

Full Length Research Paper

Biological, chemical and biochemical dynamics during litter decomposition at different depths in arable soil

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A field study was conducted to elucidate interactions among soil fauna, plant litter, soil nutrients and biochemical activities during litter decomposition in tropical desert land. Faunal association, nutrient dynamics, soil respiration and dehydrogenase activities were monitored in *Hardwickia binata* (T) tree based silvipasture system with *Cenchrus ciliaris* (CC) and *Lesiurus indicus* (LS) grass. The faunal population varied significantly ($P < 0.004$) due to changes in litter quality. Faunal association was maximum in T + CC litter. The litter decomposition varied as a function of associated fauna in different litters. This proves that decomposition was influenced by litter quality and associated soil fauna. Faunal population and litter decomposition were maximum inside the canopy of tree at 5 cm depth indicating preferred niche for soil fauna. Soil organic carbon and soil nitrate nitrogen were significantly ($P < 0.05$) higher in the mixture of tree and grass litters than tree litter alone at different decomposition durations. The soil nutrients, soil respiration and dehydrogenase activity were significantly ($P < 0.05$) higher under the canopy zone. The nutrient enrichment and enhanced biochemical activities in the mixture of litters under the tree canopy at 5 cm depth may be due to the mixing and decomposition of a greater volume of litters by soil biota. However, soil organic carbon (SOC) was significantly ($P < 0.05$) higher at surface and minimum at 5 cm depth. It might be due to the loss of carbon as CO₂ by higher microbial population at 5 cm. A positive and significant correlation and interaction among litter associated soil fauna, litter decomposition, soil nutrients and biochemical properties during decomposition clearly demonstrated the positive impact of fauna on nutrient status, microbial and other biotic activities in silvipasture systems of arid region. The strategy may be adopted for enhancement of soil productivity through litter and fauna management in dry areas of the globe.

Key words: Soil fauna, litter decomposition, nutrient dynamics, soil respiration, soil dehydrogenase activity.

INTRODUCTION

An approach for restoration of natural land is the key to address sustainability in rapidly changing global scenarios. Intensification of agriculture is closely connected with declining natural and human-managed biodiversity, leading to reduced resource flow from above-ground to below-ground system, with implication for sustainable soil fertility management (Ramakrishnan, 2009). One of the major activities occurring in the pedoecosystem is decomposition. Decomposition is central to the normal functioning of an

ecosystem. About 80 - 90% of net primary production in terrestrial ecosystems is recycled by decomposers (Giller et al., 1997). Since a great proportion of the nutrients in tropical ecosystems are incorporated into the organic matter through decomposition, litter decomposition is an important process for regenerating the nutrients to support production in the ecosystem (Cuevas and Medina, 1986). It provides basic clues in understanding and estimating productivity, energy-flow and nutrient cycling (Johansson, 1994). Soil cannot perform ecosystem services like decomposition, nutrient cycling and disease suppression without an array of soil organisms. Soil fauna affect primary production directly by root-feeding and indirectly through their contribution to decomposition and nutrient

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mineralization (Crossley et al., 1992). Wood (1991) considered the biological quality of the soil in terms of the soil organism populations or of the processes accomplished by the organisms. In agro ecosystems soil fauna play an important role in distribution of nutrients and flow of carbon within the soil system by creating galleries, chambers, burrows, mounds and nests and producing faecal matters. Soil faunal density may be linked to litter quality and nutrient cycling rates. Depending on the densities of the soil arthropod populations, the effects of their activities range from minor to major. Macro arthropods directly improve soil structure and function (Abbott, 1989) and micro arthropods affect soil structure indirectly and nutrient cycling directly (Powers et al., 1998).

Soil fauna favour microbial activity, increase enzymatic activity, stimulate root development and maintained a control over plant damaging species. They act as indicator of soil conditions and can be used for soil diagnosis (Choudhary and Roy, 1967). Knoepp et al. (2000) studied the biological indices of soil quality and compared with four common groups of soil biological indicators including soil micro arthropods. Balogh (1970) reported that the biomass of soil fauna of earth is nearly twenty times more than the biomass of human beings living on earth, that is to say, the animal life attains its greatest abundance in soil. Soil fauna and litter decomposition play a critical role in nutrient cycling and organic matter turnover within ecosystems (Smith and Bradford, 2003; Liu et al., 2004; Tripathi et al., 2005). These processes are important determinants of plant productivity and ecosystem carbon storage (Akselsson et al., 2004). This illustrates the need for a greater attention towards the ecology of soil animals. Therefore, the importance of soil fauna at this juncture can not be ignored. This is the point of attraction for biologists to look into the role of below-ground faunal activity in maintaining sustainability of arid soil system.

In Western Rajasthan, the climate is extreme with severe summer, scanty rain, high air temperature and intense solar radiation coupled with high wind velocity and nutrient deficiency. Recurring drought and famines are common features in this region. Hence soil biological process is of crucial importance to this region. *Hardwickia binata* is an important tree of arid region because its leaves contains about 10 - 20% of protein and provide good fodder for livestock. Its dense wood also yields good charcoal and provide good quality of timber. Productivity and sustainability of *H. binata* integrated silvipasture system can be enhanced by decomposition of tree and grass litters. The hypothesis was that soil fauna facilitate litter reduction and decomposition and improve soil biological processes to enrich exhausted soil. Further, very few attempts have been made to study the decomposition of naturally occurring litter mixtures (Gartner and Cardon, 2004). Therefore, the present study examines soil fauna-associated litter decomposition, nutrient dynamics and biochemical changes in *H. binata* based silvipasture

system of Indian Thar Desert.

MATERIALS AND METHODS

Site description

Studies were conducted in Jodhpur district of Rajasthan. It is situated between 26° 45' North latitude and 72°03' East longitude in the arid region of India. The climate of the region is dry tropical type characterized by extremes of temperature, fitful and uncertain rainfall, high potential evapotranspiration and strong winds. Three prominent seasons in the year are summer, monsoon and winter. Summer is the most dominant season characterized by high temperature spreading from March to middle of July. The period from mid July to September is the monsoon season, when most of the rainfall is received. The winter season spreads from November to February. The most important characteristic feature of the arid climate is the wide variations in diurnal and temporal temperature.

