Bioresource management for improvement of soil chemical and biochemical quality in arid environment

Manejo de los biorecursos para el mejoramiento de la calidad química y biológica de los suelos en ambientes áridos

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ABSTRACT

Fauna-induced litter decomposition and associated changes in soil organic carbon (SOC), total soil nitrogen (TSN), soil ammonium nitrogen (SAN), soil nitrate nitrogen (SNN) and soil available phosphorous (SAP), soil respiration (SR) and soil dehydrogenase activity (SDA) were studied in *Tecomella undulata* (T) tree based silvipature system integrated with *Cenchrus ciliaris* (CC) and *Lesiurus sindicus* (LS) grasses in dry region of India. The litter bag experiment was performed using tree and grass litters. The faunal association was maximum in T+LS litter. Whereas the litter decomposition was maximum in T + CC litter. Thus decomposition was influenced by litter mixtures and associated soil fauna. Faunal population and litter decomposition were highest inside the canopy of tree at 5 cm depth defining preferred faunal niche. SOC, TSN, SNN, SR and SDA were significantly ($P < 0.05$) higher in the mixture of tree and grass litters than tree litter alone at all decomposition periods. TSN, SAN, SNN, SAP, SR and SDA were significantly ($P < 0.05$) higher under the canopy zone. The higher nutrient enrichment and biochemical activities in the mixture of litters under the tree canopy at 5 cm depth may be due to the mixing and decomposition of greater volume of litters by soil biota. However, SOC was significantly ($P < 0.05$) higher 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. A positive and significant correlation and interaction among litter-associated soil fauna, litter decomposition, soil chemical and biochemical properties clearly demonstrate the importance of soil fauna in organic resource management in dry areas.

Key words: Dry region, soil fauna, litter decomposition, soil nutrients, silvipasture system.

RESUMEN

Se estudiaron la descomposición inducida por la fauna de la hojarasca y los cambios asociados en el carbono orgánico del suelo (COS), nitrógeno total del suelo (NTS), nitrógeno amónico del suelo (NAS), nitrógeno en forma de nitrato del suelo (NNS), fósforo disponible del suelo (FDS), respiración del suelo (RS) y la actividad de la deshidrogenasa del suelo (ADS) en árboldes de *Tecomella undulate* (T) basado en un sistema silvipasture integrado con las gramíneas *Cenchurus cilliaris* (CC) y *Lesiurus sindicus* (LS) en la región seca de la India. El experimento en bolsas con hojarasca se realizó usando hojarascas de arboles y gramíneas. La asociación faunística fue máxima en T + LS, mientras la descomposición de la hojarasca fue máxima en T + CC. Así, la descomposición estuvo influenciada por la calidad de la hojarasca y asociada con la fauna del suelo. La población de la fauna y la descomposición de la hojarasca fueron mayores dentro del dosel del árbol a 5 cm de profundidad definiendo el nicho preferido de la fauna. COS, NTS, NNS, RS y ADS fueron significativamente ($P <0,05$) mayores en la mezcla de la hojarasca de arboles y gramíneas que en solo hojarasca de árbole en todos los periodos de descomposición. NTS, NAS, NNS, FDSRS y ADS fueron significativamente ($P <0,05$) mayors bajo la zona del dosel. El mayor enriquecimiento de nutrimentos y actividades bioquímicas en la mezcla de hojarascas bajo el dosel de los árboles a 5 cm de profundidad puede deberse a la mezcla y descomposición de volumenes mayores de hojarascas por la biota del suelo. Sin embargo, COS fue significativamente ($P<0,05$) mayor en la superficie y mínimo a 5 cm de profundidad, lo que puede deberse a la pérdida de carbon en la forma de CO_2 por existir una mayor población microbiana a los 5 cm. La correlación positiva y significativa y la interacción entre la fauna del suelo asociada con la hojarasca, la descomposición de la hojarasca y las propiedades químicas y bioquímicas del suelo claramente demostraron la importancia de la fauna del suelo en el manejo de recursos orgánicos en áreas secas.

Palabras clave: Región árida, fauna del suelo, descomposición de la hojarasca, nutrimentos del suelo, sistema silvopastoril.

INTRODUCTION

Soil animals impart in several ecosystem functions such as regulation of nutrient mineralization, litter decomposition and providing buffer energy source for both plant and soil. Biological function such as the maintenance of soil fertility is based on the action of organisms including belowground micro- and macrofauna. One of the major activities occurring in the pedoecosystem is decomposition. Decomposition is central to the normal functioning of an ecosystem and it has been estimated that 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, the 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 mineralization (Crossley *et al*., 1992). Microbial-grazing mesofauna affect growth and metabolic activities of microbes and alter community composition, thus regulating decomposition rate of organic matter (Yeates and Coleman, 1982; Seastedt, 1984). Increasing rates of litter decomposition accelerate nutrient cycling within the site and indicate increased soil quality (Knoepp *et al.*, 2000).

