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# FAUNA – ASSISTED LITTER DECOMPOSITION AND ITS IMPACT ON CHEMICAL AND BIOLOGICAL HEALTH OF *BALANITES AEGYPTIACA* BASED SILVIPASTURE SYSTEM

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## ABSTRACT

Interactions among soil fauna, litter diversity, soil nutrients and biochemical properties during litter decomposition in *Balanites aegyptiaca* (T) based silvipasture system of tropical desertic land of India was studied. The system has *Cenchurus ciliaris* (CC) and *Lasiurus sindicus* (LS) grasses. 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 determined in litter decomposing soil. Faunal association and litter decomposition were maximum in T+LS litter. The faunal population and litter decomposition were significantly ($P < 0.001$) higher inside the canopy of tree and at 5 cm depth. SOC, TSN, SNN, SR and SDA were significantly ($P< 0.05$) greater in the mixture of tree and grass litters than tree litter alone. TSN, SAN, SNN, SAP, SR and SDA were significantly ($P< 0.05$) higher under the canopy zone. However, SOC was significantly ($P< 0.05$) higher at surface and minimum at 5 cm. A positive and significant correlation among litter-associated fauna, litter decomposition, chemical and biochemical properties during decomposition demonstrated the interacting effects of fauna on functional aspects of soil in *Balanites aegyptiaca* based silvipasture system. Therefore, the strategy may be adopted for decomposition of litters and improvement of soil systems employing potentials of below ground biological resources.
**Keywords :** Desert region, fauna, soil nutrients, soil respiration, soil dehydrogenase, silvipasture system.

## INTRODUCTION

Various efforts have been made in the past to understand the role of invertebrates in soil processes. Over exploitation and mismanagement of land resources had devastating impacts on biodiversity. 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. Biological functions such as the maintenance of soil fertility are based on the action of organisms including soil 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 is estimated that 80-90% of net primary production in terrestrial ecosystems is recycled by decomposers. Since a great proportion of the

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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. It provides basic clues in understanding and estimating productivity, energy-flow and nutrient cycling.

Faunal biomass is a key component for nitrogen mineralization (Anderson et al., 1985). Thus soil cannot perform ecosystem services without below-ground bioresources. Soil organisms affect primary production directly by root-feeding and indirectly through their contribution to decomposition and nutrient mineralization. Microbiel-grazing mesofauna affect growth and metabolic activities of microbes and alter community composition, thus regulatic decomposition rate of organic matter (Whitford *et al*., 1982; Seastedt, 1984). Litter decomposition is affected by litter quality and climatic condition (Frouz, 2008; Jimenez et al., 2009). Increasing rates of litter decomposition accelerate nutrient cycling and improve soil quality (Knoepp *et al.,* 2000). Diverse and active soil biota could create 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. These properties or functions of soil fauna can be used to indicate soil health.

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. Due to limited resource availability in arid and semi-arid regions, the benefits of the agroforestry system largely depend upon efficient and judicious management of soil and water resources. 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 of these nutrient deficient lands. *Balanites aegyptiaca* is a common tree of tradition agroforestry system of the northwestern arid area of India. The young leaves and shoots provide a useful livestock fodder. Their fruits are commonly eaten by local people, known as "desert date". The bark, leaves, fruits and seeds are all althelmintic and purgative. In northwestern arid area of India the bark is used for de-worming cattle. The pulp of fruit contains saponin and is used for cleaning silk and cotton cloth. There is no information about links between soil faunal bioresources and sustainability of such agroforestry tree species. Therefore, it appears necessary to evaluate the functions of soil invertebrates in nutrient establishment in arid pedoecosystem through litter decomposition. Management of such traditional pedoecosystem may optimize the below-ground biological activities for sustainable land use in arid environment.