Litter decomposition

The leaf litter of *H. binata* (T) and grass litters of *Cenchrus ciliaris* (CC) and *Lesiurus indicus* (LS) were harvested, chopped and allowed to dry. A particular amount of tree litter alone and along with grasses (CC, LS) were kept in a nylon bag of 7 mm mesh size. These litter bags were placed on horizontal and vertical positions in six replications in two hectare area of *H. binata* tree plantation to study the quantification and kinetics of fauna associated decomposition. Horizontally, they were placed outside and inside the canopy of tree. Vertically, the litter samples were placed on surface, 5 and 10 cm depth. Bags were taken out from each position at an interval of four months. The fauna associated with litter decomposition were extracted with the help of Tullgren funnel, identified and counted.

Chemical and biochemical estimations

Decomposition associated changes in chemical and biochemical properties of soil such as soil organic carbon (SOC), total soil nitrogen (TSN), soil ammonical nitrogen (SAN), soil nitrate nitrogen (SNN), soil available phosphorous (SAP), soil respiration (SR) and soil dehydrogenase activity (SDA) were analyzed as described by Anderson and Ingram (1993). Soil organic carbon was determined by Walkley and Blacks wet-digestion method. The total nitrogen was estimated by Kjeldahl method.

Ammonical nitrogen, nitrate nitrogen and available phosphorous were measured spectrophotometrically. Soil respiration and soil dehydrogenase activity were determined using potassium hydroxide (KOH) and triphenyl tetrazolium chloride (TTC) respectively.

Statistical analysis

The data recorded from different experiments on decomposition, nutrient dynamics and biochemical changes associated with faunal population was analyzed statistically with the help of a computer. Since all the data for the same study site were available for different time intervals, they were processed by repeated-measure design to test the level of significance. Duncan's Multiple Range Test (DMRT) was performed for the entire analysis to obtain homogenous subsets among the litter qualities and soil depths. Pearson correlation coefficient was calculated to know the relationship between the faunal population and litter decomposition, soil chemical or biochemical properties. The level of significance was set at 0.05.

RESULTS

Kinetics of fauna associated litter reduction

The faunal population association was significantly ($P < 0.004$) higher in T + CC litter. Whereas the litter decomposition was insignificant for litter qualities (Table 1 and Figure 1). While considering the mean of all variables for canopy zone, faunal association and litter disappearance was significantly ($P < 0.001$) higher inside the canopy as compared to outside the canopy of *H. binata*. Depth wise variation of the faunal population and litter decomposition was significantly ($P < 0.001$) greater at 5 cm as compared to other positions. Whereas they were lowest at surface layer. Faunal population and litter disappearance varied significantly ($P < 0.001$) due to changes in months. Both faunal association and litter disappearance were higher over the first four months of decomposition and it was reduced as a function of time interval. The test of between subject-effect of depth \times canopy and depth \times litter quality was significant ($P < 0.05$) for both litter fauna and litter disappearance. Whereas canopy \times litter quality and depth \times canopy \times litter quality interactions were only significant ($P < 0.05$) for litter loss. Litter decomposition and associated fauna showed a significant positive correlation ($P < 0.001$) at fourth and eight months of decomposition period (Table 2).

Decomposition-dependent chemical changes

Soil organic carbon

Soil organic carbon (SOC) varied significantly ($P < 0.05$) due to changes in litter quality. SOC was greater in T + CC litter quality. Considering the mean of all variable for canopy zone, SOC was significantly ($P < 0.001$) higher inside the canopy as compared to outside the canopy of *H. binata*. SOC was significantly ($P < 0.001$) greater in top soil layer (Table 1 and Figure 2). However, it was lowest at 5 cm depth. SOC changed significantly ($P < 0.001$) due to changes in months. About 1.5 to 2 fold higher SOC was obtained after twelve month of decomposition as compared to initial values.

Total soil nitrogen

While considering the mean of all variables for canopy zone, total soil nitrogen (TSN) was significantly ($P < 0.001$) higher inside the canopy as compared to outside the canopy. TSN was significantly ($P < 0.001$) greater at 5 cm depth. Whereas it was lowest at surface. TSN differed significantly ($P < 0.001$) due to variation in months. About 2 to 4.5 fold higher TSN was obtained after a period of twelve month as compared to initial values.

Soil ammonical nitrogen

Soil ammonical nitrogen (SAN) did not differ significantly due to changes in litter qualities. Significantly ($P < 0.001$) higher SAN was found inside the canopy zone than outside after considering the mean of all variables for horizontal position (Table 1 and Figure 3). Depth-wise variation in SAN was significantly ($P < 0.001$) greater at 5 cm. Whereas, it was lowest at surface layer. Due to variation in months the SAN varied significantly ($P < 0.001$). SAN increased about 2 to 3.5 fold after twelve months of decomposition. Associated fauna showed a significant positive correlation ($P < 0.05$) with SAN at fourth and eight months of decomposition periods (Table 2).

Soil nitrate nitrogen

Significantly ($P < 0.001$) greater soil nitrate nitrogen (SNN) was found in T + CC litter quality (Table 1 and Figure 3). Considering the mean of all variables for canopy zone, SNN was significantly ($P < 0.001$) higher inside the canopy as compared to outside the canopy of *H. binata*. SNN was significantly ($P < 0.001$) greater at 5 cm depth. However, it was lowest at top soil layer. Only the interaction between month and litter quality was significant ($P < 0.05$). Approximately 1.5 to 2 fold higher SNN was recorded after twelve month of decomposition as compared to initial values. A significant positive correlation ($P < 0.05$) between SAN and litter fauna was obtained at fourth and eight months of decomposition (Table 2).

Soil available phosphorus

Soil available phosphorus (SAP) was significantly ($P < 0.001$) higher inside the canopy than outside the canopy when mean of all variables for horizontal position were considered. SAP was significantly ($P < 0.001$) greater at 5 cm depth (Table 1 and Figure 4). Whereas, it was lowest at surface. A significant ($P < 0.000$) alteration in SAP was found due to changes in months. About 2 to 4 fold higher SAP was obtained at all positions as compared to initial values. There was a significant ($P < 0.05$) positive correlation between the associated fauna and SAP at fourth and eight months of decomposition (Table 2).

Decomposition-dependent biochemical changes

Soil respiration

Soil respiration (SR) showed insignificant variations due to differences in litter qualities (Table 1 and Figure 5). While considering the mean of all variables for canopy zone, SR was significantly ($P < 0.001$) higher inside the canopy

Table 1. Repeated measure ANOVA of different parameters in *Hardwickia binata* based litter decomposing silvipasture system.

