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PARTITION OF ENZYME CONTRIBUTION BY PLANTS AND MICROORGANISMS UNDER DIFFERENT SOIL ORGANIC MATTER LEVEL

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ABSTRACT: The plant and microbial contribution towards different plant beneficial enzyme activities (dehydrogenase, esterase, acid phosphatase, alkaline phosphatase, and phytase) was partitioned under four arid crops (pearl millet, clusterbean, mung bean, moth bean) at critical growth stage. The experiment was conducted at Aridisol under five different organic matter levels. The results showed phytase mainly contributed by the microorganisms especially under the soil having rich in organic matter. Acid phosphatase was contributed more by plants than microorganisms, while most of the alkaline phosphatase was contributed by microorganisms. The organic matter helped to improve in the root activity which influenced the esterase and dehydrogenase build up in the rhizosphere. Organic matter up to 4% level may influence dehydrogenase activity. It also enhanced esterase activity, which was more under pearl millet. There was little variation in alkaline phosphatase activity among the three legumes tested. In general, more alkaline phosphatase activity was noticed under pearl millet.

Key words: Plant and microbial contribution, phosphatases, phytase, dehydrogenase, esterase, organic matter levels

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INTRODUCTION

Nutrient cycling in soils involves biochemical, chemical and physicochemical reactions. The biochemical processes are mediated mainly by microorganisms and plant roots. It is well known that all biochemical reactions are catalyzed by enzymes, which are proteins having their power of specific activations. Bioavailability is related to both the diffusion rate of the nutrient through the soil and nutrient solution concentration at any given time. Bioavailability provides an integrated measure of ion diffusion, sorption desorption rates, and solution concentration and can then be correlated with plant nutrient uptake. The process of mineralization of phosphorus is mediated by enzymes, especially phosphatase and phytase. The phosphatase and phytase enzymes are hypothesized to hydrolyze the carbon-oxygen-phosphorus (C-O-P) ester bonds during mineralization of soil organic phosphorus. It is logical to assume that these enzymes might play important roles in the cycling of phosphorus in soils and in the phosphorus nutrition of plants (Sharpley, 1999). However, the experimental evidence is mixed concerning the efficacy of enzymes in mineralizing soil organic phosphorus. Plant roots (Tarafdar and Jungk, 1987), mycorrhizal fungi (Tarafdar and Marschner, 1994), and soil microorganisms produce these enzymes in soil (Tarafdar and Gharu, 2006; Yadav and Tarafdar, 2007). The production and secretion of acid phosphatases by some plant species are stimulated by deficient level of soil phosphorus (Dinkelaker and Marschner, 1992). The distribution of phosphatase activity and of phosphate fractions of the soil in the proximity of root was studied (Tarafdar and Jungk, 1987; Tarafdar and Claassen, 1998) in order to evaluate the significance of phosphatases in P nutrition of various plants (*Brassica oleracea, Alliumcepa, Triticum destivum, Trifolium alexand*). A considerable increase in both acid and alkaline phosphatase activity in the entire four soil-root interface was observed. Maximum distance from the root surface at which activity increases were observed ranged from 2.0 mm to 3.1 mm for acid phosphatase and from 2.0 mm to 1.6 mm for alkaline phosphatase.

The various processes and their relative contributions to the changes in the bioavailability of soil inorganic P that can occur in the rhizosphere can considerably vary with (i) plant species (ii) plant nutritional status and (iii) ambient soil conditions. Compared with the other major nutrients, phosphorus is by far the least mobile and available to plants in most soil conditions. It is therefore frequently a major or even the prime limiting factor for plant growth. Indeed, it is estimated that 5.7 billions of hectares worldwide contain too little available phosphorus for sustaining optimal crop production (Batjas, 1997 ; Gaume, 2000).

Changes of ionic concentration in the soil solution around absorbing roots or root hairs arise from the difference between the demand of the plant and supply from the soil solution (Jungk, 1996 ; Hinsinger, 1998). For P ions, mass flow contributes only a small proportion, about 5% of the actual uptake of crops, as estimated for field grown maize (Barber, 1995) and for radish in a pot experiment (Hamon, 1995 ; McLaunghlin et al.,1998) for instance. A depletion of P can be expected in the rhizosphere in most cases, because of the small concentration of P ion in the soil solution and consequently restricted contribution of mass flow to plant uptake (Jungk, 1996 ; Hinsinger, 1998).

The release of H^+ ions by plant roots thus resulted in increased bioavailability of soil P (Grinsated et al.,1982; Hedley et al., 1982) most probably because of the increased solubility of Ca phosphates with decreasing pH. The depletion of HCl-P in the rhizosphere increased with increasing rhizosphere acidification. H^+ release by plant root can considerably increase the dissolution of phosphate rocks and hence the bioavailability of P in the rhizosphere (Bolan et al., 1990; Hinsinger, 1998). Root induced acidification of the rhizosphere, or more precisely the H^+ release that originates in the roots, can thus dramatically increase the bioavailability of inorganic P whenever Ca phosphates are present its effect in soils which have an acidic pH is more questionable in the first place except when a source of Ca phosphates such as phosphate rocks is added to the soil (Hinsinger and Gilkes, 1997; Zoysa et al., 1998).