## MATERIALS AND METHODS

### Site and environmental condition

Studies were conducted in Jodhpur district of Rajasthan. It is situated between $26^0$ 45' North latitude and $72^0$ 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 evapotraspiration 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. The maximum temperature in summer was $41.5^0$C and the minimum temperature in winter was $10^0$C during the period of 2004-2005. The diurnal temperature variations were high, both in winter and summer months and this variation was narrow during the monsoon months. Maximum temperature was recorded in June which suddenly drops down to about $27^0$C during onset phase of monsoon. But there was again rise in temperature during post monsoon period and decreased further in winter. The annual rainfall in this region varied from 0.2 to 140 mm. The south west monsoon, which begins in the last week of June, lasts till middle of September. Sometimes there was a little rainfall in the winter season also. The average number of rainy days in this region was 15 to 21. Average wind speed was 14 to 18 km/$h^{-1}$. Wind speed reaching as high as 60-70 Km/$h^{-1}$ was common in summer. The winds were strongest during the months of June and July. The wind directions were east to north westerly in winter and west to south westerly in summer. Arid region experiences high rate of potential evapotranspiration. The daily potential evapotranspiration ranged from 6.8-13 mm in summer, 5.4-6.7 mm during monsoon season and 3.2-4.1 mm in winter. Potential evapotranspiration was exceedingly higher than the precipitation resulting in perpetual water deficit throughout the year. Properties of temperature, relative humidity, rainfall and evapotranspiration are shown in Fig. 1.

### Experimental Procedures

The leaf litters of *Balanites aegyptiaca* (T) and *Cenchurus cilliaris* (CC) and *Lasiurus sindicus* (LS) grasses were harvested, chopped and allowed to dry. A particular amount of tree litter alone and alongwith 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 *Balanites aegyptiaca* 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 with Tullgren funnel, identified and counted.

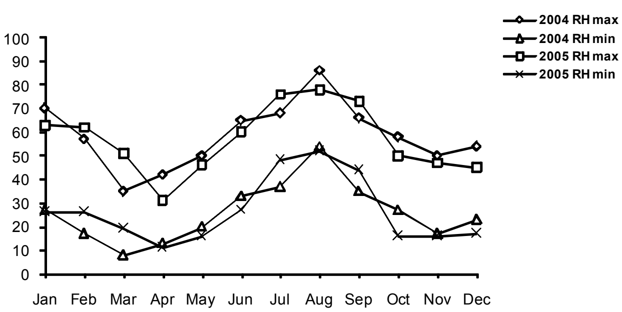
Decomposition associated changes in chemical and biochemical properties of soil such as soil organic carbon (SOC), total soil nitrogen (TSN), soil ammonical nitrogen (SAN), soil nitrate nitrogen (SNN), soil available phosphorous (SAP), soil respiration (SR) and soil dehydrogenase activity (SDA) were analyzed as described by Anderson and Ingram (1993). Soil organic carbon was determined by Walkley-Black digestion method. The total nitrogen was estimated by Kjeldahl method. Ammonical nitrogen, nitrate nitrogen and available phosphorous were analyzed spectrophotometrically. Soil respiration and soil dehydrogenase activity were determined using potassium hydroxide (KOH) and triphenyl tetrazolium chloride (TTC) respectively.

The data recorded from different experiments on decomposition, nutrient dynamics and biochemical changes associated with faunal population were analyzed employing statistical package. Since all the observations for the same study site were available for different time intervals, the data was processed by repeated-measure design to test the level of significance.

**Table 1. Repeated measure ANNOVA of different parameters in *Balanites aegyptiaca* based litter decomposing silvipasture system**

