALLAS, 1985). In the month of October increased number of microorganisms

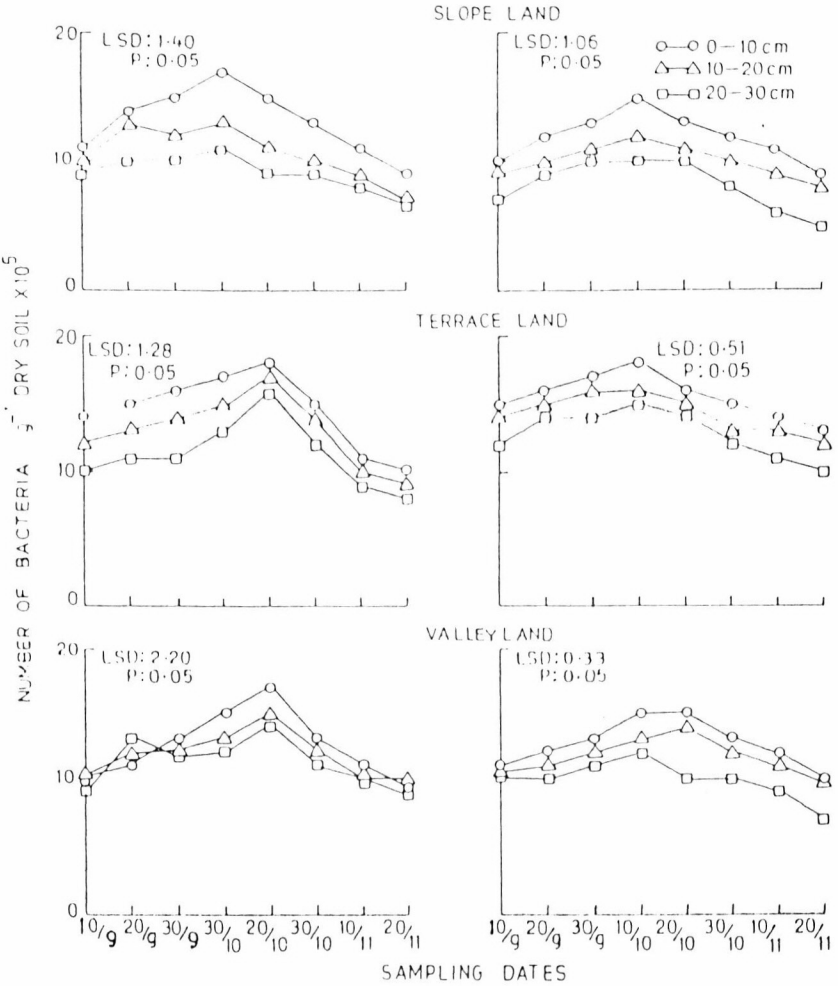


FIG. 9 Variation in number of bacteria of potato field soil under different agricultural practices.

may be due to favourable physico-chemical factors, and also due to possible increase in the root exudation during the same period (HALL & DAVIE, 1971).

Dehydrogenase has been used as a general indicator of microbial metabolism (SKUJINS, 1976; CASIDA, 1977). Generally, dehydrogenase followed a pattern valley land > terrace land > slope land which was in accordance with the more or less similar pattern in the organic carbon and number of bacteria and fungal propagules. This suggests that possibly these factors individually or in combination regulate the dehydrogenase activity. The depth wise variation in the activity was also probably governed by the same set of factors. Thus, it is inferred that the dehydrogenase activity is an organic carbon and microbial number dependent parameter. In the present study the dehydrogenase activity is correlated positively with fungi