Soil fungi play an important role for the release of available phosphorus in desert soil from organic phosphorus compounds through the production of phosphatases. There was a significant and positive correlation between biomass production and acid phosphatase activity but not with alkaline phosphatases (Tarafdar et al., 1988). Dry matter, yield, P uptake, acid and alkaline phosphatase activity and microbial population were increased in all the P treatments. Organic P enhanced alkaline phosphatase activity. Lecithin increased fungal, and phytin increased bacterial growth. The limiting factor on plant utilization of organic P is the availability of hydrolysable organic P sources (Tarafdar and Claassen, 1988). The present study aim' s to partition the contribution made by soils and plant roots to build beneficial soil enzymes like acid phosphatase, alkaline phosphatase, phytase, dehydrogenase and esterase in the rhizosphere during crop growth period.

MATERIALS AND METHODS

Level of organic matter buildup in soil with the application of vermicompost

Surface soil samples were collected from fallow lands of Central Arid Zone Research Institute, Jodhpur, Rajasthan, India. Any discernible root pieces were removed and the samples were air-dried, sieved (< 2 mm) and thoroughly mixed. The characteristic of the soil was presented as Table 1.

Table 1: Characteristics of the experimental soils.

Soil type	Aridisol, Typic Haplocambids
Textural classification	Sandy loam
Sand (%)	83.1-85.5
Silt (%)	5.7-6.9
Parameter	CAZRI farm soil, Jodhpur
Clay (%)	7.6-9.7
PH (soil : water 1:2.5)	7.5-8.4
Electrical conductivity(EC) (dSm^{-1})	0.19-0.22
Organic C (g Kg-1)	2.0-2.3
Total N (g Kg-1)	0.26-0.32
Total K (g Kg-1)	5.9-6.4
Available Fe (mg Kg-1)	2.1-2.8
Available Mn (mg Kg-1)	5.3-6.0
Available Cu (mg Kg-1)	0.23-0.25
Available Zn (mg Kg-1)	0.39-0.45
Available P (mg Kg-1)	3.8-9.9
Total P (mg Kg-1)*	870.2-1105.1
Dehydrogenase activity (n Kat g-1)	0.55-0.64
Acid phosphatase activity (n Kat 1oo g-1)	6.2-7.1
Alkaline phosphatase activity (n Kat 100 g-1)	7.0-8.9

Calculated amount of vermicompost was mixed per 10 kg soil on a pot and covered with polythene sheet to build up different levels of organic matter which was incubated at room temperature for 3 months before sowing of the crops. The moisture content at 60% field capacity was set once daily by weight loss method. There were six treatments (Table 2) each of four replications in each crop. The organic matter build up was analyzed after 3 months and the level of organic matter in each treatment was presented as Table 2. The experiment was carried out in a green house. The temperature during the growth period ranges between 32-35^{o}C with 65-70% relative humidity.

Table 2: Application of vermicompost and percent organic matter build up under different treatment.

Composition of vermicompost use		Treatment	Vermicompost applied (Kg)	Organic Matter (%)
pH	7.2	T1	0	0.2
EC(dsm^{-1})	0.82	T2	13.2	1.0
Organic Carbon (%)	20.9	T3	26.2	2.0
Free $CaCo_3$ (%)	7.8	T4	39.6	3.0
C:N ratio	34.7	T5	52.8	4.0
Total N (%)	0.56	T6	66.0	5.0
Available K ($mgkg^{-1}$)	387			
Total P_2O_5	1.48			
Total K_2O	0.36			
Fe	21.6			
Zn	12.7			
Mn	19.2			
Cu	5.8			

Pot experiment

A pot experiment was conducted for determination of bioavailable phosphorus at different level of organic matter under four different arid crops- moong bean (*Vigna radiata* L. cv S8), moth bean (*Vigna aconiticafolia* Jacq. cv K851), clusterbean (*Cymopsis tetragonoloba* L.cv CGS-936) and pearl millet (*Pennisetum americanum* L. cv HHB 67). The crops were grown in earthen pots (30 cm height and 20 cm diameter). Another set of pots without plants was used for control treatment. All treatments were replicated four times. The experiment was conducted during *kharif* season beginning at 15th of July and the crops were harvested after 4, 6, 8 and 10 weeks of crop age. We are presenting the results here at critical growth period i.e. 6 weeks of crop age as in our preliminary experiment shows highest enzyme activity in the soil under different arid crops at this crop age. Shoots were cut at the soil surface. Roots were carefully shaken to remove excess soil, and lumps of soil trapped between roots were taken out, which was designated as rhizosphere soil. Representative soil samples were taken out (approximately 100g) from the bulk soil of the pots in which plants were grown, and from control pots in which no plants were grown. Samples were frozen at 4°C for further analysis. Shoot and root dry mass was determined after drying 60°±2°C and were ground in a stainless steel ball mill for physico-chemical analysis (Jackson, 1967).

Biochemical Analysis

Dehydrogenase assay were measured in soils immediately after soil sampling or in stored soils at 4°C (within 15 days). Dehydrogenase activity was assayed by the method (Tabatabai, 1982). One gram of soil sample was taken in a screw cap test tube (15 mL capacity). To it, 0.2 mL of 3% triphenyl tetrazolium chloride (TTC) and 0.5 mL 1% glucose was added. After mixing the content, the tubes were incubated for 24 h at 30°C. Once the process of incubation was over, 10 mL of methanol was added to it. The entire material was mixed thoroughly for 1 min. After mixing, the tubes were placed in refrigerator for 3 h. The production of triphenyl formazon (TPF) was determined by measuring absorbance at 485 nm.