| Repeated measure ANOVA | Litter disappearance (%) | Fauna (# /100g litter) | 0rganic 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) | 229.76* | 154.97* | 23.04* | 37.22* | 21.29* | 4.212* | 17.17* | 651.23* | 269.06* |
| M x Depth (D) | 1.89 | 7.80* | 0.15 | 0.96 | 0.34 | 0.25 | 0.51 | 5.63* | 064 |
| M x Canopy zone (C) | 3.16* | 7.13* | 0.02 | 1.87 | 0.26 | 0.11 | 0.71 | 13.05* | 16.88* |
| M x Litter quality (L) | 0.35 | 5.73* | 0.26 | 0.14 | 0.51 | 0.02 | 0.22 | 24.07* | 5.68* |
| M x D x C | 0.30 | 0.30 | 0.01 | 0.12 | 0.12 | 0.12 | 0.44 | 25.38* | 0.65 |
| M x D x L | 0.83 | 0.74 | 0.16 | 0.20 | 0.23 | 0.11 | 0.23 | 3.4* | 0.26 |
| M x C x L | 0.14 | 0.05 | 0.26 | 0.22 | 0.45 | 0.06 | 0.70 | 2.95* | 1.75 |
| M x D x C x L | 0.09 | 0.44 | 0.29 | 0.40 | 0.16 | 0.08 | 0.33 | 5.97* | 0.33 |
| | **Test of between- subject effects** | | | | | | | | |
| D | 164.72* | 98.46* | 25.08* | 13.22* | 10.77* | 7.57* | 12.33* | 7.56* | 15.22* |
| C | 98.79* | 75.04* | 22.03* | 29.16* | 14.67* | 21.67* | 40.98* | 32.09* | 76.22* |
| L | 72.88* | 48.34* | 4.49* | 1.06 | 2.24 | 3.89* | 2.17 | 0.63 | 0.69 |
| D x C | 0.44 | 0.58 | 0.79 | 0.53 | 0.01 | 0.53 | 0.15 | 7.13* | 0.42 |
| D x L | 27.25* | 11.54* | 0.66 | 0.81 | 0.20 | 0.35 | 0.14 | 0.99 | 0.41 |
| C x L | 1.48 | 0.56 | 2.24 | 0.33 | 0.06 | 0.72 | 0.19 | 3.47* | 0.18 |
| D x C x L | 1.01 | 1.99 | 0.45 | 0.79 | 0.07 | 0.22 | 0.21 | 2.06 | 0.12 |

*Significant



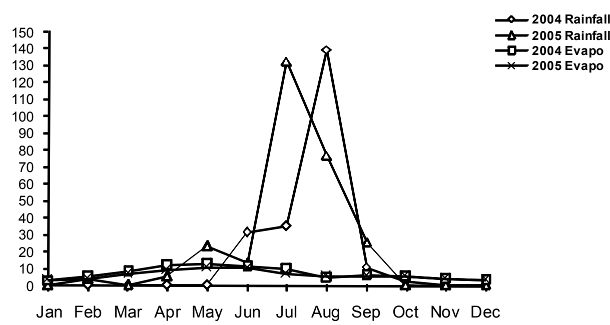




**Fig.1 : Changes in temperature, relative humidity, rainfall and evapotranpiration.**

Duncan's Multiple Range Test (DMRT) was performed 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

### Quantification and kinetics of fauna associated litter decomposition

The faunal population and litter decomposition were maximum in T+LS litter (Table 1 and Fig. 2). While considering the mean of all variables for canopy zone, faunal association and litter disappearance was higher inside the canopy as compared to outside. Depth-wise faunal association and litter decomposition were highest at 5 cm and lowest at surface. Faunal population and litter disappearance varied significantly ($P < 0.001$) due to changes in months. They were higher during the first four months of decomposition and subsequently declined as a function of time interval.

The test of within-subject effects of month x canopy interactions was significant ($P < 0.05$)

**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 *Balanites aegyptiaca* based silvipasture system at different time intervals**

| Parameter | Decomopostion period (months) | | | | | |
|---|---|---|---|---|---|---|
| | 4 (Oct.) | | 8 (Feb.) | | I2 (June) | |
| | r- Value | P-Value | r- Value | P-Value | r- Value | P-Value |
| Litter loss | 0.725 | < 0.001 | 0.679 | < 0.001 | 0.648 | < 0.001 |
| Organic carbon | 0.036 | NS | 0.035 | NS | 0.086 | NS |
| Total nitrogen | 0.427 | < 0.001 | 0.312 | < 0.001 | 0.232 | < 0.01 |
| Ammonical nitrogen | 0.462 | < 0.001 | 0.347 | < 0.001 | 0.249 | < 0.009 |
| Nitrate nitrogen | 0.365 | < 0.001 | 0.260 | < 0.007 | 0.235 | < 0.014 |
| Available phoshorus | 0.336 | < 0.001 | 0.266 | < 0.005 | 0.270 | < 0.005 |
| Soil respiration | 0.218 | < 0.023 | 0.300 | < 0.002 | 0.293 | < 0.002 |
| Soil dehydrogenase activity | 0.604 | < 0.001 | 0.414 | < 0.001 | 0.326 | < 0.001 |