Publications of reports on sustainable land use and soil biodiversity by various international organizations leave the impression that soil fertility is controlled by soil biodiversity. It means that low soil fertility occurs together with a decrease in soil biodiversity. This is the point of attraction for biologists to look into the role of below-ground faunal biodiversity in maintaining sustainability of soil system. Since valuable reports propagate below-ground biodiversity as a soil health indicator, we take an opportunity here to critically and experimentally analyze this notion. Therefore, inventory and conservation of soil bioresources must be a priority. A diverse, balanced and active soil biota could help provide soil conditions necessary for sustainable land production through increased microbial activity, carbon turnover and nutrient supply, preventing plant pathogens, supporting the populations of beneficial organisms, reducing loss of inorganic fertilizers through erosion and leaching by short-term immobilization, stabilizing soil structure, and reducing reliance upon hazardous agrochemicals. Several properties or functions of soil fauna can be used to indicate soil health (Gupta and David, 2005).

The Indian arid silvipasture land is characterized by harsh climatic conditions including low and erratic rainfall, high air temperature and intense solar radiation coupled with high wind velocity and nutrient deficiency. Recurring drought and famines are common features in the region. An efficient and judicious management of silvipasture resources is very essential due to poor soil quality in dry region. Selection of an appropriate combination of tree and subvegetation (grass, crop) and development of suitable management practices like litter decomposition, pruning, lopping and thinning are important aspects.

There is very little information on relationship between soil faunal resources and sustainability of agroforestry systems. So it appears necessary to evaluate the role of soil invertebrates in litter decomposition and nutrient enrichment. Litter resource management may optimize the below-ground biological activities for sustainable land use in arid environment. *Tecomella undulata* is a common tree of traditional agroforestry system of the northwestern dry region of India and belongs to the family Bignoniaceae. Unfortunately, this species has become victim of overexploitation for its high quality timber and medicinal values (Poffenberger *et al.*, 1992) and is now listed in the category of endangered species in the Thar desert (Khan, 1997). Therefore, fauna associated litter decomposition, nutrient dynamics and biochemical changes were studied in *T. undulata* based silvipasture system of dry region.

MATERIALS AND METHODS

Site description

Studies were conducted in Jodhpur district of Rajasthan in India. It is situated between 26^0 45` north latitude and $72^0$ 03` east longitude in arid region. 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.

Experimental procedures

The leaf litter of *T. undulata* (T) and grass litters of *Cenchrus ciliaris* (CC) and *Lesiurus sindicus* (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 four hectare area of *T. undulata* 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, 5cm and 10cm depth. Bags were taken out from each position at an interval of four months. The fauna-associated with litter decomposition were extracted by Tullgren funnel, identified and counted (Crossley and Coleman, 1999).

Decomposition associated changes in chemical and biochemical properties of soil such as soil organic carbon (SOC), total soil nitrogen (TSN), soil ammonium 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 (Walkley and Black, 1934). Total nitrogen was estimated by Kjeldahl method (Bremner, 1960). Ammonium nitrogen, nitrate nitrogen (Mulvaney, 1996) and available phosphorous (Olsen y Sommers, 1982) were measured spectrophotometrically. Soil respiration (SR) and soil dehydrogenase activity (SDA) were determined using potassium hydroxide (Franzluebbers et al., 1995) and triphenyl tetrazolium chloride (Casida et al., 1964), respectively.

The data recorded from different experiments on decomposition, nutrient dynamics and biochemical changes associated with faunal population were analyzed statistically. Since all the observations for the same study site were available for different time intervals, the data was studied 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 and biochemical properties. The level of significance was set at 0.05.

RESULTS AND DISCUSSION

Quantification and kinetics of fauna associated with litter decomposition

The faunal population association was significantly ($P < 0.003$) higher in T+LS litter. However, litter decomposition was significantly ($P < 0.001$) greater with T + CC (Table 1 and Figure 1). The mixture of two species litters generally decomposed faster than a single one. Increased decomposition and higher density of fauna in mixed litter may be due to diverse chemical composition attracting a variety soil fauna. 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).

While considering the mean of all variables for canopy zone, faunal association and litter disappearance was significantly higher inside the canopy of *T. undulata* as compared to outside. Depth-wise variation of the faunal population and litter decomposition was significantly ($P < 0.001$) greater at 5 cm. Whereas it was lowest at surface layer. This shows that soil fauna associated with litter decomposition preferred niche inside the tree canopy and at 5 cm depth. 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. 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 of decay increased with the increasing amounts of rainfall and humidity.

The highest decomposition of organic matter 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. 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 percent 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 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 decompostion.