The acid and alkaline phosphatase was assayed by adopting the standard procedure (Tabatabai and Bermner, 1969).The procedure described for assay of phosphomonoesterase activities is based on colourimetric estimation of the p-nitrophenol released by phosphatase activity when soil is incubated with buffered (pH 5.4 for acid phosphatase and pH 9.2 for alkaline phosphatase) sodium p-nitrophenyl phosphate solution.

One gram of soil (< 2 m) or 1 mL extract in case of solution culture experiments were placed in a 15 mL capacity screw cap test tube, 4 mL of p-nitrophenyl phosphate solution prepared in acetate buffer (pH 5.4 for assay acid phosphatase) or borax-NaOH buffer (pH 9.2 for assay of alkaline phosphatase) was added and swirled the test tube for a few seconds to mix the contents. The test tube was covered with screw cap, and placed it in an incubator at 35°C. After 1 h, the cap was removed and 1 mL of 0.5 M $CaCl_2$ and 4 mL of 0.5 M NaOH was added. The test tube was swirled for few seconds and the soil suspension was filtered through a Whatman no. 42 filter paper. The yellow colour intensity of the filtrate was measured spectrophotometrically at 420 nm wave length.

The p-nitrophenol content of the filtrate was calculated against the standard curve obtained with standards containing 0, 10, 20, 30, 40 and 50 μg of p-nitrophenol. One unit is the amount of enzyme, which hydrolyses 1.0 μmole of p-nitrophenylphosphate per second at pH 5.4 (acid phosphate) or pH 9.4 (alkaline phosphatase) at 35°C.
Phytase activity was assayed by the method (Ames, 1966). One gram sieved soil (1 mL aliquot incase of solution culture experiments) was placed in 15 mL capacity screw cap test tube. 4 mL of 100 M sodium acetate buffer (pH 4.5) and 1 mL of sodium phytase (1 μM) was added and incubated at 37°C for 1 h. After 1 h incubation, the reaction was terminated by the addition of 0.5 mL 10% Trichloro acetic acid (TCA) (CCl_3COOH). Proteins precipitated by TCA were removed by centrifugation at 10,000g for 10 minutes and the supernatant was analyzed for liberated inorganic P, using chlorostannous reduced molybdophosphoric blue color method as described (Jackson, 1967). One unit of phytase activity was defined as the amount of enzyme, which liberated 1 μmole Pi per minute at 37°C.
Estimation of esterase activity was made as described by (Schnüver and Rosswall, 1982) 0.5 g of samples were placed in a (18x150) test tube and 10 mL sterile K phosphate buffer (pH 7.6, 60 mM) was added to it. One mL of fluorescent diaceate (1mg mL^{-1} in acetone) was poured and the tubes were sealed and kept in an incubator at 37°C for 4 hours. After that the reaction was stopped by addition of 10 mL of acetone. The mixture was shacked and filtered through what man No. 42 filter paper and the supernatant optical density was determined in 490 nm on spectrophotometer.

Partition of plant and microbial contribution

There were two sets of pots. One set (A) was without planting only having vermicompost of different levels for organic matter build up. The other sets (B) where different crops were growing under various organic matter treatments. Under first set (A) the enzyme activity was only due to microorganisms. Under second set (B), the enzyme activity was due to both plants and microorganisms. The B-A were represented the plant contribution in enzyme build up of the soil. The moisture content at 60% was maintained as started under both the sets throughout the experiment.

Statistical analysis

The data were subjected to analysis of various and the least significant differences (LSD) were used to separate means (Sokal and Rolf, 1981).

RESULTS

Dehydrogenase activity

The dehydrogenase activity under different organic matter level respective of crops at critical growth stage was presented as Table 3. The result showed a gradual increase in dehydrogenase activity in the soil with increase in organic matter content under moth bean and mung bean. The more dehydrogenase activity under clusterbean was observed at 3% organic matter level, while under pearl millet it was at 4% organic matter level. The dehydrogenase activity, in general, was more under pearl millet (cereal) as compared to the three legumes (clusterbean, moth bean, and mung bean) tested in different organic matter level.

Table 3: Dehydrogenase activities (pKat g^{-1}) under different crops at critical growth stage (42 days of crop age).

Soil organic matter (%)	Clusterbean	Moth bean	Mung bean	Pearl millet
0.2	3.6	3.7	3.4	5.8
1	4.2	3.8	3.7	6.1
2	5.8	5.5	6.5	8.2
3	8.5	6.0	6.6	9.3
4	5.9	7.2	8.6	10.2
5	5.5	9.8	9.0	10.0
LSD (p = 0.05)	0.42	0.61	0.55	0.67

The plant and microbial contribution towards dehydrogenase activity was partitioned under different organic matter level of all the four crops. The results clearly demonstrated more plant contribution towards dehydrogenase activity with increase in organic matter level from 0.2 to 5% under all the crops. The plant contribution under clusterbean varies between 2 and 67%, under moth bean between 3 and 75% and under mung bean it was observed between 6 and 71%. The more plant contribution was observed under pearl millet where the contribution ranges between 10 and 85%. In general, the plant contribution under legumes was much less than the cereal pearl millet. Under legumes more microbial contribution was observed up to 3% organic matter level, while under pearl millet, it was up to 2% organic matter content (Fig. 1). The results clearly show that under very high organic matter content in the soil, plant contributed more towards dehydrogenase activity otherwise microbial contribution was much more than plant contribution to build up of dehydrogenase activity in the rhizosphere.

