Sci-Afric Journal of Scientific Issues, Research and Essays Vol. 2 (5), Pp. 204-217, May, 2014. ***(ISSN 2311-6188)***
http://www.sci-afric.org

Research Paper

Community Composition of Edaphic Collembola (Hexapoda) in Grazed and None Grazed Biotopes in Egypt.

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Accepted May 05th, 2014

ABSTRACT

In this study, the relationships between cattle and sheep grazing pressure and soil collembolan community composition were evaluated. Soil samples were collected from three adjacent grazed recovery and non-grazed (control) plots over a period of four seasons and was divided into three layers: surface layer, 0-5 cm soil depth, 5-10cm soil depth and 10-15 cm soil depth. The Collembola caught were counted and identified. Relative contribution, diversity, equitability and multivariate analysis were determined. Soil organic matter contents, pH, moisture, and temperature were also recorded. Mean density of total collembolan species in grazing plot was generally lower than recovery and control plots. However, these Differences were statistically significant ($p \leq 0.05$). The number of species recorded at individual sampling dates fluctuated considerably through the period of study. All euedaphic species decreased in grazing plots and slightly increased in recovery when compared with their densities in control plots which reach their optimum population size in winter. Species diversity and equitability in all cases tended to decrease in comparison to the controls, with an intermediate effect in the recovery site, and the strongest effect was recorded in grazing sites. In most seasons the majority hemiedaphic collembolan species was found in the upper soil layer. Under adverse conditions in summer a vertical migration to deeper layers was observed. No similar response was observed in winter. These patterns persist at the level of the whole Collembola population and at the species level as well. Only minute differences were observed in the vertical distribution pattern of the most abundant species, irrespectively of the life form they belong to. Multivariate analysis suggests the most important environmental variables correlated with species composition.
.It can be concluded that, negative and positive effects were found in different collembolan species. According to that study, grazing appears not to affect Collembola as a group.

Key words: Grazing, Euedaphic, Hemiedaphic, Multivariate analysis.

INTRODUCTION

Agricultural practices, such as cattle and sheep grazing, modify a variety of soil chemical and physical properties (Krzic et al. 2000), which can alter soil quality as well as density and diversity of soil fauna (Clapperton et al. 2002). Since soil fauna respond to and are influenced by soil chemical and physical properties, these organisms may provide an integrative measure of soil conditions and a particular soil's response to disturbance or management practices (Pankhurst et al. 1995). In fact, changes to the soil fauna assemblage may be detected prior to changes in chemical or physical properties, making soil fauna useful indicators of soil quality (Garay and Nataf 1982).

Recently there has been an increase in research focusing on soil fauna diversity, community structure and ecological function in different ecosystems.

However, little work has been done to evaluate the effect of livestock grazing on the soil mesofauna. Extensive grazing results in high structural heterogeneity by browsing, trampling and nutrient in- and outputs in the habitat (Fischer et al. (1996). Moreover, livestock grazing influences plant community structure, soil temperature, moisture and soil compaction and is also likely to effect directly or indirectly the populations and diversity of soil biota (Clapperton et al. 2002; Peterson et al. 2002). Collembola are among the most ecologically diversified microarthropods occurring in high abundances in grasslands. They play an important role in plant litter decomposition processes (Al Assiuty and Bayoumi1983; Klironomos and Kendrick, 1996) and in forming soil microstructure (Dunger 1983). The relatively large population sizes and potential influence on nutrient mobilization make suggests that they represent a key group for determining system's productivity.

Based on species composition, Acari and Collembola communities have a correspondence with the vegetation cover because litter formation contributes to their niche differentiation; for the formation of diverse microhabitats (Nielsen et al. 2010), shifts of plant communities as a result of heavy livestock grazing (Adams et al. 2009) in addition to litter removal and soil compaction may have effects on the soil mesofauna in grazed stands. As part of ecological implications of livestock grazing, soil mesofauna will be evaluated as an integrative measure of rangeland health in response to grazing management.