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

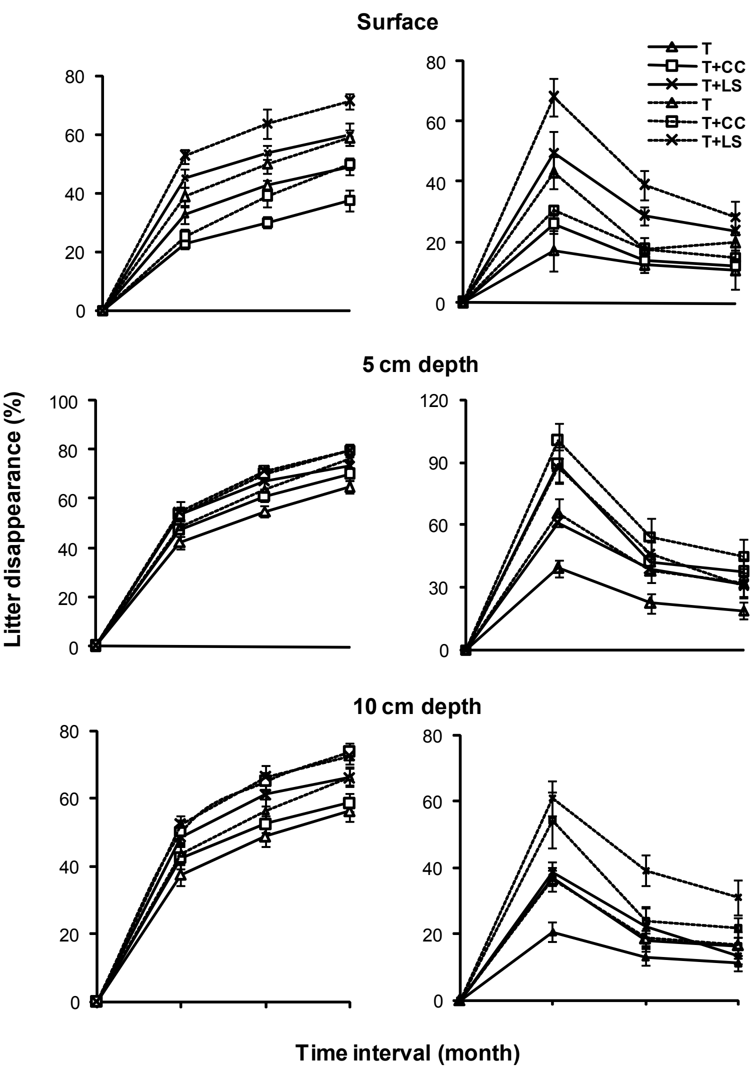



Fig. 2: Kinetics of decomposition of litters of *Balanites aegyptiaca*(T) and grasses (CC, LS) and associated soil fauna. CC : *Cenchrus ciliaris*; LS : *Lasiurus sindicus*; ( ) outside canopy; (- - -) inside canopy.

for both litter fauna and litter disappearance. However, month x depth and month x litter quality interactions were significant ($P < 0.05$) for litter disappearance. The test of between subject-effect of depth x litter quality was significant ($P < 0.05$) for both litter fauna and litter disappearance. Litter decomposition and associated fauna showed a significant positive correlation ($P< 0.001$) during all decomposition periods (Table 2).

## Decomposition dependent chemical changes

### *Soil organic carbon*

Soil organic carbon (SOC) varied significantly ($P < 0.001$) due to changes in litter. SOC was maximum in T + CC litter. Considering the mean of all variables for canopy zone, SOC was significantly ($P < 0.001$) higher inside the canopy as compared to outside. It was highest in top soil layer (Table 1 and Fig. 3) and lowest at 5 cm depth. SOC changed significantly ($P < 0.001$) due to changes in months. About 1.5 to 3 fold higher SOC was obtained after twelve month of decomposition as compared to initial values. Correlation between fauna and SOC was non- significant (Table 2).