Esterase activity

A gradual increase in esterase activity with the increase in organic matter level was observed in all the crops at critical growth stages (Table 4). The more increase was noticed under moth bean and pearl millet and least in mung bean. The activity varies between 10.0 EU x10-3 to 32.5 EU X 10-3. In general, the effect of organic matter was marginally higher under pearl millet as compared to the legumes; more build up was noticed under moth bean.

Table 4 : Esterase activity ($EUx10^{-3}$) under different crops at critical growth stage (42 days of crop age).

Soil organic matter (%)	Clusterbean	Moth bean	Mung bean	Pearl millet
0.2	10.4	10.3	10.0	10.4
1	11.0	10.9	12.5	18.2
2	15.4	13.9	16.8	20.0
3	20.6	24.2	20.4	20.2
4	23.8	27.0	20.6	22.4
5	27.8	32.4	20.2	32.5
LSD (p = 0.05)	1.31	1.85	1.96	1.89

The results demonstrated that (Fig. 2) the microbial contribution of esterase varied widely (19 to 73% under clusterbean, 34 to 98% under moth bean, 12 to 96% under mung bean and 20 to 97% under pearl millet). In general, with increase in organic matter level there was significant decline in microbial contribution under all the crops which was more under mung bean. The more microbial contribution was noticed up to 2% organic matter in all the crop rhizosphere while higher microbial contribution was also noticed at 3% level under moth bean and mung bean. The clusterbean rhizosphere results more microbial contribution than any other crop when no organic matter was added to the soil but a gradual improvement in plant contribution was noticed with the increase in organic matter gradient to the soil (Fig. 2). The results indicate that organic matter helps to improve the root activity which resulted more esterase build up in the rhizosphere.

Acid phosphates activity

The increase in acid phosphatase activity was noticed up to 4% organic matter level under all the crops (Table 5) except mung bean where insignificant increase in activity was also noticed at 5% organic matter level. The effect of plantation was observed more under here pearl millet as compared to the legumes and among the legumes moth bean was the best contributor. The effect of organic matter to build up acid phosphatase was noticed up to 20%.

Table 5 : Acid phosphatase activities ($EUx10^{-5}$) under different crops at critical growth stage (42 days of crop age).

Soil organic matter (%)	Clusterbean	Moth bean	Mung bean	Pearl millet
0.2	12.2	14.4	14.0	15.0
1	15.0	15.2	14.6	15.8
2	15.2	16.0	15.4	16.2
3	15.9	17.0	15.5	16.3
4	16.2	18.2	15.6	18.5
5	15.8	16.4	15.9	16.2
LSD (p = 0.05)	1.08	1.11	0.82	1.15

The more plant contribution towards acid phosphatase was observed under clusterbean (32 to 92%) followed by mung bean (15 to 89%). In general, more microbial contribution was observed at T_1 i.e. without additional organic matter treatment under all the four crops but with increasing in organic matter level there was an improvement of plant contribution. Clusterbean showed more plant contribution from 1% organic matter onwards; while in other crops it was more only above 3% organic matter content (Fig. 3). A gradual improvement in microbial contribution with increase in organic matter content was noticed in all the crops.

Alkaline phosphatase activity

Marginal increase in alkaline phosphatase activity was observed under all the crops with the variable organic matter level (Table 6). There were hardly any differences in activity among the crops indicated plants hardly contribute any alkaline phosphatase activity. Organic matter in soil also showed marginal contribution on alkaline phosphatase build up in the soil.

