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Ecological assessment of soil mite communities in diverse fodder production systems of semi–arid central India

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ABSTRACT

The agrarian community of North West region of Bundelkhand in Central India is mainly dependent on livestock rearing and related activities. In order to support the livestock-based economy of the area, a number of fodder and pasture development schemes are promoted by government of India. The hypothesis is that various such systems due to change in land management and vegetation pattern; may affect soil structure and native soil biota. This study presents ecological assessment of soil mite communities in selected fodder production systems in this geographical region.

Mites, the most diversified among soil biota are considered effective bio-indicators of soil conditions. So, in this study, their community structure, seasonal abundance were closely monitored and analyzed in different fodder-based land utilization schemes *viz.,* natural grasslands, cultivated pastures (*Cenchrus ciliaris* + *Stylosanthes hamata*), pure tree stands of *Albizia amara*, silvipstures (tree + grass) and fodder crop cultivation.

Mites were represented by 44 families under 4 suborders. Most dominant groups (families) observed were Tarsenomidae,Caligonellidae, Gamasellus,Dermanyssoidea, Scheloribetidae, Epilohmanniidae, Oppiidae, Galumnidae, Perlohmanniidae, Orobatulidae and Hydrozetidae. Peak population buildup was recorded in the month of August. Diversity was low in annual fodder cultivation system and bare land situations. Perennial fodder production systems namely, open tree stand of *Albizia amara*, natural grassland, improved pastures and silvipasture systems supported higher diversity of mite fauna. Greater soil mite diversity in such carefully designed perennial systems indicate that such systems might ecologically sound and would achieve long term fodder sustainability for the region.

Figures : 04 References : 20 Tables : 05

KEY WORDS : *Albizia amara*, *Cenchrus ciliaris*, Intensive fodder production system, Silvipasture, *Stylosanthus hamata*

Introduction

North West Bundelkhand region of Central India, characterized by barren degraded land scape and erratic rainfall which led to significant surface run-off makes the soil prone to erosion. The region was known for its *Cenchrus - Heteropogon* based grasslands[4]. Farmers are either land less or having fractured small land holdings. Droughts are frequent in the region and due to very low moisture retention capacity and low inherent fertility of soils, farming is feasible for about 90-150 days. Hence, the agrarian community is predominantly dependent on animal husbandry related activities. Common grazing lands are facing anthropogenic encroachments. Further, poor regeneration of natural grasses and insufficient legume component of grazing lands degenerated these common lands. In order to support the livestock-based economy of the area, and ensuring round the year fodder availability, a number of fodder and pasture development schemes on forest, community and other non-arable waste lands are promoted by government and other agencies.

Such reformed land uses may have ecological implications as the change in land management and vegetation pattern affect soil structure and native soil biota. Mites in general are most diversified soil biota[16]. They play important role in various soil processes and act as mediator of soil food web[2]. Stable communities of mites were generally associated with undisturbed natural ecosystem; while anthropogenic ecosystems were characterized by the unstable mite communities[6]. Habitat heterogeneity and complexity influence their dominance, abundance and species richness[3,17]. Their presence in almost all the niches in soil food chain, enable them as bio-indicators of soil conditions[13,20] and were proven as

TABLE-1 : Details of land use systems

Land use	Vegetation details	Level of management	Soil Samples	Type	Age (at the time of sampling)
Bare plots (BL)	No vegetation except some seasonal weeds	No land management,	n = 72		>30 year
Grassland (GL)	*Cenchrus ciliaris*linn, *Heteropogoncon tortus Panicum maximum* and bushes of *Zizyphus* sp.	No land management	n = 72	Perennial	>30 years
Pasture (PL)	Cultivated *Cenchrus ciliaris* along with legume, *Stylosanthus hamata*	Recommended agronomical & land management practices After harvesting grass biomass fertilizer applied at recommended doses	n = 72	Perennial	3 years
Open Tree stand (TS)	*Albizia amara* (400 trees/ha)	No land management	n = 72	Perennial	15 years
Silvipasture (SP)	Consisted of pasture stand of Guinea grass, Tri specific hybrid, and legume *Stylosanthes hamata* and trees of *Azadirechta indica*, *Acacia nilotica*, *Luecaena luecocephala*, *Zizyphus*sp., *Dalbergia sissoo*.	Recommended agronomical & land management practices Grass biomass harvested annually and fertilizer applied after harvest of grasses	n = 72	Perennial	5 years
Arable land (AL)	Intensive fodder production system maize (*Zia maize*) intercropped with cowpea (*Vigna unguiculata*) followed by Lucerne (*Medicago sativa*) in winters	Recommended agronomical and land management practices	n = 72	Annual	-

more effective approach for soil environment evaluation than traditional soil parameter's-based assessment which can only detect changes after actual damage was done[15].Soil mite composition and their dynamics reflect local condition of a specific habitat. Complex and mature stable habitats support richer fauna. They are, therefore, extremely reliable indicators of changes in land use types and with land use intensification mites' response in terms of community structure and diversity changes[14].

