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Spatial distribution and seasonal abundance of soil mites and collembola in grassland and *Leucaena* plantation in a semi-arid region

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Abstract: Based on an analysis of spatial distribution and seasonal abundance of soil mites and collembola in two distinct systems (grassland and *Leucaena* plantation) in a semiarid region, highly significant negative correlation (r = 0.72) was found between faunal population and soil temperature in grassland, whereas highly significant positive correlation (r = 0.96) was detected in *Leucaena* plantation. The population peaks were achieved in different seasons in these systems, winter in grassland (5.7 x 10^4 m^{-2}) and monsoon in *Leucaena* plantation (6.2 x 10^4 m^{-2}). The general distribution pattern of fauna also differed, tendency towards aggregation in grassland and random nature in *Leucaena* plantation.

Resumen: Con base en un análisis de la distribución espacial y la abundancia estacional de los ácaros y colémbolos del suelo en dos sistemas diferentes (plantación de *Leucaena* y pastizal) en una región semiárida, se encontró una correlación negativa y altamente significativa (r = 0.72) entre la población faunal y la temperatura del suelo en el pastizal, mientras que en la plantación de *Leucaena* se detectó una correlación altamente significativa y positiva (r = 0.96). Los picos poblacionales se alcanzaron en diferentes temporadas en estos dos sistemas: en el invierno en el pastizal (5.7 × 10^4 m^{-2}) y en el monzón en la plantación de *Leucaena* (6.2 × 10^4 m^{-2}). El patrón general de distribución de la fauna también difirió, con una tendencia hacia la agregación en el pastizal, mientras que en la plantación de *Leucaena* fue de naturaleza aleatoria.

Resumo: Com base numa análise da distribuição espacial e abundância sazonal dos acarinos e dos colembola do solo em dois sistemas distintos (plantações de *Leucaena* e pastagem) numa região semi-árida, determinou-se uma correlação negativa altamente significativa (r = 0,72) entre a população da fauna e a temperatura do solo na pastagem enquanto que para a plantação de *Leucaena* a correlação detectada era altamente significativa e positiva. Os picos de população atingiram-se em diferentes estações nestes sistemas, Inverno na pastagem (5,7 x 10^4 m^{-2}) e monção na plantação de Leucaena (6,2 x 10^4 m^{-2}). O padrão de distribuição geral da fauna também foi diferente, com uma tendência para a agregação na pastagem e casual na plantação de *Leucaena*.

Key words: Collembola, grassland, *Leucaena*, mites, seasonal abundance, spatial distribution.

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Introduction

The recent renewed interest in soil biodiversity is on account of the usefulness of soil organisms serving as bio-indicators of soil health in the present scenario, and the increasing realization about the general decline in the productive base of the land and urgent need for corrective measures (Pankhurst *et al.* 1998). Among soil arthropod fauna, soil mites and collembola are known to dominate the Indian soils (70-97%) and indicate the status of soil health and fertility (Veeresh 1983). Adequate knowledge of spatial pattern and seasonal population buildup of such fauna is considered desirable for understanding their ecology and role in decomposition process in major land use systems of a region for understanding the sustainability issues (Badejo *et al.* 1997). Generally, most of the collembola and mites tend to aggregate in soil and mathematical approaches are used for developing indices in order to reach to a logical explanation for their spatial distribution in ecosystem (Clarke & Evans 1954; Lloyd 1967).

Although grassland and *Leucaena* plantation (an exotic) hold promise in meeting the forage and other demands of the society besides land conservation under totally rainfed situations in semiarid regions of India, there is a lack of information on spatial distribution and seasonal abundance of such fauna inhabiting these systems. This study aimed to analyze population buildup of soil collembola and mites in two distinct land use systems – dense plantation of *Leucaena leucocephala* and a grassland in the semiarid Bundelkhand region of the country.

Materials and methods

Study site

The study was carried at Jhansi (25°27′N latitude and 78°35′E longitude and about 275 m above mean sea level) during 1995–96. During this period the average annual rainfall was 900 mm, over 70 percent rain received during July-September. May was the hottest month with mean maximum temperature of 41.3°C. January was the coldest month with mean minimum temperature of 5.6°C. The soil of the area is red with patches of red and black mixed soil, with semi-rocky substratum at places. Its texture is sandy clay loam to sandy clay and its nutrient status low to medium.