Collembola were chosen as a study group due to their ability to respond to a wide range of disturbance factors. They respond to changes in soil chemistry (Hagvar and Abrahamsen, 1984), pH (Ponge, 2000), and changes in microclimatic and microhabitat conditions like moisture (Verhoef and Van Selm, 1983; Pflug and Wolters, 2001), amount and quality of litter (Ponge et al., 1993) and humus type (Chagnon et al., 2000). Also, different vegetation communities host different species assemblages of Collembola (Benito and Sanchez, 2000); this is particularly true when comparing open and closed habitats (Bonnet et al., 1977; Ponge, 1993). Collembola communities also react to different forest and agricultural activities. Moreover, landscape configuration (e.g., heterogeneity, fragmentation) and the type of use (e.g., pasture, farm forest) also regulate Collembola community composition (Dombos, 2001).

The classification of Collembola to ecomorphological life forms was introduced by Gisin (1943) and has been widely used ever since. Species are characterized as euedaphic (species that are permanent soil dwellers), hemiedaphic (species that live in the superficial soil layers and leaf litter) and atmobios (species that live in the surface and on vegetation). It was originally assumed that the morphological characteristics of a species reflect the soil layer preferred by it, but certain species have a life strategy that does not correspond to their life form (Hagvar, 1983, Takeda, 1995). On the other hand, a differentiation in the vertical preferences within a species has been reported (Wolters, 1983) indicating that smaller individuals tend to inhabit deeper layers. Detsis (2000) stated that, in most seasons the majority of the animals were found in the upper soil layer.

To our knowledge there is little research on the impacts of cattle and sheep grazing on soil fauna in grassland soils of Egypt. Thus the purpose of this study was to examine effects of cattle and sheep grazing on the biodiversity patterns and community composition of Collembola of grazing soil in Ghabiya Governorate of Egypt. Moreover, we analysed how different ecological life forms (euedaphic and hemiedaphic) reacted to extensive grazing reflecting the severity of disturbance caused by grazing in different soil depths.

MATRIALS AND METHODS

Site description

The study was carried out in three adjacent areas in Al-Monshaat El-kobra, El-Santa center,20 km east of Tanta city, Governorate of El- Gharbia, Egypt(N, 31° 1′ 47″ E). Sheep and cattle grazing area, (ElMesalhi A wad: 0.2 hec) recovery area (Sami Abd-el-Kader A wad: was 0.31 hectar) and non grazing area (cultivated control area) (Abdullah Alsaed Ragab: 0.17 hec). The climate of the area is typically Mediterranean: about 80% of relative humidity, annual rainfall averages 20-120 mm (concentrated in November–February). while mean soil temperature varied between 18 and 24 °C; daily average air temperature between 27 and 32 °C in the period of sampling in 2010. (Data for Central Station to the Meteorological Department). The grazed plant species in cattle and sheep grazing area are (*Cypents rotundus, Cynodon dactyhim* and *Portitlaca oleracea*, the recovery area was converted from grazing to cultivated soil in the same year of sampling. The agriculture cycle in recovery and control area was Okra and maize in June, and then the land was planted with Alfa Alfa, wheat, potato and onion through year. The grazing time start from 8am to 5pm in winter and from 8am to 3pm in summer. Soils on the site have silt clay loam textures, medium pore spaces allowing rapid drainage, low nutrient holding capacity.

Sampling and microarthropod enumeration

The study took place during a period of one year, from (August 2010 till July 2011). Five samples were randomly collected seasonally by a core metal sampler (5X 5 X 15 cm). In order to investigate the vertical distribution of Collembola, each sample was divided into three layers: a layer 0-5 cm soil depth, 5-10 cm soil depth and 10-15 cm soil depth. Fifteen samples collected every season from each area. Samples were transported immediately to the laboratory in Polly ethylene bags, each sample has it is own number. Another soil samples from the same regions were collected in aluminum foil for soil analysis. Collembola, were extracted from the soil samples using Modified Berlese funnel apparatus (Macfadyen, 1953). The trapped Collembola, were separated from other micro-arthropods under a binocular stereo—microscope .Preparation for identification of species were undertaken as explained in detail elsewhere (Al-Assiuty et al., 1993). Identification was carried out using the keys of Dekinesh (1991), Fje lberg (1998) and Hopkin (2000).