The amount of litter decomposition and faunal population decreased after a span of months. Schimel and Gulledge (1998) suggested that the corresponding decrease in litter decomposition and faunal population may be due to the changes in soil and litter moisture. The 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). The test of within-subject effects of month x canopy interaction was highly significant ($P < 0.05$) for litter fauna. Litter decomposition and associated fauna showed a significant positive correlation ($P< 0.05$) during all decomposition periods (Table 2). A positive and significant ($P< 0.05$) interaction and correlation between litter associated soil fauna and litter decomposition clearly demonstrated 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.

Decomposition dependent chemical changes

SOC, TSN and SNN varied significantly ($P < 0.001$) due to changes in litter quality. Concentrations of these nutrients were greater in T + LS litter. Considering the mean of all variable for canopy zone, SOC, TSN, SAN, SNN and SAP were significantly ($P < 0.001$) higher inside the canopy as compared to outside the canopy of *T. undulata* (Figures 2, 3 and 4). Depth-wise variations in TSN, SAN, SNN and

Table 1. Repeated measure ANOVA of different parameters in *Tecomella undulata* based litter decomposing silvipasture system in Jodhpur district of Rajasthan in India.

Repeated measure ANOVA	Litter disappearance (%)	Fauna (# /100g 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)	105.59*	98.42*	49.52*	147.07*	7.11*	1.12	43.25*	3679.43*	269.84*
M x Depth (D)	0.35	0.77	0.57	2.30	0.42	0.17	2.77*	30.34*	0.42
M x Canopy zone (C)	1.35	4.39*	2.57	0.71	0.22	1.19	1.08	26.90*	18.12*
M x Litter quality (L)	1.31	0.31	0.53	2.07	0.22	4.10*	2.33	25.64*	5.69*
M x D x C	0.02	0.11	0.20	0.49	0.08	1.44	1.19	1.01	0.29
M x D x L	0.03	0.14	0.47	1.05	0.21	0.38	0.84	3.77*	0.26
M x C x L	0.32	0.07	0.34	2.35	0.15	0.43	0.96	4.01*	1.78
M x D x C x L	0.06	0.09	0.12	0.43	0.12	0.72	1.37	0.57	0.31
	Test of between- subject effects								
D	59.61*	23.68*	78.46*	68.55*	19.79*	48.29*	34.08*	62.3*	15.03*
C	55.42*	40.09*	93.35*	50.86*	37.22*	102.80*	73.02*	108.96*	80.71*
L	76.24*	6.37*	35.78*	13.42*	1.91	4.21*	2.92	0.23	0.67
D x C	1.41	0.30	4.80*	0.52	0.01	0.85	4.34*	0.88	5.46*
D x L	1.20	0.70	0.65	2.14	0.28	0.56	1.20	0.79	0.40
C x L	0.38	0.23	1.52	13.76*	0.35	4.61	0.26	14.61*	0.18
D x C x L	0.73	0.27	0.66	0.53	0.06	1.24	0.90	0.56	0.15

* Significant

SAP were significantly (P < 0.001) greater at 5 cm depth. Whereas they were lowest at surface. The 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. However, SOC was significantly (P < 0.000) greater in top soil layer and lowest at 5 cm depth. It may be due to the loss of