In this study we compared soil mite fauna of natural grassland with introduced fodder-based land management. We hypothesized that the introduced fodder production systems may affect dynamics of native soil mite population. Hence, system/s may or may not be sustainable for the region.

Materials and Methods

Fodder based production systems selected for this

TABLE-2. Occurrence frequency of mites in different land uses

Taxon	Systems						Constancy (%)
	BL	GL	PL	TS	SP	AL	
	Frequency (%)						
Prostigmata Caligonellidae	33	75	58	67	75	-	Constant
Eriophyidae	-	17	25	8	8	-	Accidental
Pediculochelidae	-	50	50	42	67	-	Accessory
Bdellidae	-	25	33	17	8	-	Accidental
Trombidiidae	-	17	8	8	8	-	Accidental
Tetranychidae	8	17	25	17	17	-	Accidental
Stigmaeidae	-	25	33	17	33	-	Accidental
Erythroeidae	-	17	8	8	17	-	Accidental
Neophyllobiidae	-	17	8	8	17	-	Accidental
Cunaxidae	-	27	18	9	18	-	Accidental
Tenuipalpidae	-	-	9	9	-	-	Accidental
Trombidium sp.	-	75	45	48	75	-	Accessory
Tarsenomidae	8	67	67	75	67	25	Constant
Scutacaridae	-	9	18	-	-	-	Accidental
Caeculidae	-	92	92	8	100	-	Accessory
Unidentified -1	-	9	-	-	-	-	Accidental
Unidentified -2	-	-	9	-	-	-	Accidental
Unidentified -3	-	-	9	-	-	-	Accidental
Unidentified -4	-	-	9	-	-	-	Accidental
Mesostigmata							

Gamasellus sp.	8	67	83	67	75	75	Constant
Cercomegistidae	8	67	58	58	33	58	Accessory
Dermanyssoidea	17	67	67	67	58	58	Constant
Veigaiidae	-	8	25	25	25	-	Accidental
Uropodidae	-	-	-	8	-	8	Accidental
Macrochelidae	17	25	8	17	25	17	Accidental
Rhodacaridae	-	36	36	64	45	-	Accessory
Oribatida							
Scheloribetidae	83	100	92	92	100	83	Absolute
Epilohmanniidae	8	100	92	92	100	100	Absolute
Oppiidae	-	75	67	50	67	58	Constant
Galumnidae	58	83	75	58	83	75	Constant
Perlohmanniidae	-	67	50	58	67	75	Constant
Orobatulidae	-	92	83	75	58	83	Constant
Hydrozetidae	-	73	73	91	64	-	Constant
Cepheidae	-	9	-	-	9	-	Accidental
Neoliodidae	-	-	17	-	-	-	Accidental
Polypterozetidae	-	18	18	9	18	-	Accidental
Mesoplorphoridae	-	8	8	17	8	-	Accidental
Hermanniidae	-	17	17	25	33	8	Accidental
Hermanniellidae	-	-	8	-	8	-	Accidental
Palaeacaridae	-	17	17	17	8	-	Accidental
Phthiracaridae	-	-	-	-	8	-	Accidental
Ameronothridae	-	25	8	-	8	8	Accidental

Carabodidae	-	8	17	8	17	-	Accidental
Hypochthoniidae	-	8	-	-	8	-	Accidental
Plateremaeidae	-	9	9	9	-	-	Accidental
Unidentified -1	8	83	75	75	75	83	Constant
Unidentified -2	-	8	8	-	-	-	Accidental
Unidentified -3	-	8	17	8	17	-	Accidental
Unidentified -4	-	-	-	8	8	-	Accidental
Unidentified -5	-	8	8	8	-	-	Accidental
Unidentified -6	-	-	8	-	-	-	Accidental
Unidentified -7	-	17	17	25	25	17	Accidental
Unidentified -8	-	25	25	17	25	-	Accidental
Unidentified -9	-	18	9	18	9	-	Accidental
Unidentified -10	-	-	9	-	9	-	Accidental
Unidentified -11	-	9	-	-	-	-	Accidental
Unidentified -12	-	9	18	9	-	-	Accidental
Unidentified -13	-	9	-	-	-	-	Accidental
Unidentified -14	-	9	9	-	-	-	Accidental
Unidentified -15	-	9	-	-	-	-	Accidental