Furthermore, environmental factors, such as soil parameters and temperature were monitored; Soil temperature was measured immediately after each sample was taken with a digital point thermometer. Soil samples adjacent to those used for the extraction of the animals the ones mentioned above were taken to the laboratory and dried overnight at 103 oC to determine water content. Hydrogen ion concentration of the different soil layer was measured using the digital pH meter (Klute, 1986). Electrical conductivity was measured according to Maas and Hoffman (1977). Mechanical analysis was carried out according to the international pipette method (Page, 1982).

Data analysis

Physical and chemical parameters, Collembola densities and number of species found at each investigated plot in each season were compared by an ANOVA. If assumptions of homogeneity of variances and normality were not met, the Kruskal–Wallis test was used instead (followed by a Dunn's test). Statistical calculations were made using the Sigma Stat software (SPSS, 1995).The distribution of individuals over species of Collembola was measured using Simpson's diversity index (D) according to Magurran (1991) and equitability (E) index which is sensitive to changes in dominance structure. Vertical Distribution was measured according to Ushers (1975). The differences between mean individual numbers at different depths were tested for significance with the T-test. Multivariate technique was used to detect significant differences in community composition between grazing, recovery and control plots according to Sousa and Gama (1994).

RESULTS

Density and species composition

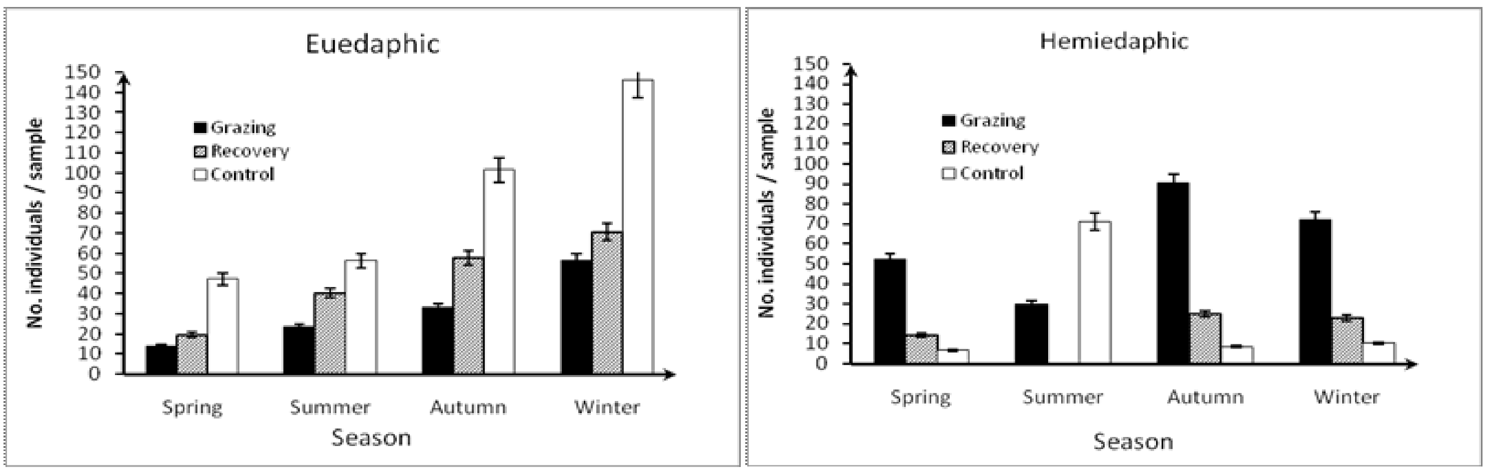
A total of fourteen Collembolan species were extracted from the investigated plots all year round (Table 1). These species belong to euedaphic and hemiedaphic collembolan species that was obtained from the grazed, recovery and control plots. The total density of Collembolan species varied between 693.5 ± 170 to 5501.3 ± 589 individuals / m2 in grazed plots during spring and autumn, respectively. In recovery plot, the density varied from 3392 ± 765 to 5701.3 ±1980 individuals / m2 during spring and autumn, respectively. While, in control plot, it varied from 5402.7 ± 1546 to 9949.3 ± 3987, respectively (Table 1).

Table 1: List of collembolan species population density throughout different seasons in the investigated areas.