Repeated measure ANOVA	Litter disappearance (%)	Fauna (# /100 g litter)	Organic carbon (ppm)	Total nitrogen (ppm)	Ammonical nitrogen (ppm)	Nitrate nitrogen (ppm)	Available phosphorus (ppm)	Soil respiration (mg CO ₂ /m ² /hour)	Soil dehydrogenase (p kat/g)
	Test of within- subject effects								
	F value	F value	F value	F value	F value	F value	F value	F value	F value
Month (M)	96.62*	73.49*	22.23*	34.40*	49.58*	3.35*	23.37*	4188.15*	268.46*
M × Depth (D)	0.65	4.63*	0.14	0.88	0.28	0.31	0.54	36.23*	0.92
M × Canopy zone (C)	0.04	1.38	0.02	1.72	0.55	0.14	0.87	28.50*	17.49*
M × Litter quality (L)	0.08	0.73	0.27	0.27	0.19	0.02	0.12	29.20*	5.66*
M × D × C	0.31	0.47	0.01	0.10	0.10	0.14	0.38	1.58	0.34
M × D × L	0.15	1.07	0.03	0.29	0.16	0.14	0.33	4.14*	0.28
M × C × L	0.09	0.07	0.10	0.16	0.28	0.03	0.13	3.29*	1.79
M × D × C × L	0.04	0.17	0.14	0.46	0.10	0.02	0.65	0.63	0.33
Test of between- subject effects									
D	307.28*	19.85*	26.08*	14.44*	11.00*	7.38*	12.37*	62.15*	26.46*
C	461.44*	25.67*	22.91*	31.86*	15.02*	21.31*	40.92*	162.97*	69.56*
L	2.06	5.96*	4.68*	0.43	2.81	4.27*	1.50	0.13	0.64
D × C	12.79*	6.29*	0.82	0.57	0.05	0.52	0.16	2.03	2.89
D × L	51.96*	2.48*	1.05	0.83	0.16	0.25	0.15	0.75	0.37
C × L	42.30*	0.12	3.05	1.08	0.05	0.53	1.22	15.87*	0.16
D × C × L	7.42*	0.25	0.42	0.59	0.04	0.19	0.24	0.47	0.09

* Significant.

as compared to outside the canopy. Depth-wise variation in SR was significantly ($P < 0.001$) greater at 5 cm. Whereas it was lowest at surface. SR varied significantly ($P < 0.001$) due to changes in months. Approximately 3 to 5 fold higher SR was found at all positions over the first four months of intervals. However, it gradually decreased as a function of time interval but remained even higher after the twelve months as compared to initial levels. The test of within-subject effects of month × depth, month × canopy, month × litter quality, month × depth × litter quality and month × canopy × litter quality were significant ($P < 0.001$) for SR. Whereas the

test of between-subject effect of canopy × litter quality interaction was significant ($P < 0.001$) for SR. A significant positive correlation ($P < 0.05$) between SR and litter fauna was obtained at fourth and eight months of decomposition periods (Table 2).

Soil dehydrogenase activity

Significantly ($P < 0.001$) higher soil dehydrogenase activity (SDA) was found inside the canopy zone than outside the canopy after considering the mean of all variables for

horizontal position. SDA differed significantly ($P < 0.001$) due to variation in soil depths. It was greater at 5 cm depth and lowest at top soil layer. Due to changes in months the SDA varied significantly ($P < 0.001$). SDA increased about 2.5 to 4 fold over the first four months of decomposition. It gradually decreased as a function of duration but remained. But it was still higher after the twelve months as compared to initial levels. The test of within-subject effects of month × canopy and month × litter quality, were significant ($P < 0.001$) for SDA. Associated fauna showed a significant positive correlation ($P < 0.05$) with SDA during at fourth and eight months