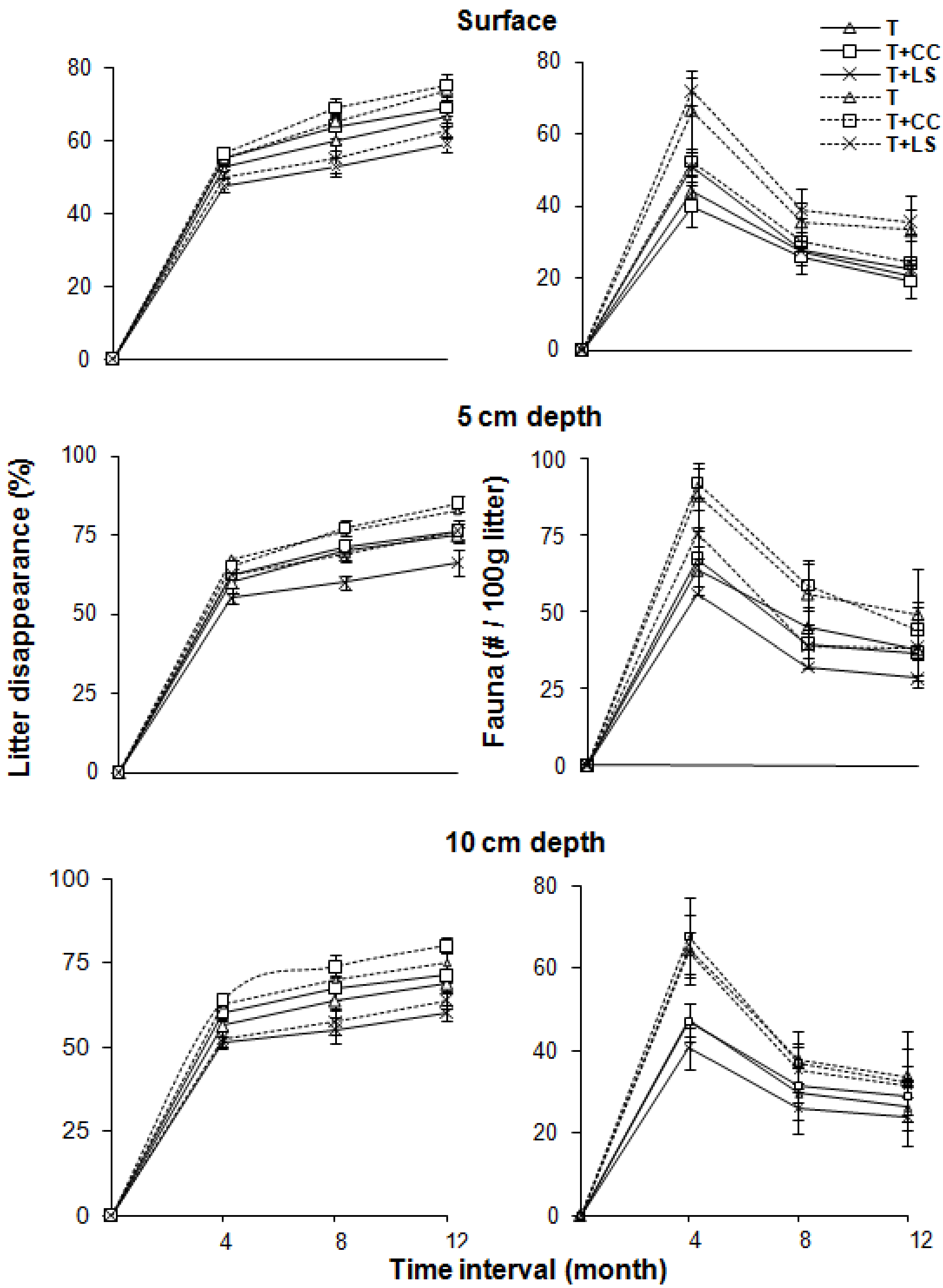

Figure 1. Kinetics of decomposition of litters of *Tecomella undulata* (T) and grasses (CC, LS) and associated soil fauna. CC: *Cenchrus ciliaris*; LS: *Lasiurus sindicus*; (—) outside canopy; (- - -) inside canopy in Jodhpur district of Rajasthan in India.

carbon as CO_2 by higher microbial population at 5 cm. About 60% of the carbon in organic materials are respired as carbon dioxide and 40% is retained as bacterial biomass (Ingham, 2007).

SOC, TSN, SAN, SNN and SAP changed significantly (P < 0.000) due to changes in months. About 2 to 4 fold higher nutrient concentrations were obtained after twelve month of decomposition as compared to initial values. Over the first four months of decomposition the increments in the soil nutrients were higher than the other periods of decomposition. 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 with soil depth and distance from the tree base. They also 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, ammonium 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 as 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 fungul and bacterial infected litter, some of the nitrogen bound in these microbes is mineralized and released as nitrogenous waste, and increase soil nutrient (Whitford *et al.*, 1982). Rao and Tarafdar (1992) reported vegetation cover, soil temperature and soil moisture as an 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 nitrate 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. Bacterial-feeding and predatory soil fauna are estimated to contribute directly and indirectly about 8 to 19% of nitrogen mineralization.

The test of between-subject effect of depth x canopy zone was significant for SOC and SAP. While the interaction between canopy and litter quality was significant (P < 0.000) for TSN. Whereas depth x canopy was significant (P < 0.000) for SAP.

Table 2. Correlation of soil faunal population with litter loss, organic carbon, total nitrogen and ammonium nitrogen, nitrate nitrogen, available phosphorus, soil respiration and soil dehydrogenase activity in *Tecomella undulata* based silvipasture system at different time intervals in Jodhpur district of Rajasthan in India.