Species	Season											
	Spring			Summer			Autumn			Winter		
	Grazing	Recovery	Control	Grazing	Recovery	Control	Grazing	Recovery	Control	Grazing	Recovery	Control
1-Hypogastrura denticulata	14.5	19	37	11.4	22.3	32	14.6	22.3	37	18.9	26.3	28.4
2-Hypogastrura inermis	0	4.7	12.5	11.8	20.1	66.3	0	12.5	33.3	6.1	13.6	49.3
3-Friesea claviseta	0	0	0	0	0	0	3.3	12.1	19.9	18.4	24.4	30.1
4-Onychiurus absoloni	22.9	23.5	46.5	18.5	30.6	33.5	22.6	42.4	95.6	21.7	40.6	60.3
5-Tullbergia callipygos	15.6	22.6	28.3	10.4	22.3	34.4	8.8	15.8	26.6	0	0	0
6-Folsomides parvulus	16.3	23.9	24.7	22.3	37.7	58	22.9	38.3	70	15.6	25.8	66.3
7-sotomina thermophila	13.3	19.4	32.5	18.1	21.5	26.2	17.2	25.4	50	18.2	28.8	77
8-Isotomurus palustris	37.8	14.1	6.1	0	0	0	38.4	10.3	7.5	27	0	2
9-Entomobrya musatica	0	0	0	14.7	0	3.1	0	0	0	0	0	0
10- Seira traegaardhi	0	0	0	0	0	0	0	0	0	14.7	0	6.5
11-Lepidocyrtus cyaneus	0	0	0	18.5	12.7	3	14		0.8	14.5	0	0.9
12-Cyphoderus bidenticulatus	0.7	0	14.6	5.7	18.7	30.1	12.5	20.2	31.6	5.3	17.3	32.4
13-Sminthurides pumilis	14.3	0	0.4	14.5	0	3.7	0	0	0	0	0	0
14-Sminthurus multifasciatus	0	0	0	0.5	0	64	52	14.5	0.8	45	22.7	8
Total number per sample	135.4	127.2	202.6	146.4	185.9	354.3	206.3	213.8	373.1	205.4	199.5	361.2
Total number per m2 (mean ± standard error)	3610.7 ±685	3392.0 ± 765	5402.7 ± 1546	3904.0 ± 856	4957.3 ± 1203	9448.0 ± 3459	5501.3 ± 589	5701.3 ± 1980	9949.3 ± 3987	5477.3 ± 201	5320.0 ± 1023	9632.0 ± 3658
Species richness	8	7	9	11	8	11	10	10	11	11	8	11

Mean density of total collembolan species in grazing plot were generally lower than recovery and control plots. However, these Differences were statistically significant ($p \leq 0.05$). Total density was considerably higher at control plots (1291.5 ± 170) than at grazed plot (693.5 ± 95), considering the density of both collembolan life forms only hemiedaphic (*Isotomurus palustris, Entomobrya musatica, Sminthurides pumilis* and *Sminthurus multifasciatus*) collembolan species reached remarkably higher densities at grazed plot than recovery and control plots. In contrast, the relative abundance of euedaphic collembolan species (*Friesea claviseta, Isotomina thermophila, Seira traegaardhi* and *Cyphoderus bidenticulatus*) from the grazing plots was lower than the relative abundance from the recovery and control plots during the whole period of study (Table1). All euedaphic species decreased in grazing plots and slightly increase in recovery when compared with their densities in control plots which reach their optimum population size in winter (Fig.1). Control plot may be considered to have slightly higher species richness (ranged from 9-11 sp) than heavily grazed plot (ranged from 8-11) in all season of the year. In recovery plot, the species richness ranged from 7-10 sp in all season of the year.