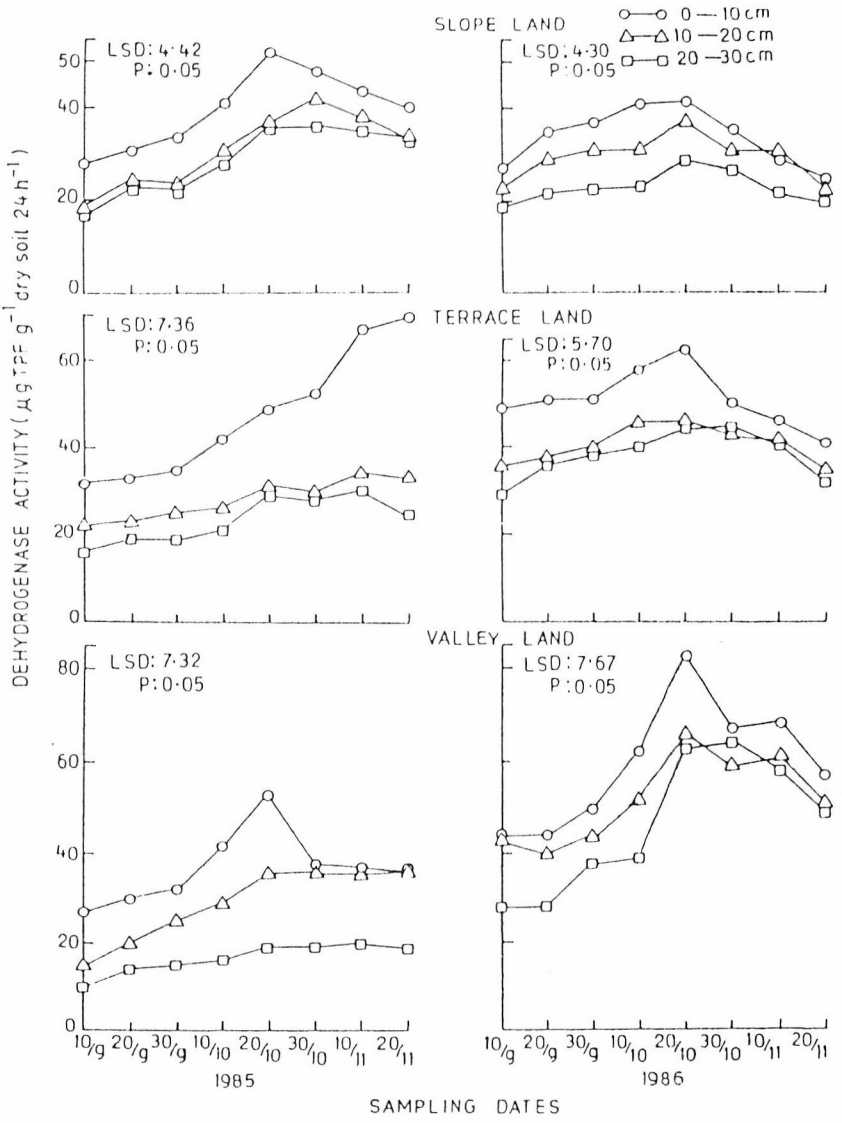


FIG. 10. — Variation in dehydrogenase activity of potato field soil under different agricultural practices.

in all the agricultural system while it is correlated with bacteria only in valley land soil (Tab. I). It suggests that probably fungi are a more important contributor to the dehydrogenase activity in these soils.

In the planted soil continued addition of enzyme could be expected from plant roots (Hall & Davie, 1971) and from associated microorganisms (Speir, 1976). It is likely that supplementation from these sources accounted for the increase in urease activity during the middle age of the plants *i. e.* in the month of October.