Parameter	Decomopostion period (months)					
	4 (Oct.)		8 (Feb.)		I2 (June)	
	r- Value	P-Value	r- Value	P-Value	r- Value	P-Value
Litter loss	0.575	< 0.001	0.524	< 0.001	0.470	< 0.001
Organic carbon	0.125	ns	0.015	ns	0.103	ns
Total nitrogen	0.389	< 0.001	0.273	< 0.004	0.382	< 0.001
Ammonium nitrogen	0.372	< 0.001	0.289	< 0.002	0.295	< 0.002
Nitrate nitrogen	0424	< 0.001	0.286	< 0.001	0.348	< 0.001
Available phosphorus	0.324	< 0.001	0.436	< 0.001	0.426	< 0.001
Soil respiration	0.527	< 0.001	0.375	< 0.001	0.398	< 0.001
Soil dehydrogenase activity	0.486	< 0.001	0.527	< 0.001	0.336	< 0.001

Sampling months are in bracket; ns, Nonsignificant

Associated fauna showed a significant positive correlation (P< 0.05) with TSN, SAN, SNN and SAP during all decomposition periods (Table 2). A positive and significant correlation and interaction among litter-associated soil fauna and soil nutrients during decomposition period clearly demonstrated the impact of fauna on soil nutrients. The increased rates of nutrient mineralization suggested 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

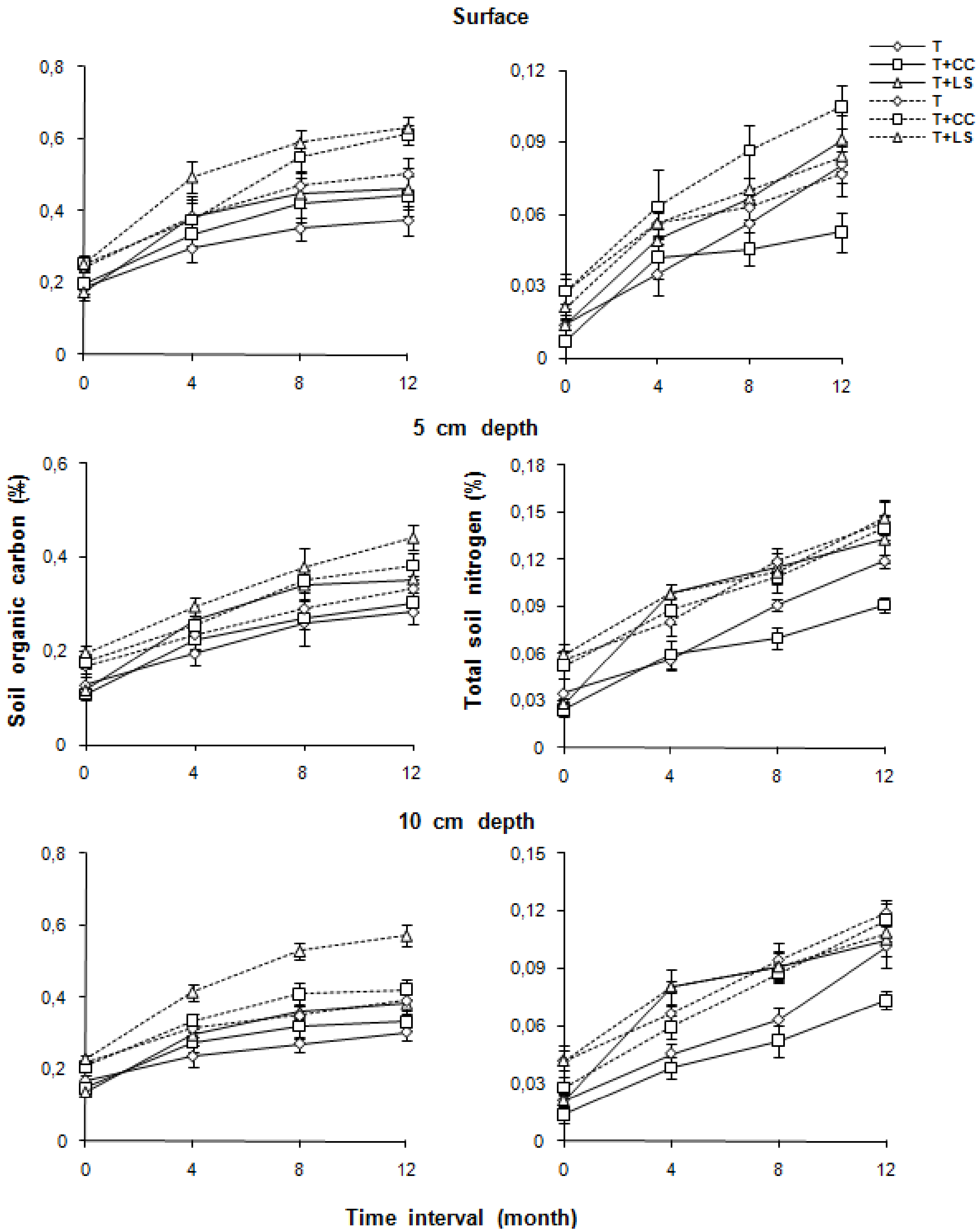

Figure 2. Changes in organic carbon and total nitrogen in litter decomposing soil of *Tecomella undulata* based silvipasture system. T: *Tecomella undulata*; CC: ***Cenchrus ciliaris***; LS: *Lasiurus sindicus*; (—) outside canopy; (- - -) inside canopy in Jodhpur district of Rajasthan in India.