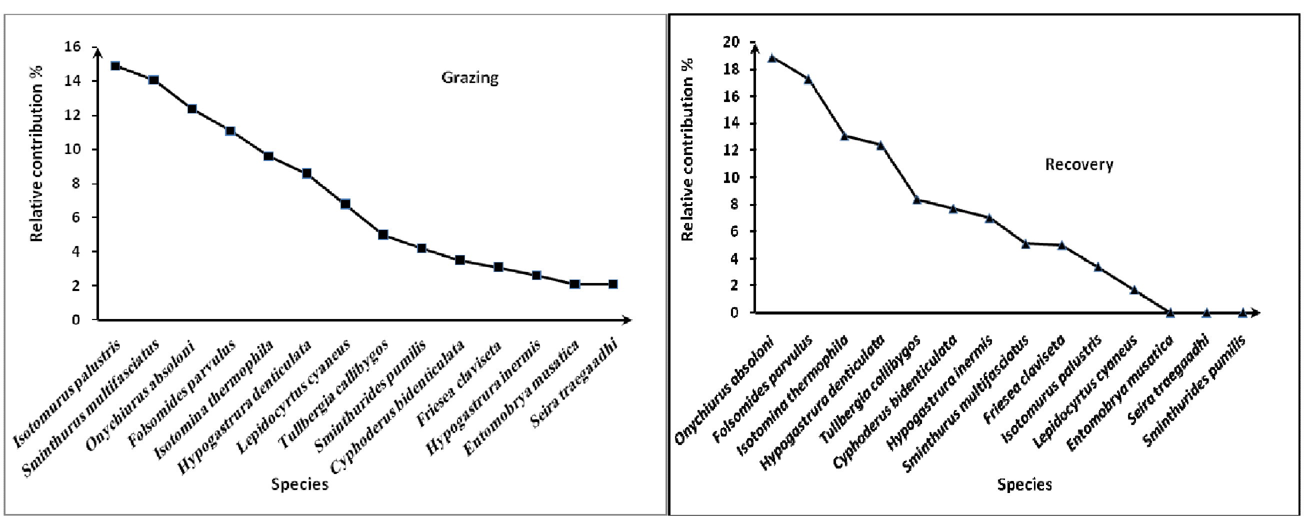
Figure 1: Mean number of collembolan groups under the effect of grazing, recovery compared with control plots during all season of study.

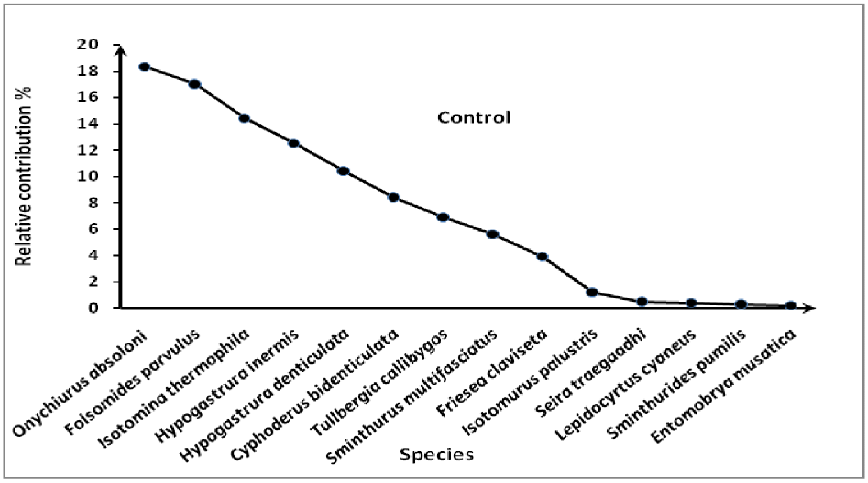


***Remark:** Each value is the mean of five replicate ± standard error.

The obtained results indicate that the collembolan species Hypogastrura denticulata and Isotomina thermophila decreased and became subdominant (8.6 and 9.6%, respectively) in grazing plot, compared with 12.4 and 13.1% and 10.4 & 14.4% in recovery and control plots, respectively. The species *Onychiurus absoloni* and *Folsomides parvulus* showed a high degree of constancy maintaining the same degrees of dominance as in grazing, recovery and control plots (Figure 2).

Figure 2: Rank abundance curves showing changes in dominance of collembolan species in grazing, recovery and control plots.





Isotomurus palustris was the only collembolan species that showed an increase in its abundance; it represented about 14.9% of the total collembolan individuals in grazing plot. Moreover, it became a minor species in recovery and control plots (3.4 and 1.2%, respectively). In grazing plot, *Lepidocyrtus cyaneus* increased in density and represented subdominant species in this plot with a relative contribution of 6.8% (Table 2).

Table 2: Annual population density and relative contribution of collembolan species in the investigated areas.