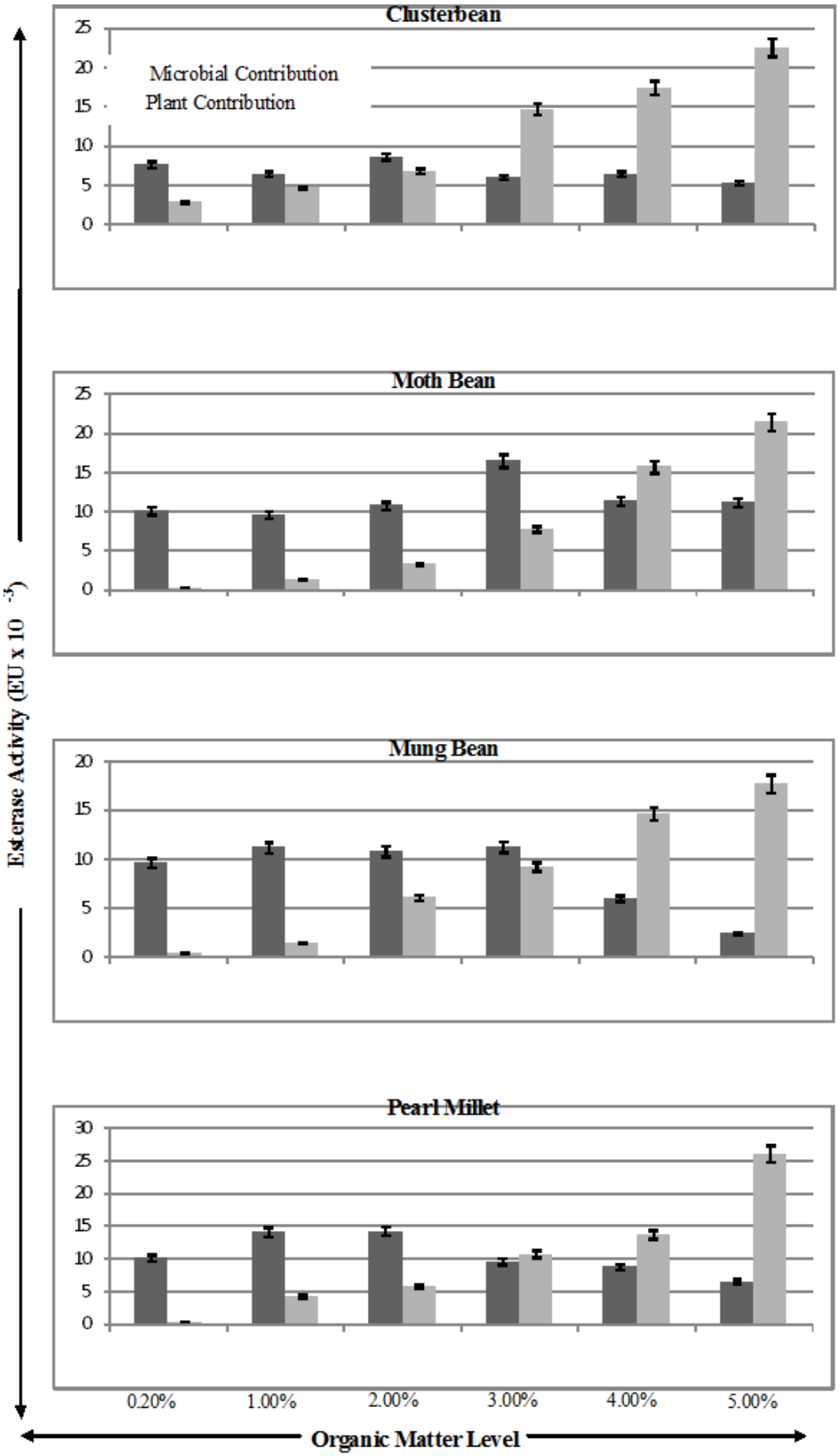

Fig.2. Esterase Activity (EU x 10^{-5}) at critical growth stages contributed by plant and microorganisms at variable organic matter content of the soil