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 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 reflected fauna-induced

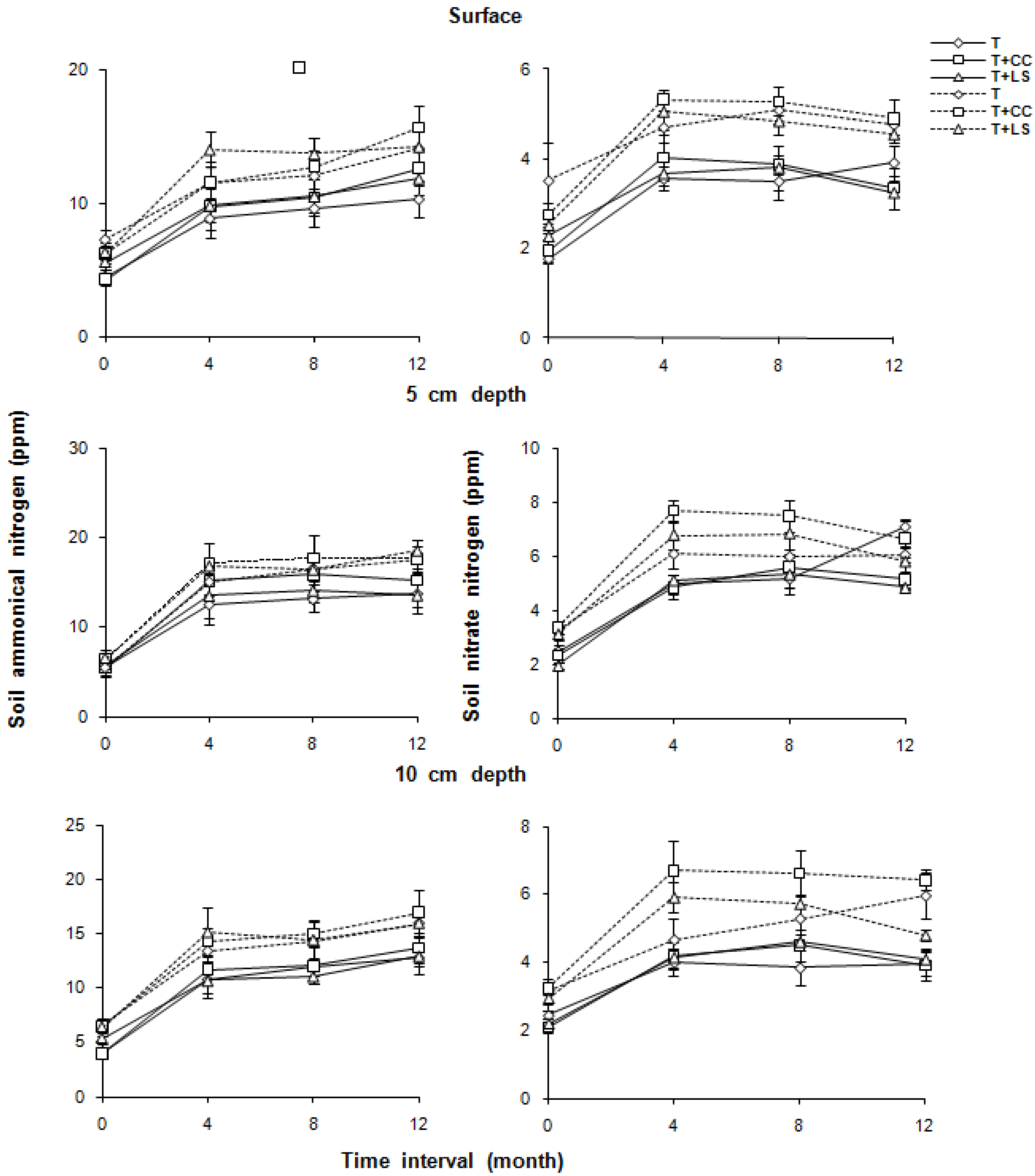

Figure 3. Changes in ammonium nitrogen and nitrate nitrogen in litter decomposing soil of *Tecomella undulata* based silvipasture system. T: *Tecomella undulata*; CC: ***Cenchrus ciliaris***; LS: *Lasiurus sindicus*; (—) outside canopy; (- - -) inside canopy in Jodhpur district of Rajasthan in India.

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 may increase the productivity of *T. undulata* based silvipasture system on a sustainable basis in dry areas.