Plot / Species	Grazing		Recovery		Control	
	No	%	No	%	No	%
Hypogastrura denticulata	59.4	8.6 C	89.9	12.4 B	134.4	10.4 B
Hypogastrura inermis	17.9	2.6 D	50.9	7.0 C	161.4	12.5 B
Friesea claviseta	21.7	3.1 D	36.5	5.0 C	50	3.9 D
Onychiurus absoloni	85.7	12.4 B	137.1	18.9 B	235.9	18.3 B
Tullbergia callibygos	34.8	5.0 E	60.7	8.4 C	89.3	6.9 C
Folsomides parvulus	77.1	11.1 B	125.7	17.3 B	219	17.0 B
Isotomina thermophila	66.8	9.6 C	95.1	13.1 B	185.7	14.4 B
Isotomurus palustris	103.2	14.9 B	24.4	3.4 D	15.6	1.2 D
Entomobrya musatica	14.7	2.1 D	0	0.0	3.1	0.2 E
Seira traegaadhi	14.7	2.1 D	0	0.0	6.5	0.5 E
Lepidocyrtus cyaneus	47	6.8 C	12.7	1.7 D	4.7	0.4 E
Cyphoderus bidenticulata	24.2	3.5 D	56.2	7.7 C	108.7	8.4 C
Sminthurides pumilis	28.8	4.2 D	0	0.0	4.1	0.3 E
Sminthurus multifasciatus	97.5	14.1 B	37.2	5.1 C	72.8	5.6 C
Total number per sample (Mean ± Standard error)	693.5 ± 95		726.4± 102		1291.2 ±170	

% relative contribution in community; dominance class is indicated by capital letter, A eudominant: over 30% of individuals, B dominant: 30-10% of individuals, C sub – dominant: 10-5% of individuals, D minor: 5-1% of individuals and E rare: less than 1% of individuals (Engelmann, 1978)

Moreover, it became minor and rare species in recovery and control plots (1.7%and 0.4% respectively). *Entomobrya musatica, Seira traegaardhi* and *Sminthurides pumilis* had the same degree of dominance (minor) in grazing plot. These species were not found in recovery plot but were found in the control plot as rare species (0.2%, 0.5% and 0.3%, respectively). Significant increase ($p \leq 0.05$) in the density of *Sminthurus multifasciatus* which became dominant (14.1% of the total abundance) in comparison with 5.1 and 5.6% in recovery and control plots, respectively. *Hypogastrura inermis, Friesea claviseta* and *Cyphoderus bidenticulatus* were minor in grazing plot (2.6, 3.1 and 3.5%, respectively) while it became subdominant in recovery plot (7.0, 5.0 and 7.7%, respectively) .The same species seemed to be differed in their position in control plot (Table 2). *Tullbergia callipygos* was rare in grazing plot but it became subdominant in recovery and control plot. Tables (3 and 4) show a summary of the effects, using the Kruskal–Wallis test applied to the all collected species from grazing, recovery and control areas during the four seasons of the study. Obviously species-specific effects could be observed for all collembolan species in all seasons of the year except *Tullbergia callipygos* and *Folsomides parvulus*, as no negative effects for their densities are seen in spring.

Table 3: Kruskal–Wallis tests for differences in the number of Collembolan species per sample between grazing, recovery and control plots in all four seasons of study.

Kruskal Wallis Test	Spring		Summer		Autumn		Winter	
	H	P-value	H	P-value	H	P-value	H	P-value
Hypogastrura denticulata	4.264	0.005*	13.678	0.004*	6.679	0.010*	6.359	0.031*
Hypogastrura inermis	5.046	0.024*	24.678	0.001*	7.698	0.014*	12.369	0.001*
Friesea claviseta					4.697	0.005*	27.649	0.024*
Onychiurus absoloni	6.024	0.003*	3.046	0.048*	34.341	0.001*	14.396	0.001*
Tullbergia callipygos	1.654	0.097	2.378	0.037*	24.37	0.001*		
Folsomides parvulus	1.852	0.069	7.694	0.002*	19.679	0.001*	24.367	0.001*
Isotomina thermophila	6.541	0.020*			37.858	0.001*	21.367	0.001*
Isotomurus palustris			6.348	0.007*			30.679	0.001*
Entomobrya musatica								
Seira traegaardhi			6.378	0.019*	8.674	0.004*	2.367	0.025*
Lepidocyrtus cyaneus	14.354	0.001*	8.647	0.006*	12.745	0.003*	11.369	0.001*
Cyphoderus bidenticulatus	24.036	0.001*	4.397	0.024*			10.679	0.028*
Sminthurides pumilis			23.478	0.001*	21.547	0.001*		
Sminthurus multifasciatus								

The data are based on grazing, recovery sites and a control.H, Kruskal–Wallis test statistic (2 degrees of freedom), P, level of significance.