### *Total soil nitrogen*

TSN did not varied significantly due to changes in litter quality. While considering the mean of all variables for canopy zone, TSN was

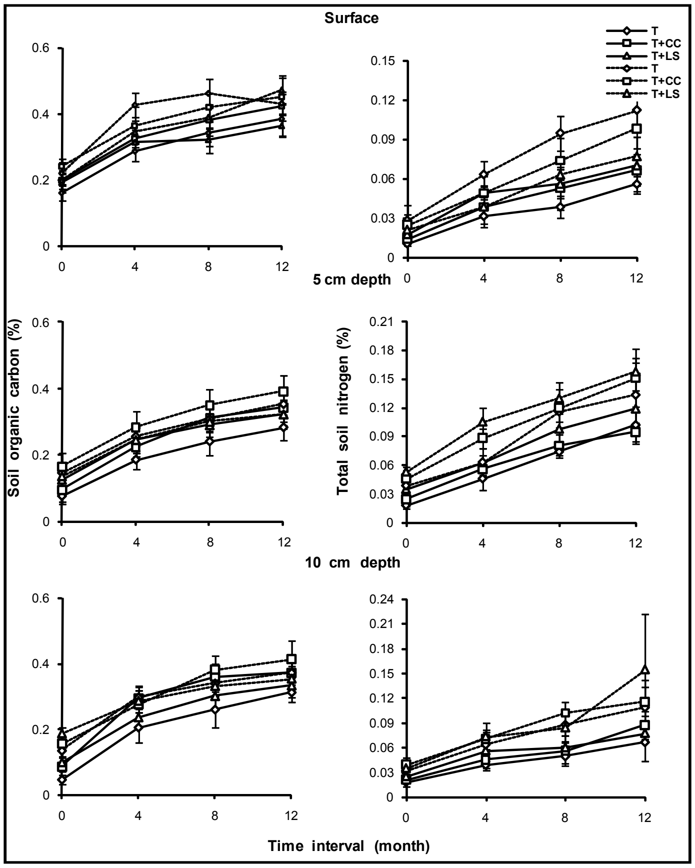



Fig. 3. Changes in organic carbon and total nitrogen in litter decomposing soil of *Balanites aegyptiaca* based silvipasture system. T: *Balanites aegyptiaca*; CC : *Cenchrus ciliaris* ; LS : *Lasiurus sindicus*; ( ) outside canopy; (- - -) inside canopy.

significantly ($P < 0.001$) higher inside the canopy as compared to outside the canopy (Table 1 and Fig. 3). It was significantly ($P < 0.001$) greater at 5 cm depth and lowest at surface. TSN differed significantly ($P < 0.001$) due to variation in months. About 2 to 4 fold higher TSN was obtained after the period of twelve months as compared to initial values. There was a significant ($P < 0.001$) positive correlation between the litter-associated fauna and TSN at different decomposition durations (Table 2).

***Soil ammonical nitrogen***

SAN did not differ significantly due to changes in litter qualities. However, 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 Fig. 4). Depth-wise variation in SAN was significantly ($P < 0.001$) greater at 5 cm and lowest at surface. SAN varied significantly ($P < 0.001$) due to changes in months. It increased about 2 to 4 fold after twelve months of decomposition. Interaction terms were not significant. Litter-associated fauna showed a significant positive correlation ($P < 0.001$) with SAN at fourth and eight months of decomposition (Table 2).

***Soil nitrate nitrogen***

SNN varied significantly ($P < 0.001$) due to changes in litter quality. Maximum SNN was found in T + CC litter. Whereas the other two quantity of litter show almost similar values of SNN (Table 1 and Fig. 4). Considering the mean of all variables for canopy zone, SNN was significantly ($P < 0.001$) higher inside the canopy as compared to outside the tree. After averaging the data for all soil layers, SNN was highest at 5 cm depth and lowest at top soil layer. Approximately 1.5 to 2 fold greater 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 different decomposition periods (Table 2).