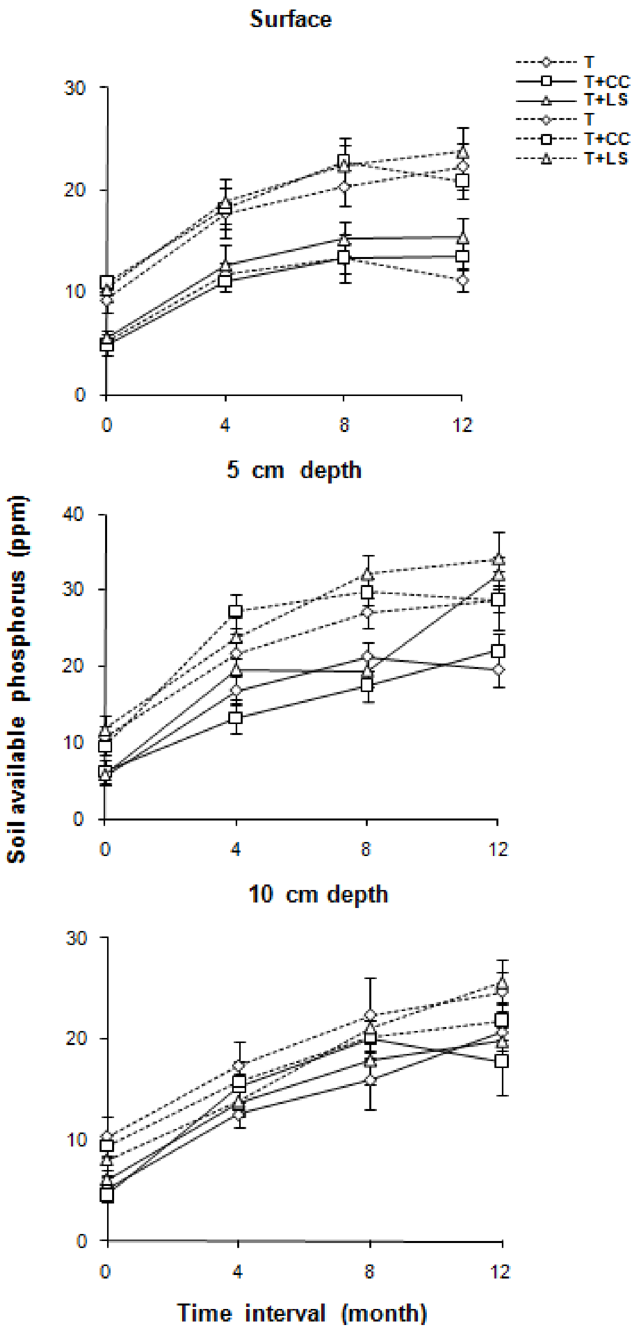

Figure 4. Changes in available phosphorus in litter decomposing soil of *Tecomella undulata* based silvipasture system.T: *Tecomella undulata*; CC: ***Cenchrus ciliaris***; LS : *Lasiurus sindicus*; (—) outside canopy; (- - -) inside canopy in Jodhpur district of Rajasthan in India.

Decomposition dependent biochemical changes

While considering the mean of all variables for canopy zone, SR and SDA were significantly ($P < 0.001$) higher inside the canopy as compared to outside (Figure 5). Depth-wise variation in SR and SDA were significantly ($P < 0.001$) greater at 5 cm. Whereas they were lowest at surface. SR and SDA varied significantly ($P < 0.001$) due to changes in months. Approximately 3 to 5 fold higher SR and SDA were found at all position over the first four months of intervals. However, they gradually decreased as a function of time interval but remained higher after the twelve months as compared to initial levels. 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). 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. Dehydrogenases give us information about the influence of natural environmental conditions of the microbial activities of the soil because they are more related to the metabolic state of microbial population. 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).

As dehydrogenase activity reflects the activity 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). They also observed significantly higher population of different microorganisms during July-August. Dormaar *et al.* (1984) observed low activities of dehydrogenase during summer in mixed prairie of Canada. In many desertic soils, higher temperatures and soil drying during summer months bring down the microbial population to very low levels (Sasson, 1972) resulting in low dehydrogenase activities. 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 months of rainy season at litter decomposing sites.