Table 4: Kruskal – Wallis tests for differences in the number of Collembolan species per sample between grazing, recovery and control plots per year.

Kruskal Wallis Test	Grazing		Recovery		Control	
	H	P-value	H	P-value	H	P-value
Hypogastrura denticulata	1.733	0.630	12.067	0.002*	29.075	0.000*
Hypogastrura inermis	2.000	0.157	9.000	0.029*	39.174	0.000*
Friesea claviseta	10.714	0.001*	4.000	0.046*	2.373	0.123
Onychiurus absoloni	0.694	0.875	6.679	0.083	36.097	0.000*
Tullbergia callipygos	1.600	0.449	1.900	0.387	1.506	0.471
Folsomides parvulus	2.221	0.528	5.819	0.121	22.918	0.000*
Isotomina thermophila	1.435	0.697	1.667	0.644	34.005	0.000*
Isotomurus palustris	3.500	0.174	0.667	0.414	2.176	0.337
Entomobrya musatica	-	-	-	-	-	-
Seira traegaardhi	-	-	-	-	-	-
Lepidocyrtus cyaneus	1.000	0.317	-	-	0.875	0.646
Cyphoderus bidenticulatus	10.333	0.016*	0.421	0.810	7.185	0.066
Sminthurides pumilis	-	-	-	-	0.034	0.853
Sminthurus multifasciatus	9.800	0.007*	1.324	0.250	3.441	0.179

Collembolan diversity

Simpson's D diversity index and their associated equitability index were used to evaluate the effect of grazing on level of Collembolan communities seasonally sampled from grazing, recovery and control sites. Table (5) shows that species diversity and equitability in all cases tended to decrease in comparison to the controls, with an intermediate effect in the recovery site, and the strongest effect in grazing sites. Simpson's diversity index ranged between 6.14 and 9.11and its equitability index ranged between 0.614 and 0.957. The highest diversity (D) was recorded in the control plot (8.93, 9.09, 8.82 and 9.11 in the four seasons). Species diversity reached its lowest value in grazing plots (6.66, 7.09, 6.14 and 7.14 in the four seasons).

Table 5: Simpson's D diversity index and their associated equitability index calculated for Collembolan communities seasonally sampled from grazing, recovery and control sites.

Season Species	Spring			Summer			Autumn			Winter		
	Grazing	Recovery	Control	Grazing	Recovery	Control	Grazing	Recovery	Control	Grazing	Recovery	Control
Simpson's D diversity index	6.66	7.66	8.93	7.09	7.65	9.09	6.14	7.09	8.82	7.63	7.86	9.11
equitability index	0.832	0.957	0.992	0.699	0.826	0.946	0.614	0.709	0.801	0.714	0.827	0.954

Vertical distribution

The pattern of vertical distribution observed at the species level coincides with the one observed for the whole Collembola population (Table 6). In grazing site *Folsomides parvulus, Entomobrya musatica, Lepidocyrtus cyaneus,* and *Sminthurus multifasciatus* are ecologically similar since they concentrated in the upper soil horizon (0-5). Their mean depth remain the same and the depth deviation is small in all seasons of the year of collection. Species *Hypogastrura denticulate, Hypogastrura inermis, Onychiurus absoloni, Tullbergia callipygos, Isotomurus palustris* and *Cyphoderus bidenticulatus* are concentrated in the second soil horizon (5-10). The variation in their mean depth and the intensity of depth deviation are not significantly different (P>0.05). Species *Tullbergia callipygos* and *Isotomina thermophila* are concentrated in the third soil horizon (10-15) in all seasons.