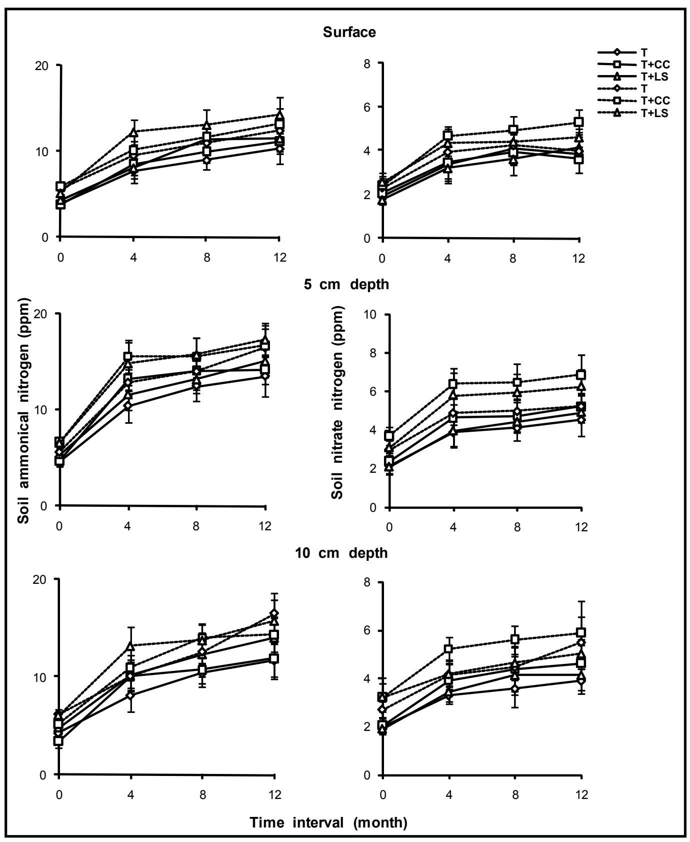



Fig. 4. Changes in ammonical nitrogen and nitrate nitrogen in litter decomposing soil of *Balanites aegyptiaca* based silvipasture system. T : *Balanites aegyptiaca;* CC : *Cenchrus ciliaris*; LS : *Lasiurus sindicus*; ( ) outside canopy; (- - -) inside canopy.

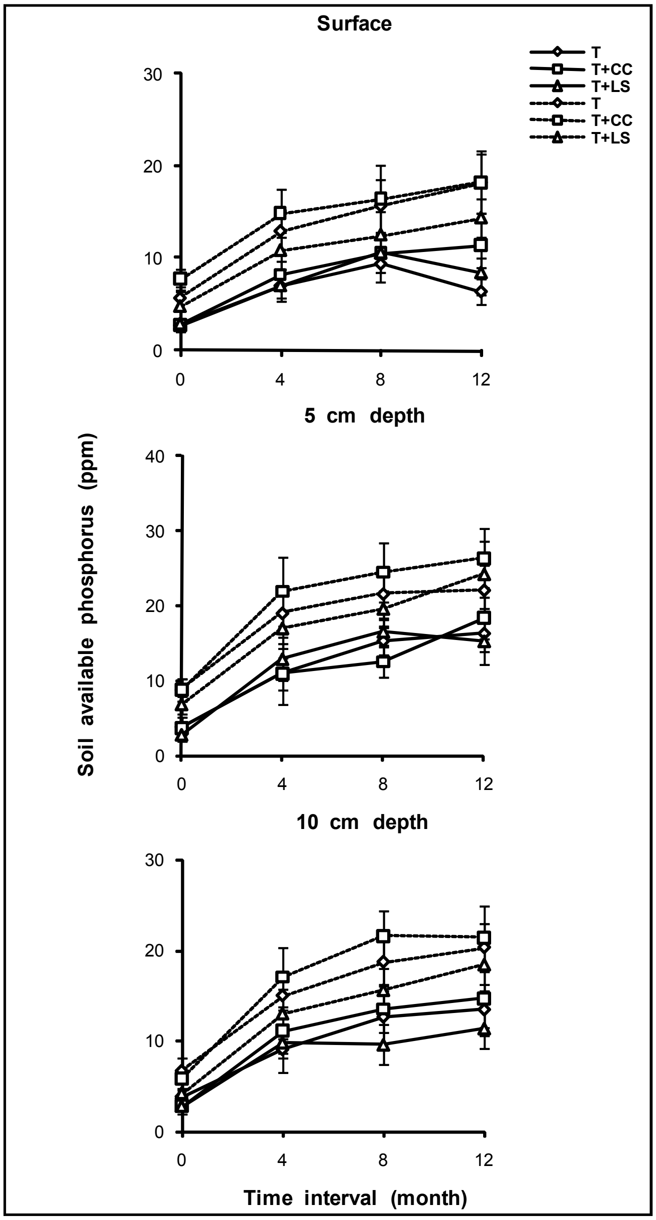



Fig. 5: Changes in available phosphorus in litter decomposing soil of *Balanites aegyptiaca* based silvipasture system. T : *Balanites aegyptiaca*; CC : *Cenchrus ciliaris* ; LS : *Lasiurus sindicus*; ( ) outside canopy; (- - -) inside canopy.