The test of within-subject effects of month x canopy, month x litter quality were significant ($P < 0.001$) for SR and SDA. Whereas month x depth, month x depth x litter quality and month x canopy x

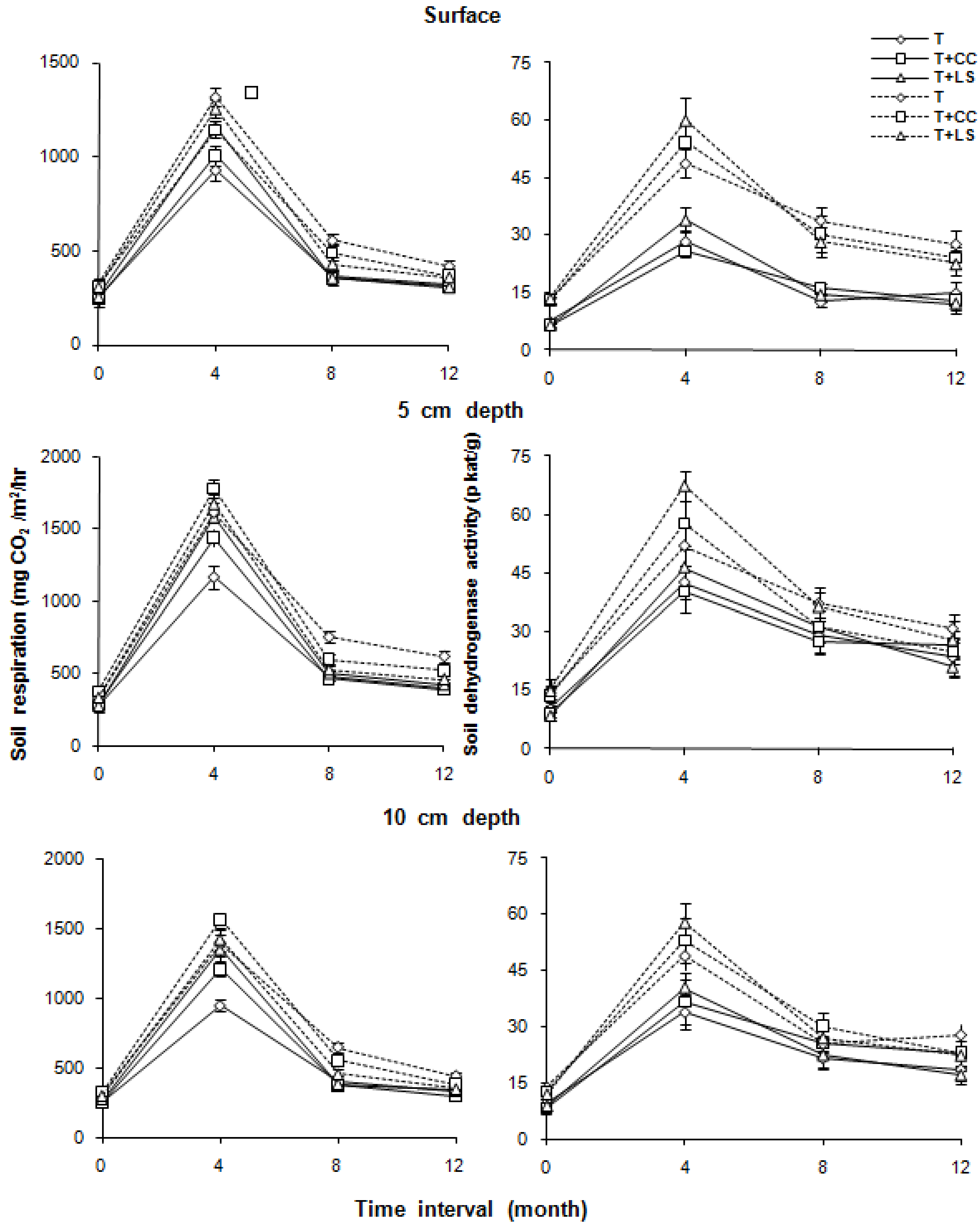

Figure 5. Changes in soil respiration and dehyrogenase activity in litter decomposing soil of *Tecomella undulate* based silvipasture system. T: *Tecomella undulat*; CC: ***Cenchrus ciliaris***; LS: *Lasiurus sindicus*; (—) outside canopy; (- - -) inside canopy in Jodhpur district of Rajasthan in India.

litter quality were only significant ($P < 0.001$) for SR. While the test of between-subject effect of canopy x litter quality and depth x canopy interaction was significant ($P < 0.001$) for SR and SDA respecively. Associated fauna showed a significant positive correlation ($P < 0.05$) with SR and SDA during all decomposition periods (Table 2). A positive and significant correlation and interaction among litter-associated soil fauna, soil respiration and dehydrogenase activity during decomposition period clearly demonstrated the impact of fauna on biotic activities. The changes in soil respiration and dehydrogenase activity along with changes in soil faunal population disclosed 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. High fertility and nutrient status of the soil may be due to the presence of the diverse soil fauna which may assist in humus formation. A positive and significant correlation and interaction among litter-associated soil fauna, litter decomposition, soil chemical and biochemical properties during decomposition suggested the impact of fauna on soil health

CONCLUSIONS

The colonization of microarthropods have a significant role in trapping energy and nutrients from decomposing litter and enhancing biological activity in soil. The present findings may be useful in restoration and enrichment of degraded level in dry areas through management of litter resources and soil biota.

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