(Constancy: 1-25% = Accidental; 26-50% = Accessory; 51-75% = constant; 76-100% = Absolute; - = not observed)

study were, cultivated pasture (Cenchrus ciliaris + Stylosantheshamata + Leucaena leucocephalaas hedge), open tree stands of Albiziaamara; a fodder tree, silvipsture (trees + grasses) system and fodder crop cultivation (Maize + Cowpea – Lucerne).

Study sites : Experimental sites were located on red alfisol at Jhansi (25°27'N latitude and 78°35'E longitude and about 275 m above mean sea level) in the Central research farm of the IGFRI. Four experimental land use types were selected *viz.,* Improved pasture land (PL), Tree stand (TS), Silvipasture (SP) and Intensive fodder production system (AL) for this study. All the perennial land uses (PL, SP, TS and GL) were having six blocks each of were 50×50 m. AL was also having 6 replicated plots of 5×5 m as per standard recommendation. Close to the field sites, a Natural grassland (GL) around one ha area and a rocky bare land (BL; except some seasonal weeds) of around one ha area was maintained as check. The land uses are described in Table-1. Soil of the experiment site was classified as red alfisols. Texture

TABLE-3 : Diversity of soil mites under different land uses (mean ± S.E.) and ANOVA (á =0.05)

	Shannon-Wiener	Simpson's Dominance	Total number	No of species	Richness
Bare Plot	0.36^a	0.56^c	7.28 ± 0.38^a	12	1.58 ± 0.04^a
Grassland	1.15^c	0.37^a	29.92 ± 0.49^c	31	5.53 ± 0.05^c
Pasture	1.03^c	0.41^b	25.69 ± 0.36^b	34	5.18 ± 0.05^c
Tree stand	0.82^b	0.51^c	24.56 ± 0.38^b	32	3.97 ± 0.04^b
Silvipasture	0.99^b	0.45^b	33.58 ± 0.51^c	34	5.31 ± 0.05^c
Arable land	0.89^b	0.29^a	44.56 ± 0.51^d	16	4.50 ± 0.05^b
ANOVA	$F_{32,363} = 2.46$	$F_{32,363} = 1.88$	$F_{32,363} = 2.02$		$F_{32,363} = 2.34$
results	P = 0.00003	P = 0.003	P = 0.001		P = 0.0001

was sandy clay loam to sandy clay. Soil was neutral in pH with 38.6 per cent water holding capacity. Soil nutrient status was low to medium range (organic carbon - low to medium range; nitrogen - low to medium; phosphorus - low and potassium - medium).

Soil Sampling and Extraction: Soil samples were collected randomly from each block at monthly intervals using a steel cylindrical corer (5 cm diameter ´ 15 cm depth). All the samples were carefully sealed in separate polythene bags and taken to laboratory for further processing by Berlese-Tullgren funnels. Mites were separated from the collecting vials by means of a fine camel hairbrush under a stereo zoom microscope. After sorting, they were preserved in 70 percent alcohol for further studies and identified following manual of acarology[9].

Statistical analysis: Basic community structure parameters viz., abundance per square meter, relative abundance, frequency and constancy of mites were calculated. Frequency was calculated for comparison of samples within a single habitat whereas constancy was calculated for comparison among the samples of different habitats. Constancy values were classified into four categories *viz.*, Accidental (1-25%), Accessory (26-50%), Constant (51-75%) and Absolute (76-100%). Mite population (m^2), relative abundance, frequency and constancy were estimated by using the following formulas[19].

$$\text{Population/m}^2 = \frac{10000X}{0.785d^2}$$

Where, *X* is the number of mites per sample and d^2 diameter of sampler

$$\text{Frequency or Constancy} = \frac{\text{No. of samples containing perticular species}}{\text{Total no. of samples}} \times 100$$