## *Soil available phosphorus*

SAP did not varied significantly due to change in litter qualities. SAP was significantly ($P < 0.001$) higher inside the canopy than outside the canopy when it was considered with the mean of all variables for horizontal position. SAP was highest at 5 cm depth (Table 1 and Fig. 5) and lowest at surface. A significant ($P < 0.001$) alteration in SAP was observed due to changes in months. About 2 to 4 fold higher SAP was obtained at all positions as compared to initial

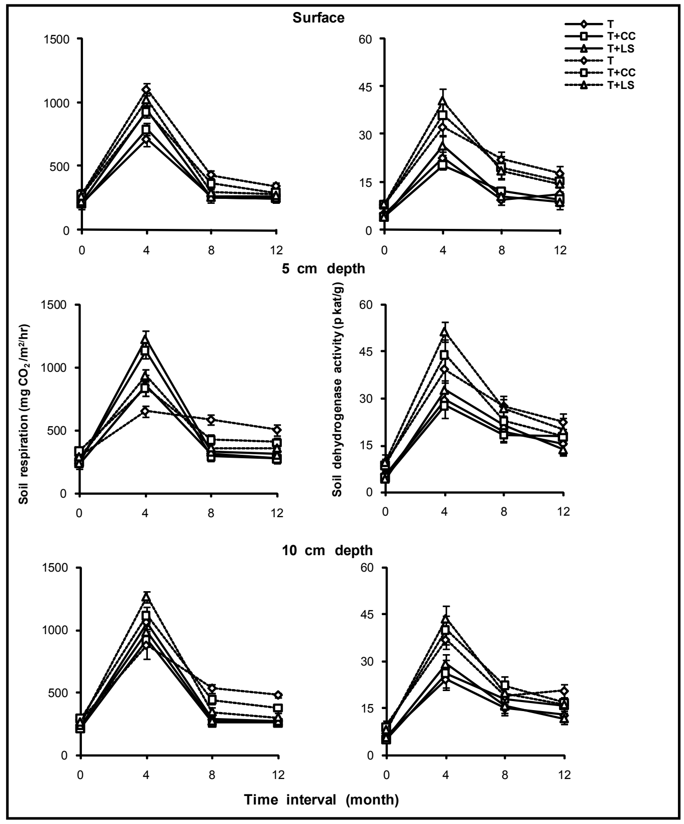



Fig. 6. Changes in soil respiration and dehyrogenase activity in litter decomposing soil of *Balanites aegyptiaca* based silvipasture system. T:*Balanites aegyptiac*;CC: *Cenchrus ciliaris*;LS :*Lasiurus sindicus*; ( ) outside canopy; (- - -) inside canopy.

values. There was a significant ($P < 0.05$) positive correlation between the litter-associated fauna and SAP at all decomposition periods (Table 2).

## Decomposition dependent biochemical changes

### *Soil respiration*

SR did not vary with the variation in litter quality (Table 1 and Fig. 6). While considering the mean of all variables for canopy zone, it was significantly ($P < 0.001$) higher inside the canopy as compared to outside the canopy. Depth-wise variation in SR was maximum at 5 cm and minimum 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 during the first four months of decomposition. However, it gradually decreased as a function of time interval and remained still higher at twelve months as compared to initial levels. All the interaction terms of the test of within-subject effects were significant ($P < 0.05$). The test of between-subject effect of depth x canopy and canopy x litter quality were significant ($P < 0.05$). A significant positive correlation ($P < 0.001$) between SR and litter fauna was found at different decomposition periods ( Table 2).

***Soil dehydrogenase activity***

SDA did not differ significantly due to changes in litter quality (Table 1 and Fig. 6). However, significantly ($P < 0.001$) higher SDA was found inside the canopy zone than outside the tree 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 maximum at 5 cm depth and minimum in top soil layer. SDA varied significantly ($P < 0.001$) as a function of month. It increased about 3 to 4 fold over the first four months of decomposition. However, it declined slowly as a function of decomposition period. The test of within-subject effects of month x canopy and month x litter quality were significant ($P < 0.001$). litter-associated soil fauna showed a significant positive correlation ($P < 0.05$) at all decomposition periods (Table 2).