The grassland vegetation consisted of a mixed stand having five major perennial grass species viz., *Cenchrus ciliaris* Linn., *Chrysopogon fulvus* (Spreng) Chiov., *Dichanthium annulatum* (Forsk.) Stapf, *Heteropogon contortus* (L.) Beauv. Ex. Roem. and Schult, *Sehima nervosum* (Willd.) Stapf. *Leucaena leucocephala* (Lam.) de Wit plantation (2500 trees ha^{-1}) was over 15 years of age.

Methods

In order to quantify microarthropod population in soil (0-10 cm), soil samples were collected at monthly (in the 1st week) interval from each system, using a cylindrical core sampler (diameter 5 cm). Each core was carefully sealed in a separate polythene bag and taken to laboratory for extraction. Berlese-Tullgren Funnel (dynamic) method with suitable modifications was used for the extraction of microarthropods and the fauna were collected in vials on account of their negative phototropic behavior. The microarthropods were separated from the collecting vials by means of a fine camel hairbrush under a microscope. After sorting, collembola and mites were preserved in 70 per cent alcohol and Oudemen's fluid, respectively. Faunal population was estimated per square meter using the following formula (Singh *et al.* 1978):

$$P = 10000\ X / 0.785\ d^2$$

where, P = population m^{-2}, X = population $sample^{-1}$; d = diameter of sampler.

During sampling soil temperature was measured *in situ* by soil thermometer. Small quantity of soil was taken for determination of moisture content using gravimetric method.

The densities of collembola and mite population were transformed to square root (x + 0.5) for comparing the differences. The mean and variance (σ^2) of each group were calculated in order to determine the patchiness of the distribution (σ^2 = m: random; σ^2 > m: aggregated) as proposed by Taylor (1961). The corrections of

Lloyd (1967) were considered and mean crowding (m^*) was calculated as under:

$$m^* = m + (\sigma^2/m-1) = m + m/k$$

where, k = dispersion parameter.

The patchiness of a population is given by the proportion by which mean crowding m^* exceeds mean density (m) and it is equal to the reciprocal of k, dispersion parameter

$$m^*/m = 1+1/k$$

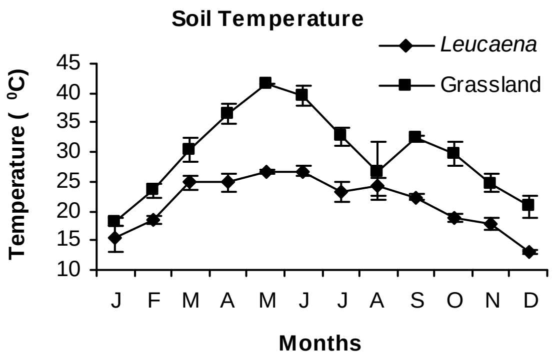
where, $k = m/(\sigma^2 - m)$

If k >2, the population is considered random. k = 2, m^* is half as great as m, population is considered aggregated. As k approaches zero, the population becomes patchier.

Results and discussion

Soil and moisture regime

The soil temperature and moisture regimes in the grassland and plantation systems are depicted in Fig.1. While soil temperature was higher, soil moisture was lower in the grassland compared to *Leucaena* plantation. A wide temperature difference of 2.6°C and 15.0°C in between these systems implied great difference in their heat contents of the soil. Higher soil moisture content (0.14-1.6%) in *Leucaena* plantation at the time of sampling was favorable for the soil organisms. Similar trends of lower temperature and higher moisture regimes in plantations compared to open grasslands, mainly on account of the shade, have been reported in semiarid (Reddy & Venkataiah 1990) and humid regions (Badejo *et al.* 1997). Such fluctuations in temperature and moisture regimes are more pronounced in surface layers and are partially responsible for the migration of microarthropods by indirectly affecting the growth of microflora, especially fungi, besides enhancing palatability of litter to macrophagophytes. Thus, it is evident that *Leucaena* plantation provides a better habitat for soil organisms compared to grassland in semiarid region.