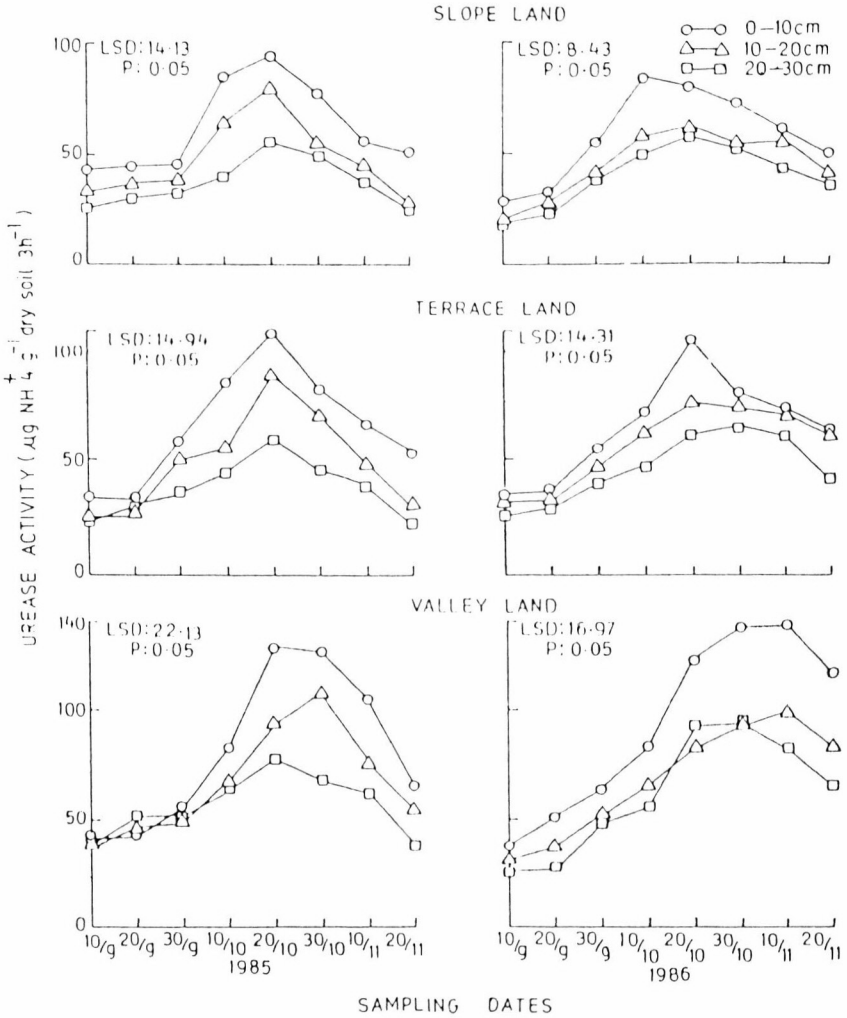


FIG. 11. – Variation in urease activity of potato field soil under different agricultural practices.

Studies on the urease activity and its significant correlation with organic carbon content of the soil is reported by some authors (TABATABAI, 1977; DAS *et al.*, 1981). The relationship between urease activity and soil characteristics supports MCLAREN'S (1975) proposal that urease can exist as an extracellular enzyme in a "three dimentional network of organo-mineral complexes." In the present study urease activity showed a positive correlation with microbial number and CO_2 evolution (Tab. I) while ALEXANDER (1977) noted that urease activity correlated poorly with respiration rate.

Phosphatase activity in all the systems decreased with increasing depth. The variations with depth may be explained by the differential distribution of roots