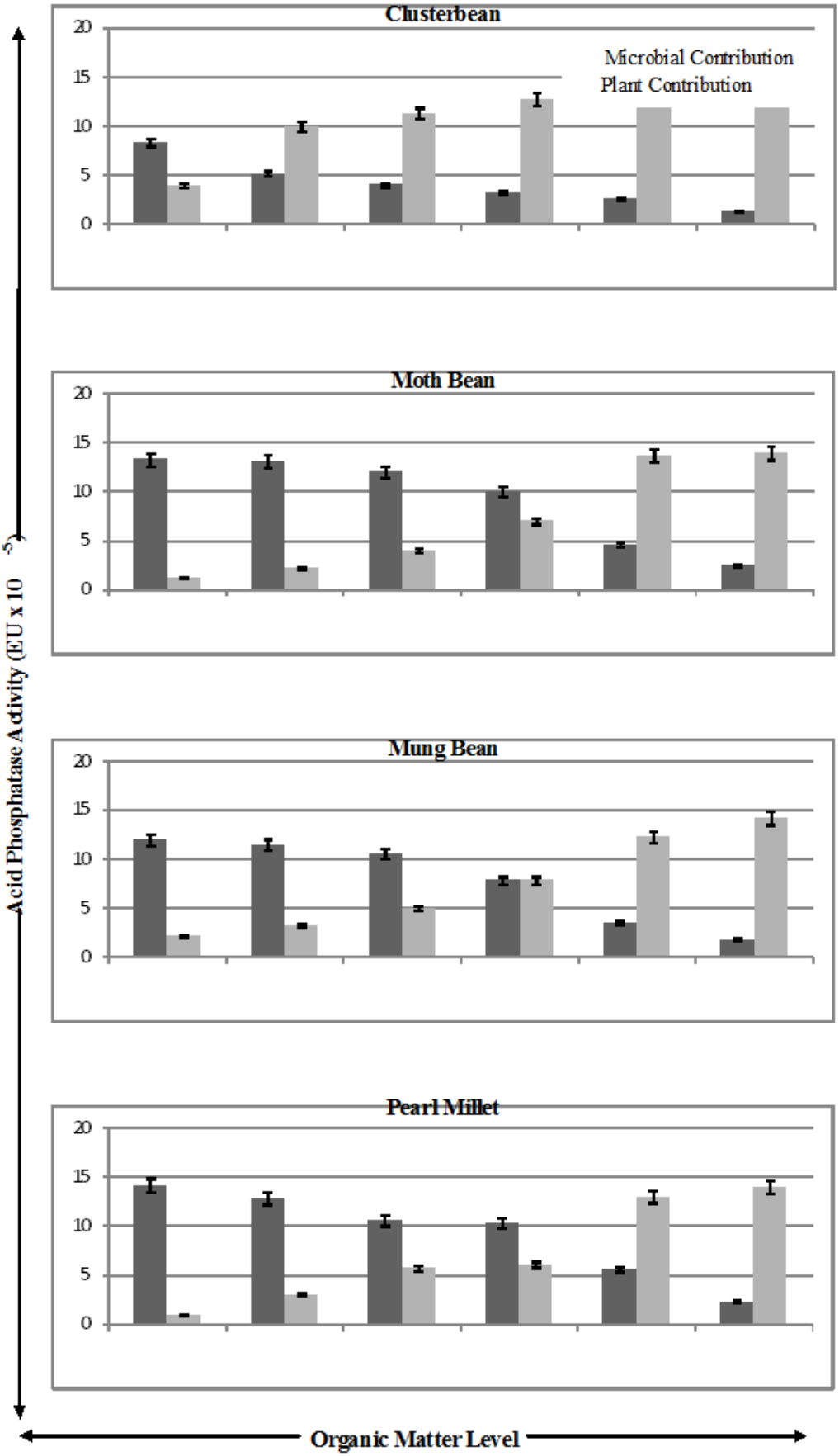

Fig.3. Acid Phosphatase Activity (EU x 10^{-5}) at critical growth stages contributed by plant and microorganisms at variable organic matter content of the soil.

Table 6: Alkaline phosphatase activities (EUx10^{-5}) under different crops at critical growth stage (42 days of crop age).

Soil organic matter (%)	Clusterbean	Moth bean	Mung bean	Pearl millet
0.2	14.6	14.8	14.9	14.8
1	14.9	15.1	15.1	15.2
2	15.2	15.3	15.2	15.4
3	15.3	15.4	15.3	15.4
4	15.5	15.4	15.3	15.2
5	15.5	15.3	15.4	15.2
LSD (p = 0.05)	0.71	0.52	0.08	0.05

The alkaline phosphatase contribution by plants was negligible even at higher organic matter gradient under all the crops. The maximum plant contribution was observed up to 15% under clusterbean and pearl millet, 14% under moth bean while only 13% under mung bean that too at 5% organic matter content. In general, 85 to 99% of alkaline phosphatase in the crop rhizosphere was contributed only by microorganisms (Fig. 4). Organic matter can only little helped towards the increase in alkaline phosphatase release by the plants. The results clearly indicated that plants mainly release acid phosphatase in the crop rhizosphere and alkaline phosphatase is, in general, coming out from microorganisms.

Phytase activity

Except clusterbean, under all the other crops the phytase activity has been increased till 5% organic matter level where as under clusterbean the increase was noticed up to 4% organic matter level (Table 7). The phytase activity was found to be more responsive to organic matter.

Table 7 : Phytase activities (EUx10^{-4}) under different crops at critical growth stage (42 days of crop age).

Soil organic matter (%)	Clusterbean	Moth bean	Mung bean	Pearl millet
0.2	82.4	88.8	81.1	82.0
1	88.8	113.4	90.0	168.4
2	98.4	114.2	120.2	170.5
3	138.2	125.8	150.0	172.8
4	170.1	140.8	152.1	178.2
5	138.8	200.0	170.2	200.0
LSD (p = 0.05)	7.88	9.53	9.66	11.50

Interestingly more phytase contribution by microorganism irrespective of organic matter gradient was observed under mung bean, which varies between 87 and 97%; while under other crops higher microbial contribution was observed after 3% organic matter level. In general, with increase in organic matter content there was increase in phytase contribution by plants under all the crops, the more variation was observed under clusterbean and pearl millet. The least microbial contribution (19%) was observed under clusterbean at 5% organic matter content (Fig. 5). The results suggested that phytase mainly contributed by microorganisms except under clusterbean where plant also contributed an appreciable amount (21 to 81%) of phytase especially at higher organic matter content in the soil.