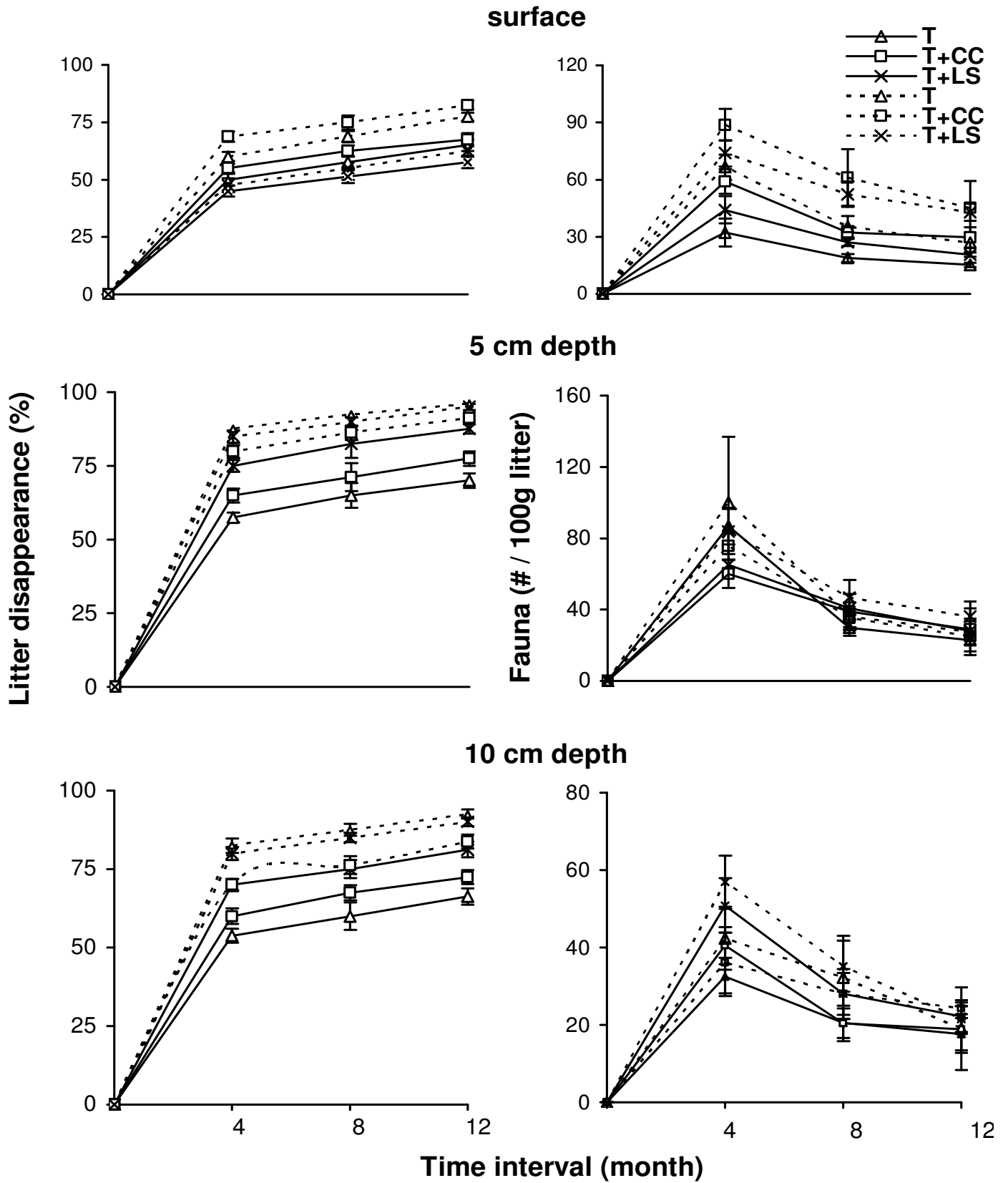


Figure 1. Kinetics of decomposition of litters of *Hardwickia binata* (T) and grasses (CC, LS) and associated soil fauna. CC: *Cenchrus ciliaris*; LS: *Lasiurus sindicus*; (—) outside canopy; (---) inside canopy.

Table 2. Correlation of soil faunal population with litter loss, organic carbon, total nitrogen and ammonical nitrogen nitrate nitrogen, available phosphorus, soil respiration and soil dehydrogenase activity in *H. binata* based silvipasture system at different time intervals.

Parameter	Decomposition period (months)					
	4 (October)		8 (February)		12 (June)	
	r- Value	P-Value	r- Value	P-Value	r- Value	P-Value
Litter loss	0.340	< 0.001	0.317	< 0.001	0.116	NS
Organic carbon	0.030	NS	0.079	NS	0.100	NS
Total nitrogen	0.125	NS	0.173	NS	0.045	NS
Ammonical nitrogen	0.208	< 0.031	0.257	< 0.003	0.030	NS
Nitrate nitrogen	0.249	< 0.010	0.213	< 0.027	0.082	NS
Available phosphorus	0.344	< 0.001	0.262	< 0.006	0.114	NS
Soil respiration	0.287	< 0.003	0.230	< 0.017	0.132	NS
Soil dehydrogenase activity	0.304	< 0.001	0.359	< 0.001	0.652	NS

Sampling months are in bracket; NS, Non – significant.

of decomposition periods (Table 2).

DISCUSSION

Fauna associated litter decomposition

In *H. binata* based silvipasture system the faunal population associated with litter was maximum with T + CC litter in comparison to other quality of litters (Figure 1). Higher density of fauna in mixed litter may be due to its diverse chemical composition attracting soil fauna as compared to single species litter. It is also because mixture of litter from different species with differing resource quality and leaf structure changes the chemical environment and physically alters the total litter surface where decomposition is occurring (Hector et al., 2000). However, Gartner and Cardon (2004) clearly established that decomposition patterns of litter-mixes are not always predictable from litter dynamics of single species. Probably the abundance and activity of invertebrates was influenced by the initial litter chemistry (Zimmer, 2002). Schadler and Brandl (2005) described that different species of invertebrates may be attracted to certain litter types and with an increasing richness of litter decomposer may show complementary resources use, thereby higher faunal population associated with the mixture of litters. An increased number of trophic levels would increase decomposition rate (Bengtsson et al., 1995).

Litter decomposition and associated faunal population were higher inside the canopy of tree than outside in a horizontal position. However, in a vertical position, both the litter decomposition and associated fauna were higher at 5 cm depth and lower at surface. This shows that soil fauna associated with litter decomposition preferred niche inside the tree canopy and at 5 cm depth. The observation of greater mass loss in buried bags draws support from Beare

et al. (1992) and Tyab and Reshi (2008) who described greater mass loss in buried bags on compared to surface bags. Due to sufficient availability of litter as food and best climatic condition of rainy season for growth and development of soil fauna, the disappearance of litter and associated fauna were higher over the first four months of decomposition. The percentage age of decay is found to increase with increasing amounts of rainfall and humidity. The highest intensity of organic matter decomposition was observed under conditions of moderate temperature (30°C) and soil moisture content (60 - 80%) (Kononova, 1975). Nearly similar climatic condition was found during first four months of litter decomposition in the present study. Shanks and Olson (1961) compared litter decay beneath natural stands at various elevations and concluded that there was an average decrease in breakdown of nearly 2% for each 1°C drop in mean temperature. Lang (1974) found five folds higher decay of litter during autumn as compared to the winter and summer. Boonyawat and Ngampongsai (1974) also observed the highest decomposition of hill evergreen forest litter in the late rainy season and early winter and the lowest rate in summer. Brinson (1977) and Vander Drift (1983) pointed out that precipitation and temperature were important factors for litter decomposition because they affect both the development of plant cover and the activities of soil fauna, which are highly critical factors in litter decomposition.

Madge (1985) described higher litter disappearance during the wet season, which may be due to the activity of dense population of mites and collembolans. Schowalter and Sabin (1991) reported higher microarthropods densities during wet months. The faunal association and litter decomposition was higher in lower layers than top soil surface layer. During the wet months the percolating water from rainfall may leach the excrements and remains of organisms down to the lower horizons, where other specialized microbes will attack organic molecules and

increase the rate of litter decomposition and faunal density at lower depth in comparison to surface. The amount of litter decomposition and faunal population decreased after four months. Schimel and Gullledge (1998) suggested that the corresponding decrease in litter decomposition and faunal population may be due to the changes in soil and litter moisture. These consequences of climate change are likely to induce changes within functional groups or shifts in the balance between different functional groups in the soil decomposer community, which could significantly affect litter decomposition (Swift et al., 1998). A positive and significant ($P < 0.05$) interaction and correlation between litter associated soil fauna and litter decomposition clearly demonstrate the positive impact of soil fauna on litter decomposing activities in silvipasture system of desert region. It was observed that the litter decomposition varied as a function of associated fauna in different litters. This proves that decomposition was influenced by litter quality and associated soil fauna (Zimmer, 2002).