## DISCUSSION

### Fauna associated litter decomposition

In *Balanites aeyptiaca* based silvipasture systems the faunal population associated with litter was maximum with T + LS litter in comparison to other quality of litters (Fig. 2). However, the litter disappearance was more or less equal in all quality of litters. Higher density of fauna in mixed litter may be due to its diverse chemical composition attracting soil fauna as compared to single species litter. Abundance and activity of invertebrates are influenced by the initial litter chemistry. 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. Hence higher faunal population associated with the mixture of litters was observed.

Litter decomposition and associated faunal population were higher inside the canopy of tree than outside the canopy 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. 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 is found to increase with increasing amounts of rainfall and humidity. The highest intensity of organic matter decomposition was observed under conditions of moderate soil temperature (30°C) and moisture content (60-80 %) (Kononova, 1975). Nearly similar climatic condition was found during first four 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 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 demonstrated 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 decompostion.

Madge (1965) documented higher litter disappearance during the wet season, which may be due to the activity of dense population of mites and collembolans. Schowalter et al., (1991) reported higher microarthropods densities during wet months. The faunal association and litter decomposition was higher in lower layers than top soil 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 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 Gulledge (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 signiûcantly 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 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-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 (Fig. 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.

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 content with soil depth and distance from the tree base. They showed a significant decrease in soil nitrogen and significant changes in phosphorus 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 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 soil fauna 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 status (Whitford *et al*., 1982). Organic matter in soil is the most important fraction that supports microbial populations. Microbial biomass, acts as the engine for organic matter turnover and nutrient release. 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 showed that all the parameters such as soil organic carbon, soil total nitrogen, soil ammonical nitrogen, soil nitrate nitrogen and soil available phosphorous differed significantly ($P < 0.05$) due to changes in month, soil depth and canopy zone. A positive and significant correlation and interaction among litter associated soil fauna and soil nutrients during decomposition 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 be supported by the report of Maity and Joy (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 greater 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 present strategy may be adopted for decomposition of litters and improvement of soil. Therefore, the litter and below-ground fauna management may increase the productivity of *Acacia senegal* based silvipasture system on a sustainable basis in dry region.

**Biochemical changes during decomposition**

Soil respiration and soil 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 (Fig. 6). Soil respiration and dehydrogenase activity were 3-5 fold higher at all positions after four months of decomposition suggesting improvement in soil biological activities. Differences in soil respiration rates among distant sites may be due to climatic differences (Raich and Potter, 1995). Other factors which potentially inûuenced 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).

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. 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. In many desertic 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 activities. In winter, the low dehydrogenase activity might be due to the fact that the microorganisms remain in a state of biochemical inactivity (Milosevic, 1988). This was the main reason why there was gradual decrease in soil dehydrogenase activity after four month of rainy season at litter decomposing sites.

Repeated measure ANOVA showed that soil respiration and dehydorogenase activity differed ($P < .05$) 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 demonstrated the impact of fauna on biotic activities. The changes in soil respiration and dehydrogenase activity alongwith the changes in soil faunal population disclosed the possibility of a strong relationship between soil faunal activity and functional aspects of soil. Hense, the increase in faunal population with the increase in soil respiration and dehydrogenase activity reflected the role of soil fauna in improving functional aspects of soil in silvipasture systems of arid region.

## CONCLUSIONS

The nutrient enrichment of the soil was due to mixing and decomposition of greater volume of litters through soil biota. A positive and significant correlation and interaction among litter associated soil fauna, soil nutrients, soil respiration and dehydrogenase activity during decomposition period clearly demonstrate the impact of fauna on soil nutrients, microbial and other biotic activities. It reflects fauna-induced increase in microbial and decomposition activities in soil. Therefore, the role of fauna may be important for soil health and sustainability of dry land in arid zone. This strategy may be adopted for decomposition of litters and improvement of soil systems employing potentials of below ground biological resources. The study may help in understanding the fauna – tree interaction for litter decomposition and improvement of soil system through organic waste resource management. It may increase the productivity of dry land on a sustainable basis in arid region of Rajasthan.

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