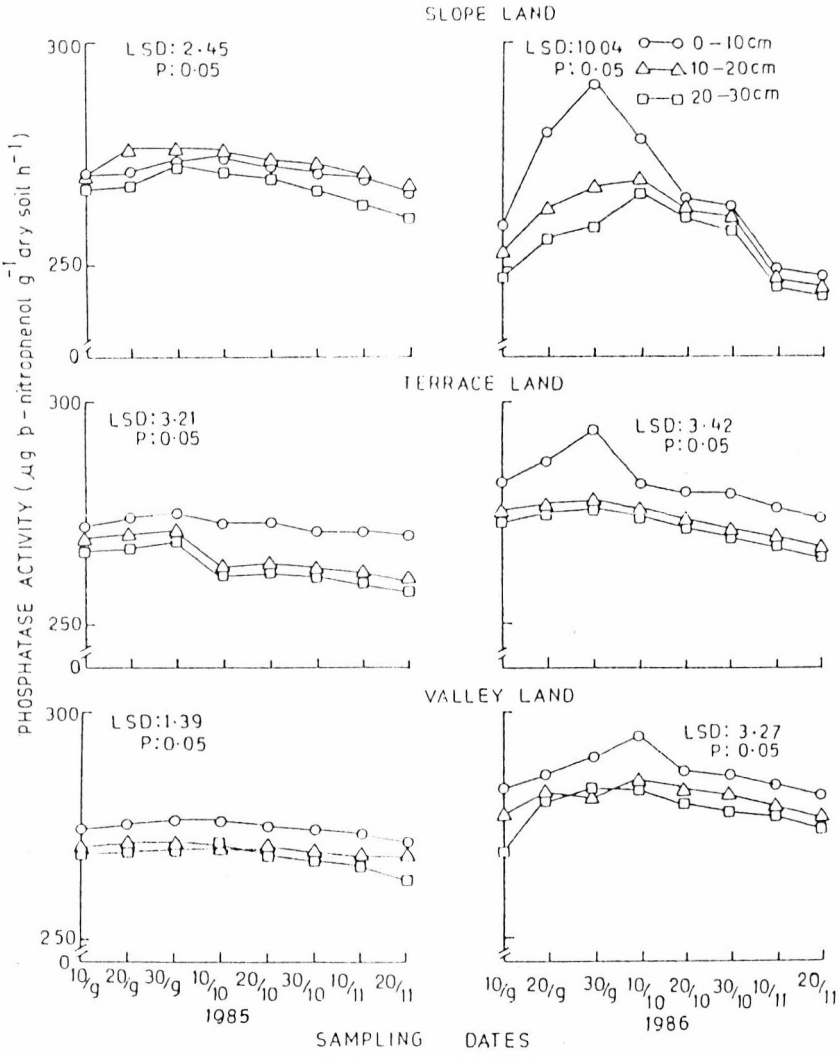


FIG. 12. — Variation in phosphatase activity of potato field soil under different agricultural practices.

and microorganisms in soil which are a major source of phosphatase (GREAVES & WEBLEY, 1969). The number of microbes was higher in 0-10 cm horizon and decreased with depth. It might be responsible for the similar variation in the phosphatase activity. The correlation of phosphatase with organic matter content is probably associated with the fact that phosphatase like enzymes become bound in humo-protein complex (LADD & BUTLER, 1975; MCLAREN, 1975) which possibly protects the enzymes from decomposition.

Respiration activity is influenced by microbial number, organic carbon and inorganic nutrient contents (STROO & JENCKS, 1982). It appears that CO_2 evolution