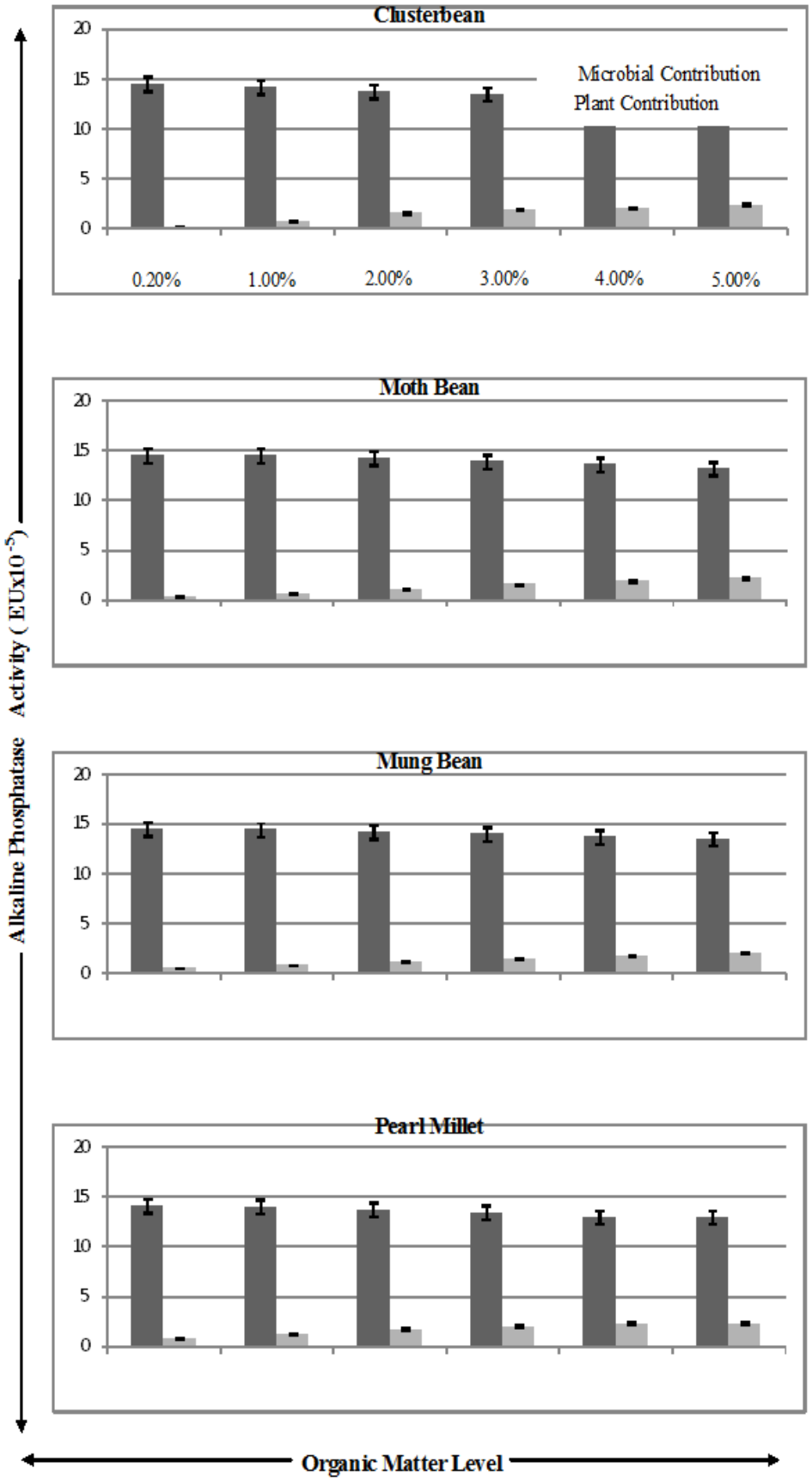

Fig.4. Alkaline Phosphatase Activity (EU x 10^{-2}) at critical growth stages contributed by plant and microorganisms at variable organic matter content of the soil.