Decomposition-induced chemical changes

SOC, TSN, SAN, SNN and SAP were higher in the mixture of tree and grass litters than tree litter alone at all positions and different decomposition durations (Figures 2 to 4). They were higher under the canopy zone. The higher nutrient enrichment of the soil under tree canopy was due to mixing and decomposition of greater volume of litters through soil biota. Further the nearest zone would have received more nutrients from the tree since the soil adjacent to the tree trunk had been covered by the canopy for the longest period which supports the establishment of decomposer community for higher decomposition. In vertical position, the concentrations of soil nutrients were maximum at 5 cm and minimum at surface except in case of soil organic carbon. However, soil organic carbon was maximum at surface and minimum at 5 cm depth. It may be due to the loss of carbon as CO_2 by higher microbial population at 5 cm. About 60% of the carbon in organic materials is respired as carbon dioxide, but 40% of that carbon is retained as bacterial biomass (Ingham, 2007).

Over the first four months of decomposition the increments in the soil nutrients were higher than the other periods of decomposition. This is in accordance with Singh et al. (2004) and Tyab and Reshi (2008) who reported relatively fast decomposition rate during initial stages followed by slower rate of decomposition in the later stages. The increase in nutrients except soil organic carbon at depth may be due to leaching and deposition of elements. Muoghalu and Awokunle (1994) studied the spatial pattern of soil properties under tree canopy in a forest region and reported a significant decrease in organic matter content with soil depth and distance from the tree base. They showed a significant decrease in soil nitrogen and significant changes in phosphorus content with the

distance from tree base. The concentration of soil organic carbon, total nitrogen, ammonical nitrogen, nitrate nitrogen, available phosphorous were 1.5 - 3 fold higher after the twelve months of decomposition suggesting improvement in nutrient status. Coleman et al. (1992) documented bacteria and fungi one of the major nutrient cycling processors in soil. The waste products of bacteria produce soil organic matter and thus increase the level of organic carbon in soil. When microarthropods graze on fungal and bacterial infected litter, some of the nitrogen bound in these microbes is mineralized and released as nitrogenous waste and increase soil nutrient status (Whitford et al., 1982). Rao and Tarafdar (1992) reported vegetation cover, soil temperature, soil moisture as important variable for the different status of phosphorus in soil. Organic matter in soil is the most important fraction that supports microbial populations. Microbial biomass (MB), the living component of soil organic matter, constitutes 2- 5% of the organic carbon in soils. MB acts as the engine for organic matter turnover and nutrient release (Ingham, 2007). Therefore, higher nutrient concentration was obtained at greater faunal density during decomposition.

Pramanik et al. (2001) studied nutrient mobilization from leaf litter by detritivore soil arthropods and documented significantly high rates of organic carbon and nitrates release by soil fauna. It also supports the present findings of higher nitrogen content at a greater faunal density in litter decomposing places. Griffiths (1994) estimated from several independent food web studies that soil microfauna were responsible for 20 – 40% of net nitrogen mineralization under field conditions. In addition, leaching from damaged fungal hyphae due to mesofauna grazing may also increase ammonia content in soil. Beare (1997) reported that fungal-feeding microarthropods are very important in mobilizing nutrient from surface residues through grazing. In addition to protozoa, bacterial-feeding and predatory soil fauna are estimated to contribute directly and indirectly about 8 to 19% of nitrogen mineralization.

ANOVA depicted that all the parameters such as soil organic carbon, soil total nitrogen, soil ammonical nitrogen, soil nitrate nitrogen and soil available phosphorous generally differed significantly ($P < 0.05$) due to changes in month, soil depth and canopy zone. A positive and significant correlation among litter associated soil fauna and soil nutrients during decomposition period clearly demonstrate the impact of fauna on soil nutrients. The increased rates of nutrient mineralization suggest a more rapid cycling of organic matter and greater amounts of nutrients availability by soil fauna induced litter decomposition. The present observations on soil arthropod associated changes in nutrient status may be supported by the report of Maity and Jay (1999) who described that the colonization of microarthropods have a significant role in trapping energy and nutrients from decomposing litter and in enhancing biological activity in soil. Kumar et al. (1999) also found high diversity and density of soil fauna with very