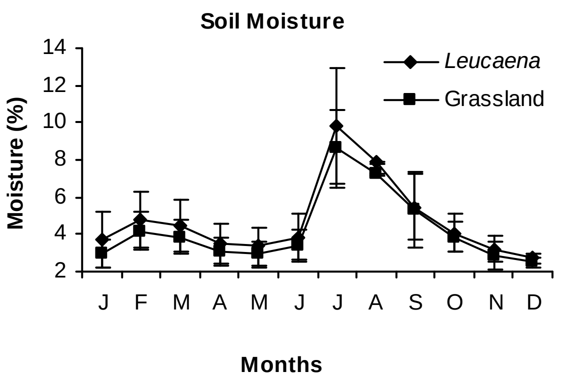


Fig. 1. Soil temperature and moisture of the top soil (0-10 cm) under grassland and *Leucaena* plantation.

Seasonal population

The estimated monthly populations of collembola and mites in grassland and *Leucaena* plantation is depicted in Fig. 2. The peak population buildup was noticed during winters in grassland (5.7×10^4 m^{-2}) and during monsoon in *Leucaena* plantation (6.2×10^4 m^{-2}). The populations were lowest during summer (grassland 0.01×10^4 m^{-2}, *Leucaena* plantation 0.05×10^4 m^{-2}).

The population buildup of soil micro arthropods is influenced by a variety of factors viz., vegetation, soil, climate etc. and their interaction (Narula *et al.* 1998). Many workers have reported higher population buildup of soil microathropods during rainy season and a sharp decline during summer months (Hazra & Sanyal 1996; Jam *et al.* 1986; Reddy & Venkataiah 1990; Reddy *et al.* 1992). Similar results have been obtained in this study also in case of mites (peak population buildup in rainy season and sharp decline in summers) and collembola (sharp decline in summers). However, peak population buildup of collembola during winters in this study differs from majority of the other reports; only few studies have shown post-monsoon increase winters peak reported (Sinha *et al.* 1991).

The correlations of microarthropod population with soil temperature and moisture in grassland and *Leucaena* plantation are presented in Table 1. Highly significant and positive correlation was encountered in both systems between collembola and mites. In grassland, highly significant negative correlation was found between soil temperature and faunal population (collembola r = 0.72; mites r = 0.53). Similar trend in correlation between soil microarthropod fauna and temperature has been reported in northeast India (Sarkar 1991). However, in *Leucaena* plantation, a highly significant positive correlation was found between soil moisture and population (collembola r = 0.96; mites r = 0.89). Various abiotic factors viz., temperature, relative humidity, soil organic matter, soil moisture, inorganic nutrients, vegetation, cultivation practices etc. are known to influence

Table 1. Correlation between faunal population and soil microclimate in grassland and *Leucaena* plantation.

	Grassland		Plantation	
	Collembola	Mites	Collembola	Mites
Collembola	1		1	
Mites	0.66 **	1	0.82 **	1
Soil temperature	-0.72 **	-0.53 **	0.00	-0[illegible]
Soil moisture	-0.07	0.32	0.96 **	0[illegible]

r (5 %) = 0.40; r (1 %) = 0.51

Table 2. Statistical parameters used to determine the spatial distribution of mites and collembola in grassland and *Leucaena* plantation.

Parameters	Rainy season		Winter season		Summer season	
	1	2	1	2	1	2
Grassland						
Mean (m)	1.43	2.42	3.83	2.68	0.98	1.46
Variance (σ^2)	0.49	1.39	2.20	0.63	0.21	0.31
σ^2/m	0.34	0.58	0.57	0.24	0.22	[illegible]
Mean crowding (m*)	2.57	3.40	4.60	3.06	-10.07	[illegible]
Patchiness index (m*/m)	1.79	1.40	1.20	1.14	-10.27	1.46
Dispersion parameter (k)	-1.52	-0.42	2.35	+0.76	-1.28	-0.79
Spatial pattern	A	A	R	A	A	A
***Leucaena* Plantation**						
Mean (m)	2.53	2.87	1.67	3.02	1.47	2.03
Variance (σ^2)	2.46	1.83	0.84	1.38	0.88	1.68
σ^2/m	0.97	0.64	0.52	0.46	0.60	0.83
Mean crowding (m*)	4.14	3.84	2.99	3.70	3.34	3.66
Patchiness index (m*/m)	1.63	1.34	1.85	1.23	2.27	1.81
Dispersion parameter (k)	-34.27	-2.76	-2.09	-1.84	-2.50	-5.80
Spatial pattern	R	R	R	LA	R	R