For spatial distribution indices calculations, densities per sample were transformed to square root (x + 0.5). The patchiness of a population may be calculated as the proportion by which mean crowding m* exceeds mean density (m) and it is equal to the reciprocal of dispersion parameter (k). If k > 2, the population is randomly distributed. However, k = 2, m* is half great as m, population considered as aggregated, k tends towards zero population is more aggregated[11].

$$\text{Mean Crowding } (m^*) = m + \left(\frac{\sigma^2}{m} - 1\right) = m + \frac{m}{k}$$

$$\text{Patchness Index } = \frac{m*}{m} = 1 + \frac{1}{k}$$

$$\text{Dispersion parameter } (k) = \frac{m}{\sigma^2 - m}$$

Diversity indices (Shannon index, Simpson's dominance index) were calculated by using Biological

TABLE-4 : Spatial distribution (k) pattern of soil mites in different seasons

	Bare Plot	Grassland	Pasture	Tree Stand	Silvipasture	Arable Land
Winter	4.15	5.66	-2.45	4.65	1.66	-1.88
Summer	11.46	70.46	51.97	4.14	-5.83	2.10
Rains	0.85	-22.31	-1.74	-1.98	-2.26	0.26

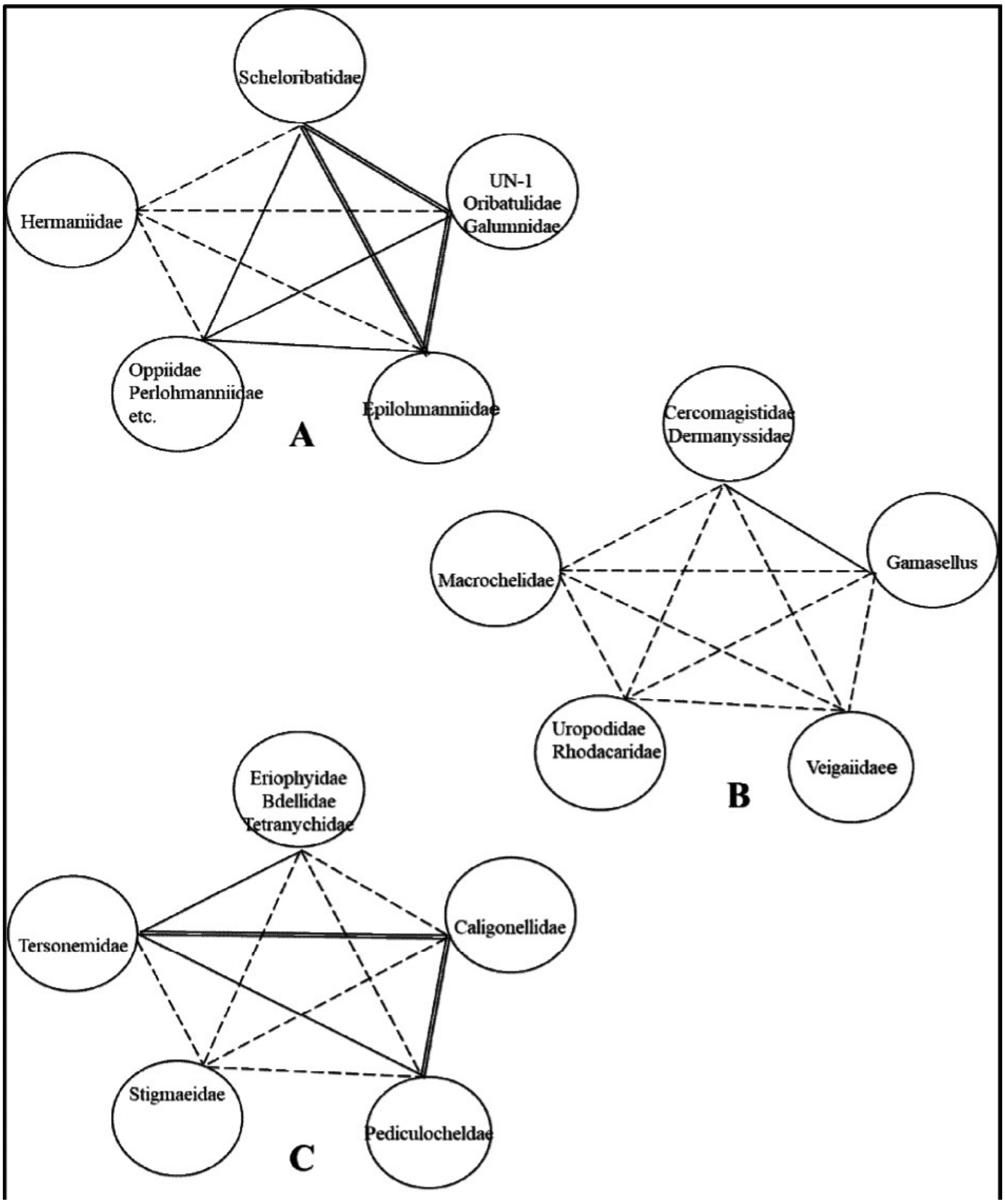

Fig. 1. Interspecies association of mites based on Pearson's correlation

(A = Oribatida; b = Mesostigmat; C = Prostigmata; Euclidean distance between the clusters shown as double line indicate the significant association at 1%, single lines indicated significance at 5% and broken lines for non-significant association)

TABLE-5 : Average population of different mites ($\times 10^2 m^{-2}$) at study site

	Oribatida	Mesostigmata	Prostigmata
Bare Plot	15.76	1.48	1.27
Grassland	120.96	15.71	42.60
Pasture	106.43	14.25	30.08
Tree stand	100.93	9.06	34.63
Silvipasture	118.63	15.42	63.41
Arable land	151.92	23.75	4.24

CD (p value)

	df	Shannon-Wiener	Simpson's dominance
Land use	5	0.47 (p = 0.04)	0.21 (p = 0.08)
Mites*	2	0.33 (p = 0.03)	0.15 (p = 0.03)

*Astigmata mites were not included in analysis as their population was negligible