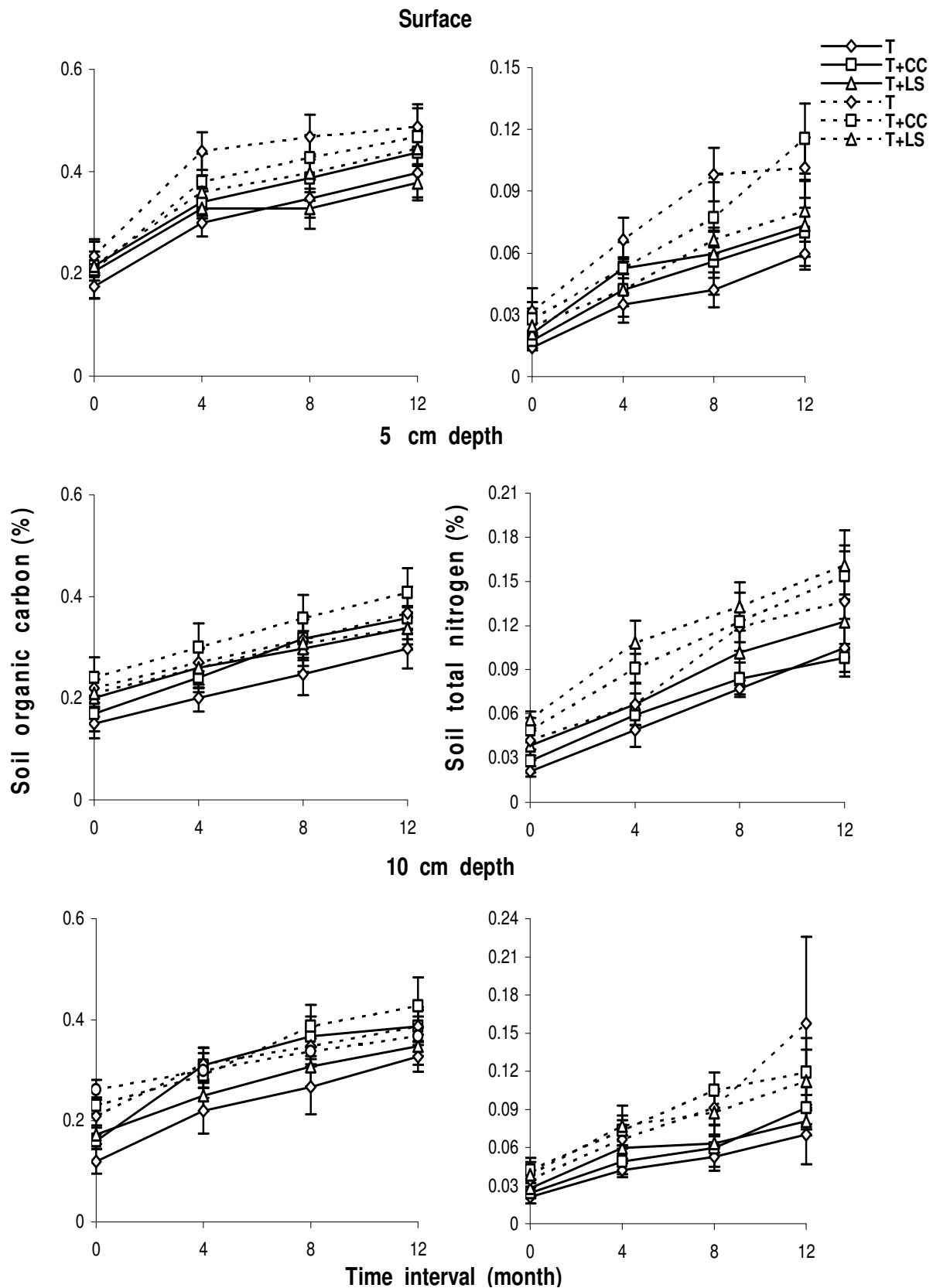


Figure 2. Changes in organic carbon and total nitrogen in litter decomposing soil of *H. binata* based silvipasture system. T: *H. binata*; CC: *Cenchrus ciliaris*; LS: *Lasiurus sindicus*; (—) outside canopy; (---) inside canopy.

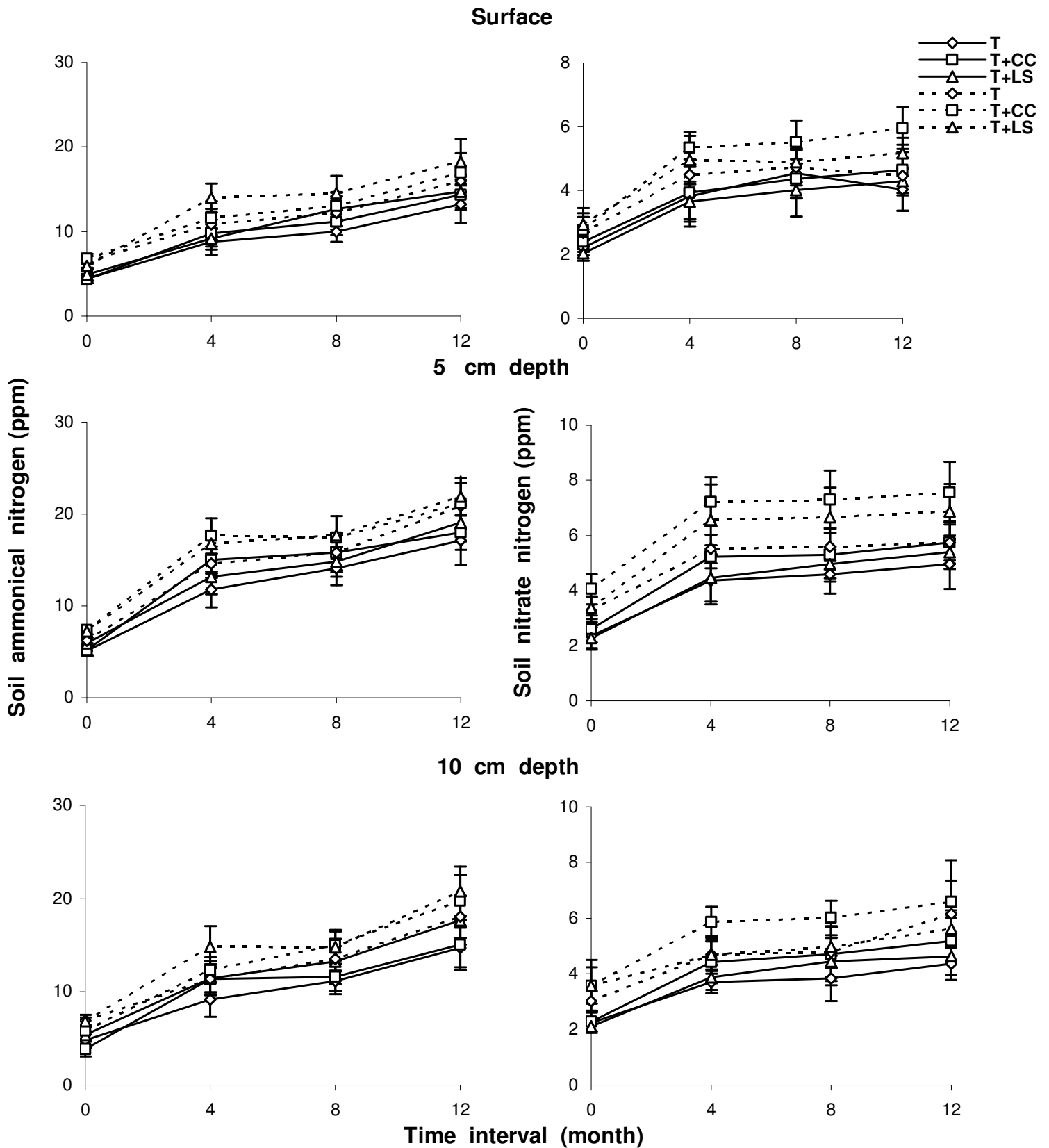


Figure 3. Changes in ammoniacal nitrogen and nitrate nitrogen in litter decomposing soil of *Hardwickia binata* based silvipasture system. T: *H. binata*; CC: *C. ciliaris*; LS: *L. sindicus*; (—) outside canopy; (- -) inside canopy.