(1 = Collembola; 2 = Mites; A = Aggregate; LA = Less Aggregate; R = Random)

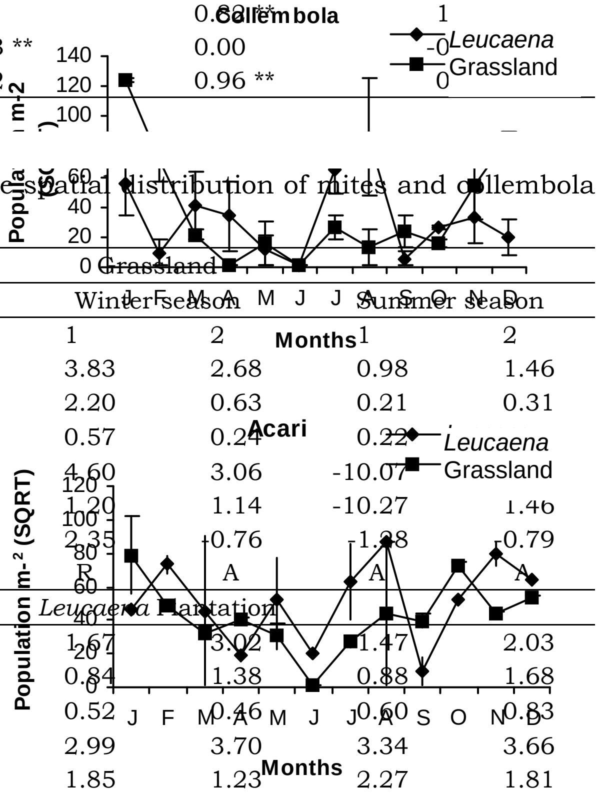


Fig. 2. Seasonal abundance of collembola and mites in top soil (0-10 cm) under grassland and *Leucaena*

population of soil microarthropods (Hijii 1987; Narula *et al.* 1998). Several earlier works have supported a significant positive correlation between soil moisture and population in alluvial soils (Hazra & Sanyal 1996) and deciduous forests (Narula *et al.* 1998).

Spatial distribution

The statistical parameters used to determine the spatial distribution of soil mites and collembola are presented in Table 2. In grassland the population of soil mites had the tendency of becoming aggregated in all seasons whereas collembolans exhibited the tendency to remain aggregated during rainy and summer seasons but random during winters. In *Leucaena* plantation, the population of collembola and mites was largely random in all seasons, except during winter when the mites tend aggregate.

The distribution pattern of collembolans and mites is a useful basis for meaningful ecological interpretation of their temporal population built up. It is interesting to note that in both systems collembolans were random during winter, the period of their peak population. This signifies the potential ecological role of this group in addressing the sustainability issues and in serving as an easy indicator of soil health. The behavior of mites was different in both systems – being random during rainy season (their peak population period) in *Leucaena* plantation and aggregated in the grassland system. During summer, when population of both collembola and mites were low, the distribution remained aggregated in grassland and random in *Leucaena* plantation. In this study the random distribution of microarthropods in *Leucaena* plantation is likely to be on account of more favorable climatic conditions when compared to grassland. The aggregating tendency in soil microarthropods occur because of several reasons viz., (i) eggs are generally laid in patches and animals remain near hatching place; (ii) population aggregate in places where microclimatic conditions are favorable, especially moisture and humidity; (iii) specific feeding habits; (iv) inherent gregarious nature. The differences in behavior towards randomness or aggregation of soil mites and collembolans in the present study may be attributed to their nature and feeding habits besides favorable microclimatic conditions and availability of food. Similar trends have been reported with respect to acarina in contrasting tropical environments (Badejo 1990) and with mites and springtails under different temperature and moisture regimes in tropical rainforests (Badejo *et al.* 1997).

The present study shows that the fauna were aggregated in the grassland, characterized by high temperature and low moisture and were random in *Leucaena* plantation where lower temperature and higher soil moisture conditions prevailed. Such differential behavior in the two land use systems has important ecological implication and offers a strategy of sampling; fewer number of samples may be drawn in case of fauna exhibiting random nature compared to the fauna exhibiting aggregate nature for arriving at a similar level of precision.

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