Tool Box version 0.10 Add-In for Excel 5.0. The interspecies association was estimated based on Pearson's index and Euclidian distance was used to combine species showing positive association was performed for untransformed abundance data by SPSS13 window version. Dominance – diversity relationship was ascertained by the curve as the ordinate represents log of the percent abundance against ranked species sequence. Untransformed abundance data were used for calculating interspecies association based on Pearson's index and Euclidian distance by SPSS13. ANOVA and other statistical analysis were performed in Microsoft Excel 13.0.

Results

Diversity: Mites were represented by 44 families under 4 suborders. The Oribatida mites were the dominant (69.43%) followed by Prostigmata (19.91%), Mesostigmata (9.0%) and Astigmata (1.66). Most frequently observed species were Tarsenomidae, Caligonellidae, Gamasellus, Dermanyssoidea, Scheloribetidae, Epilohmanniidae, Oppiidae, Galumnidae, Perlohmanniidae, Orobatulidae, Hydrozetidae (Table-2). Glycyphagidae, Chaetodactylidae, Anoetidae were three astigmata mites recorded during investigation.

ANOVA analysis indicated that land uses significantly affected diversity and abundance of mites (Table-3). Lowest Shannon-Wienerindex was lowest in BL (0.36) and highest in GL (1.15). Higher value of Simpson's index for BL (0.56) indicates that there were few dominant species associated with the land use. Significantly highest mean abundance per sample was recorded in AL (44.56) followed by SP (33.58) and GL (29.92).

A strong interspecies association was observed (Fig. 1). Among oribatids; Oribatulidae, Galumnidae, Scheloribatidae, Epilohmanniidae were strongly correlated (p=0.01). Among the mesostimatid mites *Gamasellus* sp. Cercomegistidae and Dermanyssoidea were correlated (p = 0.05). The Prostimatids *viz.,* Caligonellidae, Tersonemidae and Pediculochelidae were highly correlated (p = 0.01).

Spatial Distribution: The dispersion parameter (k) showed aggregated distribution pattern (k<2) of mites in rainy season (Table-4). While they were randomly distributed during winter and summer seasons (k>2). The aggregated distribution in rainy season across the land uses may be due to the favorable climatic conditions which supported population buildup (Fig. 2).