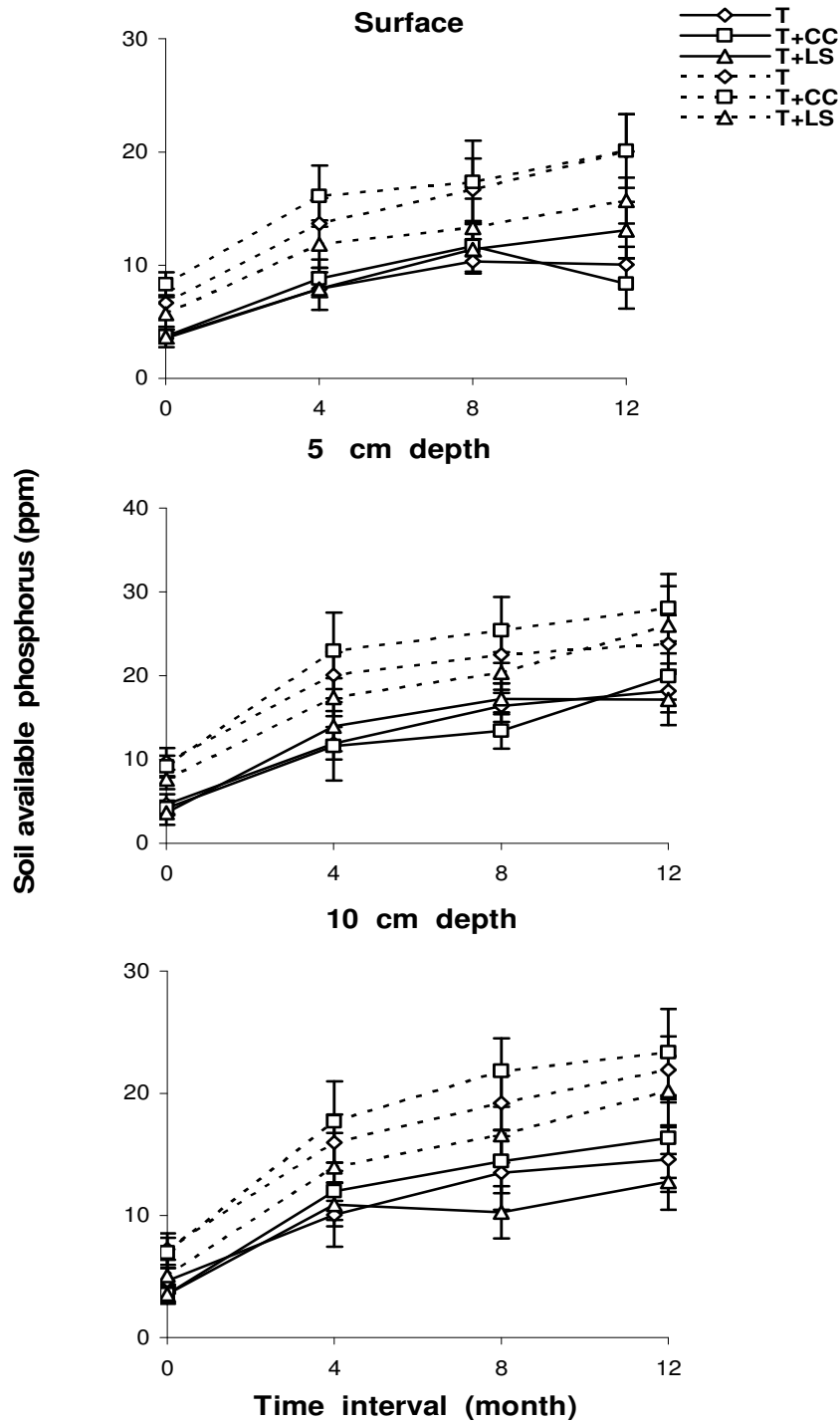


Figure 4. Changes in available phosphorus in litter decomposing soil of *H. binata* z based silvipasture system. T:*H. binata*; CC: *C. ciliaris*; LS: *L. sindicus*; (—) outside canopy; (- -) inside canopy.

high nutrient status in soil. They remarked that high fertility and nutrient status of the soil may be due to the presence of the diverse soil fauna which assist in humus formation. The increase in soil nutrients was associated with the

increase in soil faunal population. It reflects fauna-induced increase in decomposition activities in soil. The strategy may be adopted for decomposition of litters and improvement of soil. Therefore, the litter and fauna management