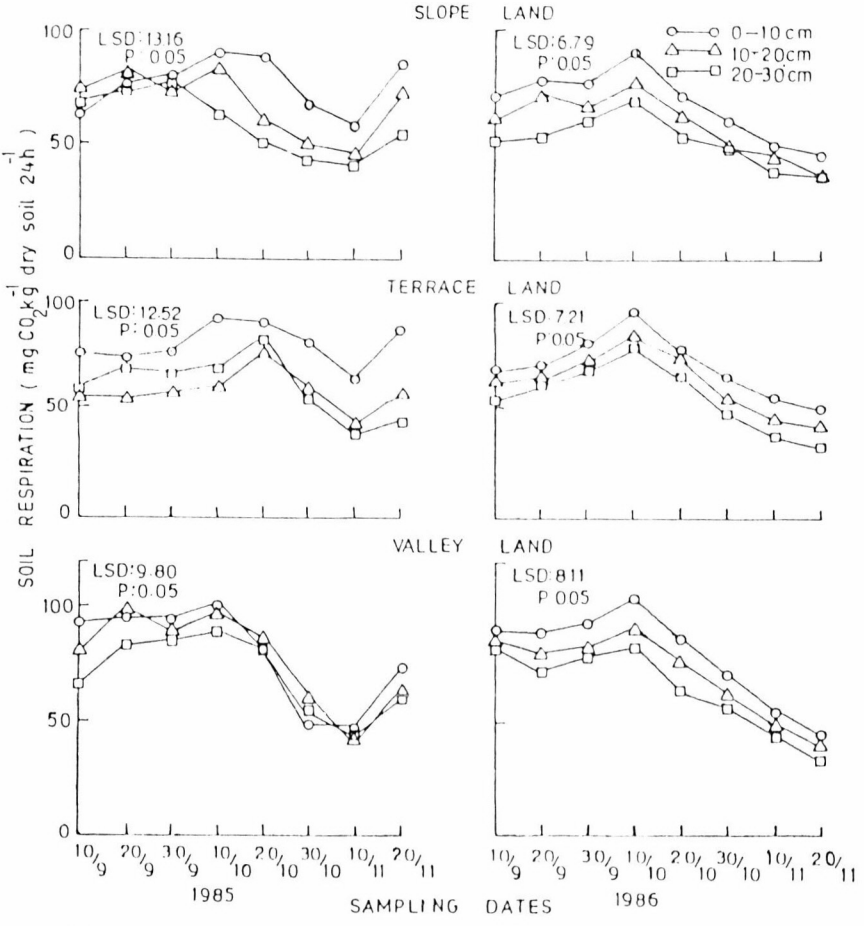


FIG. 13. — Variation in soil respiration of potato field soil under different agricultural practices.

was also regulated by the same or similar set of physico-chemical and biological factors as that of enzymes activities. This was contrary to the observation of Ross (1973) who noted that each biochemical activity has its own characteristic distribution in soil. Respiration was related to the soil biochemical activities which may be because of similar response to the environmental and soil factors. The organic carbon was found to be strong predictor of CO_2 evolution from soil by Stroo & Jencks (1982). However, in the present study the total nitrogen content of soil was a more important factor determining the soil respiration rate than the organic carbon content (Tab. I).

A perusal of results shows that the microbial population and activity followed the general trend: valley land > terrace land > slope land and in depthwise 0-10 cm > 10-20 cm > 20-30 cm suggesting that organic carbon, inorganic nutrients and soil moisture are the most important factors regulating the microbial number

TABLE 1. Simple correlation coefficient (r) values between enzymes activities, fungi and bacteria number, soil respiration and physico-chemical characteristics of soils.

Variables	Fungi	Bacteria	Dehydrogenase	Urease	Phosphatase	Soil respiration
			Slope land			
Moisture content	0.49***	NS	NS	NS	0.59***	0.45**
pH	0.30*	NS	NS	NS	0.33*	NS
Organic C	0.28*	NS	NS	NS	0.31*	NS
Total N	0.55***	0.85***	NS	0.57***	0.51***	0.63***
Available P	0.56***	0.82***	NS	0.78***	0.59***	0.58***
Exchangeable K	NS	NS	NS	NS	NS	NS
Fungi	–	NS	0.32*	0.41**	0.71***	0.86***
Bacteria	–	–	NS	0.64***	0.63***	0.72***
Dehydrogenase	–	–	–	NS	0.28*	NS
Urease	–	–	–	–	0.42**	0.36*
Phosphatase	–	–	–	–	–	0.77***
			Terrace Land			
Moisture content	NS	NS	NS	NS	0.43**	0.29*
pH	NS	NS	NS	NS	NS	NS
Organic C	0.43**	0.53***	0.53***	NS	0.52***	0.44**
Total N	0.88***	0.30*	0.30*	0.40**	0.48***	0.80***
Available P	0.78***	0.62***	0.62***	0.66***	0.52***	0.72***
Exchangeable K	0.44**	0.59***	0.59***	0.47***	0.35*	0.28*
Fungi	–	0.40**	0.40**	0.52***	0.28*	0.81***
Bacteria	–	–	NS	NS	0.29*	NS
Dehydrogenase	–	–	–	0.56***	0.58***	0.36*
Urease	–	–	–	–	NS	0.34*
Phosphatase	–	–	–	–	–	0.39**
			Valley Land			
Moisture content	NS	NS	NS	NS	0.28*	0.31*
pH	NS	NS	NS	NS	NS	NS
Organic C	0.79***	NS	0.57***	0.49***	0.52***	0.52 NS
Total N	0.79***	0.72***	0.51***	0.34*	0.44**	0.65***
Available P	0.75***	0.74***	0.29*	NS	0.62***	0.68***
Exchangeable K	NS	NS	0.52	0.34*	NS	NS
Fungi	–	0.69***	0.33*	0.29*	0.57***	0.77***
Bacteria	–	–	0.34*	0.37**	0.46***	0.58***
Dehydrogenase	–	–	–	0.66***	0.36*	NS
Urease	–	–	–	–	0.35*	NS
Phosphatase	–	–	–	–	–	–