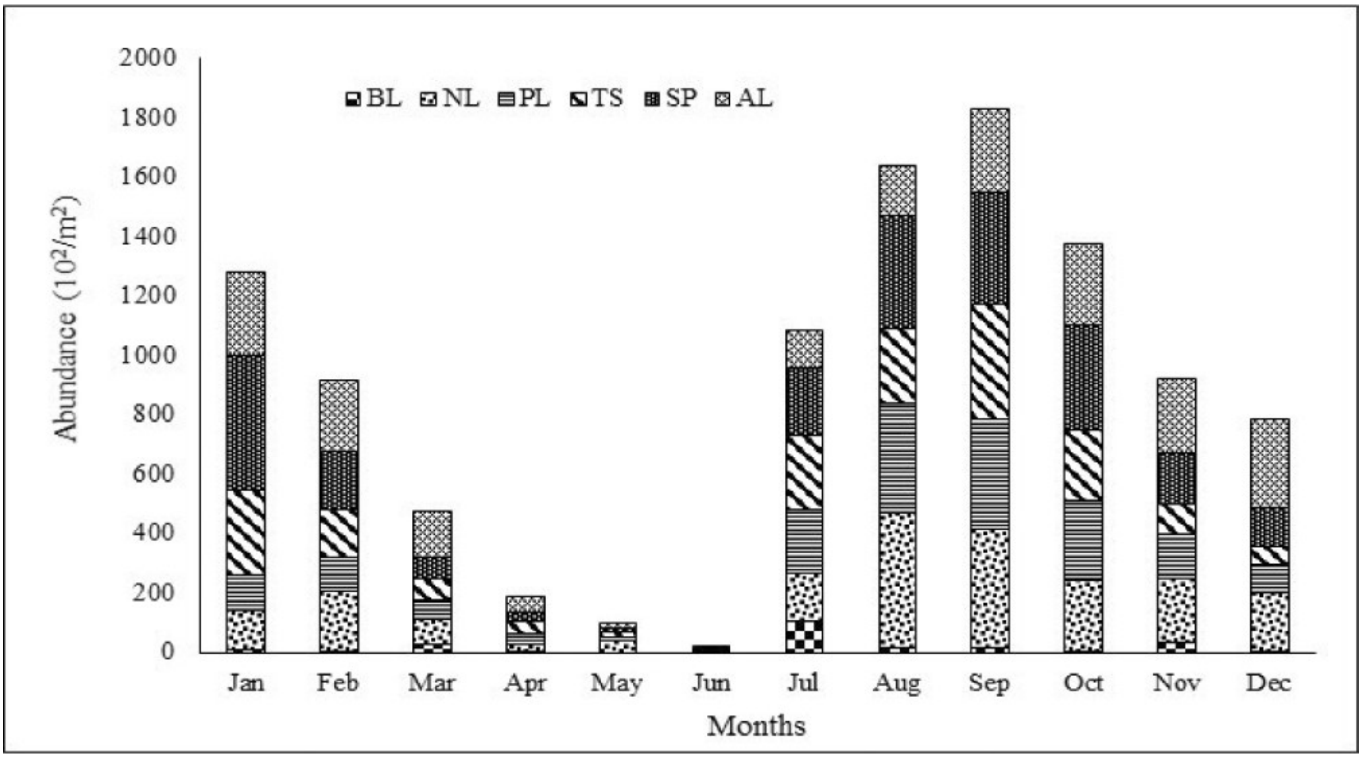

Fig. 2: Seasonal abundance of mites in different land use systems

Temporal Distribution: Highest average population of mites was recorded in SP ($201\times10^2/m^2$) followed by GL ($180\times10^2/m^2$), AL ($180\times10^2/m^2$), TS ($155\times10^2/m^2$) and PL ($151\times10^2/m^2$). Bare land had considerably low abundance ($19\times10^2/m^2$)).AL harbored more Oribatida (($152\times10^2/m^2$) and Mesostigmata($24\times10^2/m^2$) mites compared to other systems. Prostigmata were more in the GL, SP, TS & PL (Table-5).

A seasonal trend in population build up was also observed. Peak population build up was recorded in GL ($450\times10^2/m^2$) and SL ($381\times10^2/m^2$) in the month of August. Highest population of oribatida ($202.2 \times 10^2/m^2$) and Mesostigmata ($30.9 \times10^2/m^2$) was recorded in August. While, Prostigmata were highest ($96.9 \times 10^2/m^2$) during January. Lowest population ($0.85\text{-}7.43\times10^2/m^2$) was recorded during summer months in all the land use types (Fig. 2).

Discussion

Soil mite composition and their dynamics reflect local condition of a specific habitat. Distribution of soil fauna exhibited different spatial patterns in response to the environmental factors, especially temperature and moisture, which affect their biology[18]. Their temporal and spatial distribution depend on the fluctuations in soil environment[17]. Community pattern of soil mites may be used as indicator of sustainability of production system[1,3]. Some multi-scale studies have shown that mites exhibit significant spatial correlation and may be aggregated in patches of 20 cm to <100 meter in size[7,10]. In this study similar trend in spatial correlation and aggregation in distribution was observed.