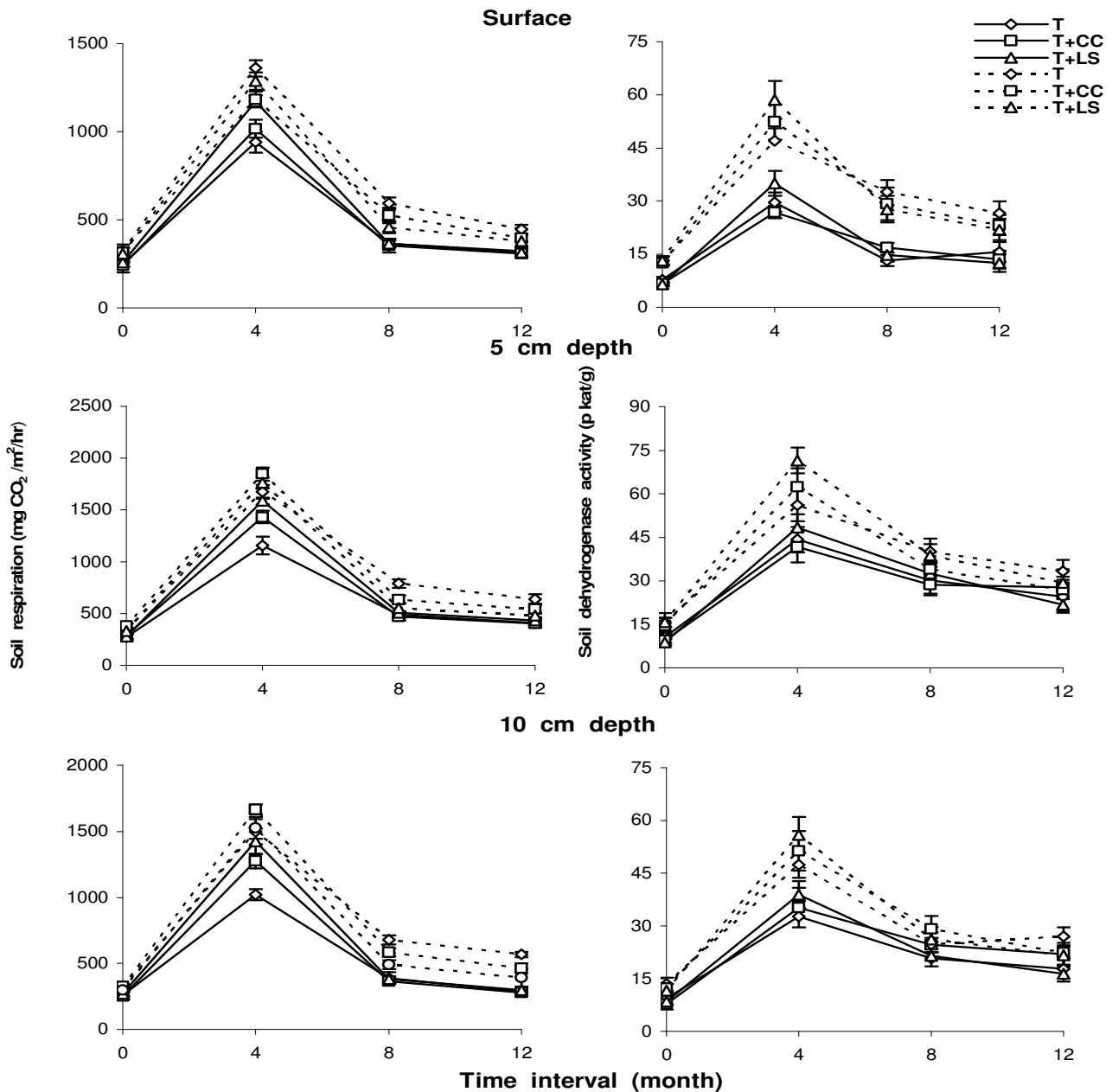


Figure 5. Changes in soil respiration and dehydrogenase activity in litter decomposing soil of *H. binata* based silvipasture system. T: *H. binata*; CC: *C. ciliaris*; LS: *L. indicus*; (—) outside canopy; (- - -) inside canopy.

may increase the productivity of *H. binata* based silvipasture system on a sustainable basis in arid region of Rajasthan.

Biochemical changes during decomposition

Soil respiration and dehydrogenase activity were higher in the mixture of tree and grass litters than tree litter alone at all positions during different decomposition periods. Soil

respiration and soil dehydrogenase activity were higher under the canopy zone. In vertical position, these activities were maximum at 5 cm and minimum at surface. It may be due to association of higher faunal population with litters inside the canopy and at lower depth. Over the first four months of decomposition the increments in the soil microbial activities (SR and SDA) were higher than the other periods of decomposition. However, soil respiration and dehydrogenase activity decreased at eight and twelve months of litter decomposition (Figure 5).

Soil respiration and dehydrogenase activity were 3 - 5 fold higher at all positions after four months of decomposition suggesting improvement in soil biological activities. The present observations are not in agreement to the reports of some workers (Osono and Takeda, 2002; Tyab and Reshi, 2008) who suggested role of soil fungi and temperature in litter decomposition and soil respiration and dehydrogenase activity did not show any significant correlation with litter decomposition. Differences in soil respiration rates among distant sites may be due to climatic differences (Raich and Potter, 1995). Other factors which potentially influenced the rates of soil respiration are the availability of carbon substrate for microorganisms (Seto and Yanagiya, 1983), soil biota population (Singh and Shukla, 1977; Rai and Srivastava, 1981), soil physical and chemical properties (Boudot et al., 1986) and soil drainage (Luken and Billings, 1985; Moore and Knowles, 1989; Freeman et al., 1993). The rate of soil respiration is highly spatially and temporally variable. Lundegårdh (1927) observed greater soil respiration in forests than in grasslands and was consistently greater in grasslands than in croplands. Tewary et al. (1982) found that soil respiration rates beneath coniferous trees were lower than those beneath broad-leaved trees in a mixed forest in Northern India.

Dehydrogenase activity appears to be more related to the metabolic state of microbial population of the soil than to the activity of specific free enzymes acting on a particular substrate. As dehydrogenase reflects the activity of microorganisms in the soil (Lenhard, 1956), the higher dehydrogenase activity during the rainy season may be due to optimum moisture and temperature for the growth of microorganisms at that time (Rao and Venkateswarlu, 1993). Seasonal variations in the enzymatic activities of soil are biologically important because they change the quantity and quality of substrates upon which they act and are responsible for altering the rate of various soil processes. Soil enzyme activities are often closely related to soil organic matter, soil physical properties and microbial activity and biomass (Tate, 1995). Dormaar et al. (1984) observed low activities of dehydrogenase during summer in mixed prairie of Canada. In many desert soils, higher temperatures and soil drying during summer months bring down the microbial population to a very low level (Sasson, 1972) resulting in low dehydrogenase activity. In winter low dehydrogenase activity might be due to the fact that the microorganisms remain in a state of biochemical inactivity (Milosevic, 1988). Therefore, there was a gradual decrease in soil dehydrogenase activity after four month of rainy season in litter decomposing sites.

Repeated measure ANOVA predicts that soil respiration and soil dehydrogenase activity differed ($P < 0.01$) due to month, soil depth and canopy zone. A positive and significant correlation and interaction among litter associated soil fauna, soil respiration and dehydrogenase activity during decomposition period clearly demonstrate the impact of

fauna on biotic activities. This may be substantiated by the reports of Gupta and Singh (1997), Lekha (1987), Setala and Huhta (1990) who described more decomposition in litter bags accessible to soil fauna than in litter bags that exclude soil fauna. The changes in soil respiration and dehydrogenase activity along with changes in soil faunal population disclose the possibility of a strong relationship between soil faunal activity and functional aspects of soil. The increase in faunal population with the increase in soil respiration and dehydrogenase activity clearly reflects the role of soil fauna in improving functional aspects of soil in silvipasture systems of arid region.

Conclusion

The present study established a strong relationship between soil faunal activity and functional aspects of soil in silvipasture systems of arid land. Colonization of microarthropods has a significant role in trapping energy and nutrients from decomposing litter and enhancing biological activity in soil. A positive and significant correlation and interaction among litters associated soil fauna, litter decomposition, soil chemical and biochemical properties during decomposition clearly demonstrate the impact of soil fauna on pedoecosystem. Therefore, the potentials of soil fauna may be utilized for decomposition of litters and improvement of soil health in desertic land.

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