*, **, *** Indicated significance at the 0.05, 0.01 and 0.001 P levels, respectively. Degree of freedom: 47.

as well as their activities. Most of the biological activity parameters are dependent variables. The temporal variations are significant in all the agricultural soils showing that single determination of biological activity of any soil may not reflect the true picture of the soil as the value may vary considerably with the season, crop growth and agriculture practices. The interrelationships determined by correlation

coefficient (r) analysis shows that the relationship between any two factor may vary with the agricultural system as two parameters closely related in one soil may not be related in the other. The present study also demonstrates that correlation are more established in the valley land soils which is least affected by the water erosion and fewer significant correlation coefficient values are noted in slope land which is most seriously affected by the water erosion. This hints towards the possibility to suggest that for any analysis of interrelations between various physico-chemical and biological parameters one should select a stable and least disturbed system.

Summary

Measurements were made on microbial number and their biochemical activities of potato field soil in three different agricultural practices prevalent in hill region viz; hill slope, terrace and valley. Maximum number of fungi was recorded from valley land soil and minimum in slope land soil. Generally, bacterial number was higher in terrace land soil as compared to valley land and slope land soil. Dehydrogenase, urease and phosphatase activities were maximum in valley land soil followed by terrace land and slope land soil. Rate of soil respiration also followed similar general trend while in relation to soil organic carbon it was the highest in slope land followed by valley land and terrace land soil. Number of microorganisms as well as their activities decreased along depth. Microbial number, soil respiration, dehydrogenase, urease and phosphatase activities were significantly correlated ($P = 0.05$) with each other. Generally, microbial number, soil respiration and enzyme activities followed a trend valley land > terrace land > slope land.

Resumé

Distribution temporelle et spatiale des microorganismes, des activités enzymatiques et de l'activité respiratoire du sol dans des champs de pommes de terre situés dans différents systèmes de culture dans les collines du Nord-Est de l'Inde

Les mesures des effectifs de microorganismes et de leurs activités biochimiques ont été réalisées dans des champs de pommes de terre situés dans les trois systèmes d'exploitation dominants dans les reliefs du Nord-Est de l'Inde, les pentes des collines, les terrasses et les vallées. Les effectifs les plus élevés de champignons ont été rencontrés dans le sol de vallée, les plus faibles dans le sol de pente. Généralement, les effectifs bactériens ont été plus élevés dans les sols de terrasse. Les activités enzymatiques (déhydrogénase, uréase, phosphatase) se sont révélées maximales dans le sol de vallée, minimales sur les pentes. L'activité respiratoire a suivi cette même tendance générale bien que, rapportée au carbone organique, elle était plus élevée sur les sols de pente. Les effectifs de microorganismes et les niveaux d'activité décroissent avec la profondeur. Les effectifs microbiens, l'activité respiratoire du sol, les activités enzymatiques – déhydrogénase, uréase, phosphatase – étaient corrélés l'un avec l'autre de manière significative ($P = 0,05$); les effectifs et les niveaux d'activité suivaient une tendance générale : sols de fond de vallée > sols en terrasse > sols en pente.

Acknowledgements

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