Complex and mature stable habitats like forest and grasslands where significant amount of litter recycling takes place are known to support richer fauna. Whereas, soil fauna community structure is quite simple in open systems like agro-ecosystems; where residues/ litter were not present or removed[5]. In this study we have observed similar trend. Moderate slope of Rank relative abundance curves of GL, PL, SP and TS reflected that these land uses were equally rich in species diversity. While, the steepness of the curve reflects low species richness in bare land and annually cultivated fodder production system (Fig. 3). Cluster analysis of abundance data also indicated that the GL, PL, TS and SP were closely related while, BL and Al falls under dispersed group (Fig. 4).

Higher diversity and abundance of mites in perennial systems may be attributed to the least land disturbance while productivity was managed through the integral legume and grass components for these systems. Some researchers[12] in a study at Kenya, stated that land use types have significantly influenced the diversity of soil mites. Intensification lowered the diversity and abundances, resulting in less complex mite's community structures.

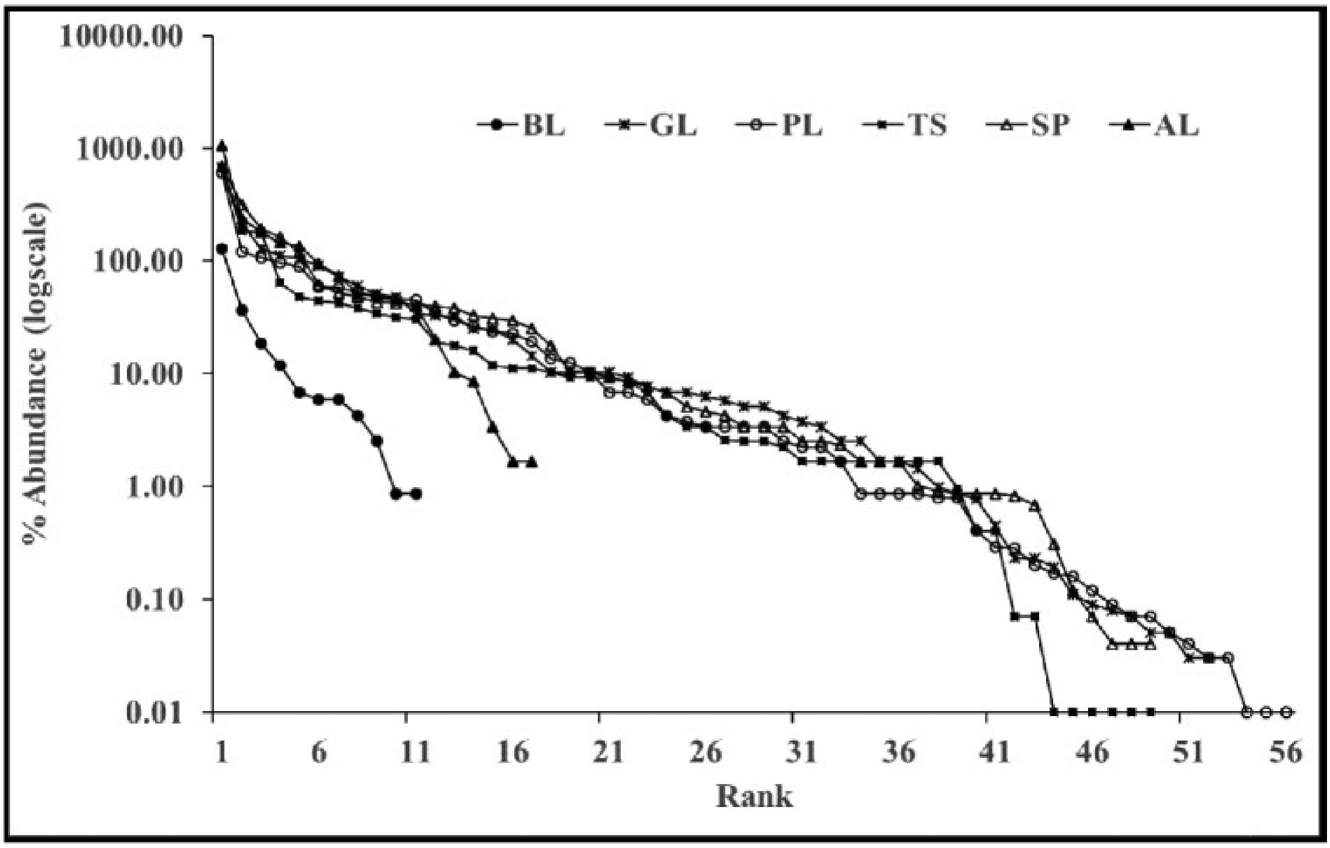

Fig. 3: Rank-relative abundance curves of soil mites for land uses

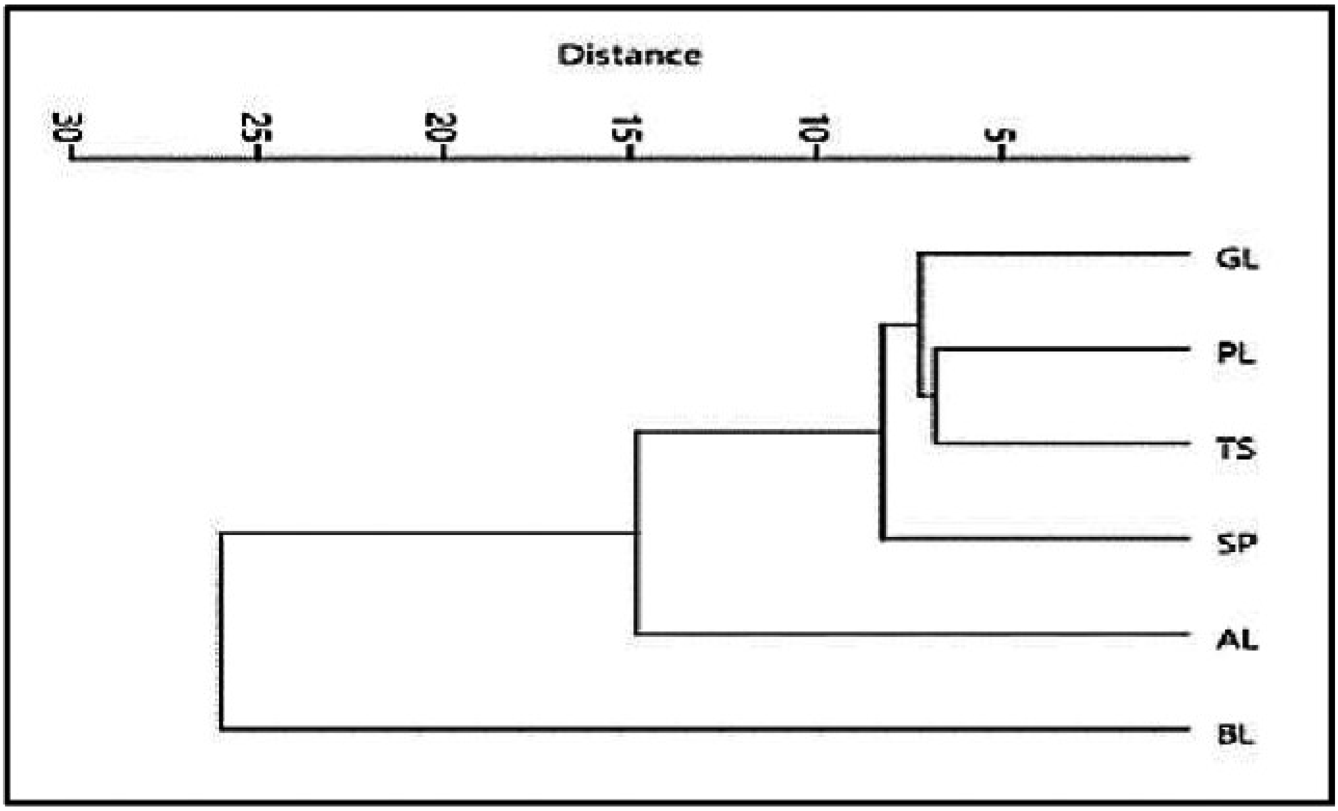

Fig. 4: Hierarchical cluster analysis for land use similarity using Euclidian distance (paired group) algorithm

Conclusion

Greater thrusts on perennial fodder production systems may be accorded in larger areas to meet the fodder requirements of livestock besides restoration of degraded lands in this region on ecological considerations that is based on mite diversity and abundance, an important bio-indicator.

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