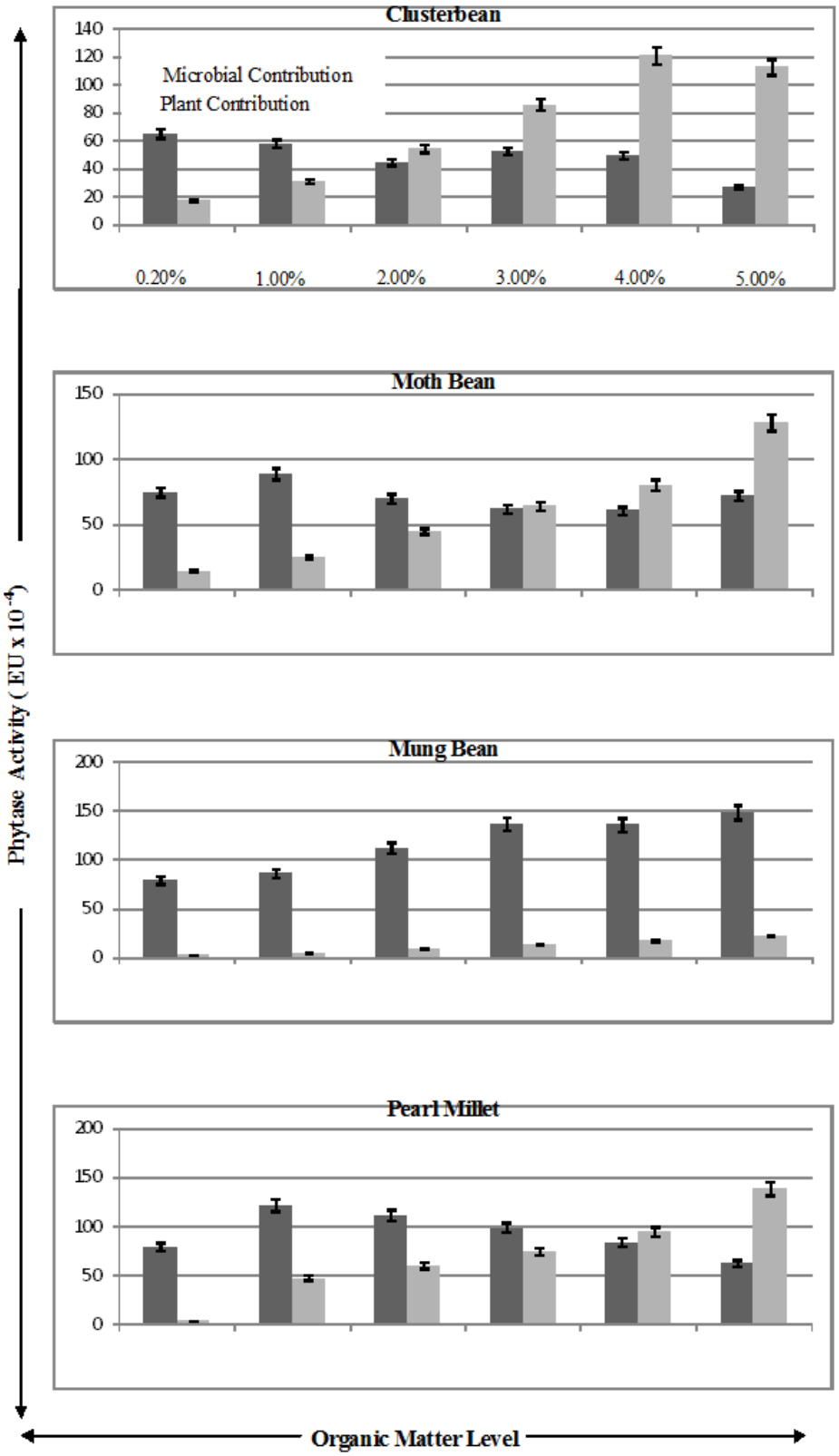

Fig.5. Phytase Activity (EU x 10^{-4}) at critical growth stages contribute by plant and microorganisms at variable organic matter content of the soil.

DISCUSSION

Organic matter enhanced the plant height, root length and total biomass. This may be due to the more water retention, organic C and microbial build up at higher organic matter level.

Organic matter binds soil into aggregates, giving rise to soil structure and associated soil porosity which is important properties with regard to root proliferation, gas exchange and water retention and movement (Hamblin, 1985). A continuing decrease in soil organic matter levels because of reduced inputs, leads to a subtle deterioration of soil structure which creates difficulties of root growth (Papendick, 1994) because of crusting and compaction.

Plant species differ in their ability to obtain P from soils, and adopt different physiological strategies (Lajtha and Harrison, 1995). The secretion of acid phosphatase by plant roots also exerts a significant effect on soil P availability (Tarafdar and Jungk, 1987). The activity of acid phosphatase secreted by the roots of legume plants was higher than that of other plants. The dehydrogenase, esterase and alkaline phosphatase activities were higher under more organic matter level. Both dehydrogenase and alkaline phosphatase activities were associated with total microbial activity of the soil (Skujins, 1973; Tabatabai and Bremner, 1969). This may partly be ascribed to better specific interactions between plant roots and microbes in the rhizosphere (Attiwill and Adams, 1993). Among the large number of factors controlling phosphatase activity of soil, the P concentration in soil solution (McGill and Cole, 1981), the humus content (Tarafdar et al., 1989), the presence of organic P substrates (Tarafdar and Claassen, 1988; Helal, 1990), and the application of pesticides (Speir and Ross, 1978) might be the most important.

Partition of plant and microbial contribution towards phosphatases and phytase activities were demonstrated. A gradual improvement in microbial contribution with increase in organic matter content was observed under all the crops. The results indicated that organic matter helps to improve the root activity, which helps in more enzyme build up in the rhizosphere. In general, microbial contribution was more than plant contribution. Besides the cleavage of C-O-P bond by microbial phosphatase and phytase, the microorganisms may also produce organic acids such as malate, citrate, oxalate, which may possibly help in greater release of Pi (Jones and Edwards, 1998). Santi *et al*. (2000) reported that *Aspergillus niger* BCC F194 was able in solubilizing different types of partially soluble phosphates by producing oxalic acid, citric acid and gluconic acid. Shen *et al.* (2001) identified that elephant grass (cv Napier) exude pentanedioic acid under P deficient condition which has high P mobilizing activity, and mobilize $FePO_4$ and $AlPO_4$. Tarafdar and Gharu (2006) indicted that *Chaetomium globosum* may release organic acids besides phosphatase and phytase, which helps to mobilize unavailable phosphorus compounds.

Enhanced secretion of phosphatases and phytase (Li et al., 1997; Yadav and Tarafdar, 2001) by plant roots and rhizosphere micro-organisms (Tarafdar and Marschner, 1994) may contribute to Pi acquisition by hydrolysis of organic P ester in the rhizosphere. Richardson et al. (2001) highlighted the potential of soil microorganisms for increasing the availability of P from phytate through the provision of phytase activity and presumably by affecting the availability of phytase itself. However, they mentioned that extent to which such micro-organisms release P from phytate in soil for subsequent uptake by plant roots remains to be determined. The contribution of alkaline phosphatases mainly due to microorganisms supports the finding (Tarafdar, 1989) that plant can release only acid phosphatase and alkaline phosphatase are solely microbial in origin.

CONCLUSION

This study has shown that in aridisol under arid environment phytase mainly contributed by the microorganisms. Acid phosphatase was contributed more by plants than microorganisms while most of the alkaline phosphatase was contributed by microorganisms. Organic matter influenced the esterase and dehydrogenase activity. The result of this study implied that both plants and microorganisms are responsible to build up soil enzymes in the rhizosphere which was more at critical growth period.

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