Table 6: Data of the Collembola Sampling show the mean number of Collembola collected / year (N), the mean depth (M) and the depth deviation (S).

Species	Treatment								
	Grazing			Recovery			Control		
	N	M	S	N	M	S	N	M	S
1-Hypogastrura denticulata	61.2	5.94	2.31	96	5.83	2.35	14.60	5.80	2.36
2-Hypogastrura inermis	17.9	6.32	1.77	51.3	1.45	2.43	–	5.64	2.46
3-Friesea claviseta	21.7	12.29	1.16	36.1	11.51	1.98	3.3	11.23	2.28
4-Onychiurus absoloni	84.7	7.69	2.99	137.1	6.85	2.69	22.6	6.95	3.25
5-Tullbergia callipygos	34.8	6.37	2.08	60.7	11.61	1.95	8.8	11.26	2.19
6-Folsomides parvulus	76.5	3.72	2.43	125	3.62	2.07	22.9	3.99	2.28
7-Isotomina thermophila	66.8	10.79	2.37	94.3	11.47	2.01	17.2	11.26	2.19
8-Isotomurus palustris	15.6	6.02	2.28	24.4	5.98	2.29	7.5	6.37	2.08
9-Entomobrya musatica	3.1	2.50	0	-	-	-	14.7	5.98	2.34
10-Seira traegaardhi	6.5	8.65	4.12	-	-	-	6.50	7.19	4.13
11-Lepidocyrtus cyaneus	4.7	4.62	2.47	12.7	7.22	3.62	0.8	7.39	3.57
12-Cyphoderus bidenticulatus	26.2	6.79	3.52	56.3	6.74	3.47	12.5	7.80	3.43
13-Sminthurides pumilis	28.7	4.57	2.45	–	-	-	28.7	4.18	2.36
14-Sminthurus multifasciatus	9.3	4.11	2.33	36.5	3.86	2.22	161.0	4.98	3.25

In recovery site species *Hypogastrura inermis* and *Folsomides parvulus* are occur in the upper soil horizon (0-5) since they are clustered into the center of this second horizon in spring (Table 7). The main depth of *Hypogastrura inermis* increases in summer and autumn and the individuals are found deep in the third horizon (Table 7 b, c). Species *Hypogastrura denticulate, Onychiurus absoloni, Isotomurus palustris* and *Cyphoderus bidenticulatus* are concentrated in the second soil horizon (5-10). The variation in their mean depth is significantly different P<0.05.species *Friesea claviseta, Tullbergia callipygos* and *Isotomina thermophila* are concentrated in the third horizon (M ranged between 10.66 and 11.98). The remaining seven species are different in their ecological patterns since *Friesea claviseta, Entomobrya musatica, Seira traegaardhi, Lepidocyrtus cyaneus, Cyphoderus bidenticulatus* and *Sminthurus multifasciatus* disappeared from grazing, recovery and control sites in spring (Table 7a). In control site species *Folsomides parvulus, Sminthurides pumilis* and *Sminthurus multifasciatus* are concentrated in the upper soil horizon (0-5). Their mean depth remain the same and the depth deviation is small in all seasons of the year of collection but *Sminthurus multifasciatus* disappear during the all seasons except in winter (Table 7d).

Table 7a: Data of the Collembolan Sampling show the mean number of Collembola collected in spring (N), the mean depth (M) and the depth deviation (S).

Species	Treatment								
	Grazing			Recovery			Control		
	N	M	S	N	M	S	N	M	S
1-Hypogastrura denticulata	11.0	8.36	4.25	19.0	5.39	2.46	37.0	5.33	2.47
2-Hypogastrura inermis	-	-	-	4.7	2.5	0	12.5	5.49	2.44
3-Friesea claviseta	-	-	-	-	-	-	-	-	-
4-Onychiurus absoloni	21.9	7.06	3.14	23.5	6.96	2.95	36.5	5.23	2.48
5-Tullbergia callipygos	15.6	11.98	2.69	22.6	11.92	1.59	28.3	11.03	1.94
6-Folsomides parvulus	24.7	3.85	2.22	23.9	3.33	1.91	16.3	3.98	2.43
7-Isotomina thermophila	13.3	11.25	2.16	19.4	11.36	2.43	32.5	11.73	1.86
8-Isotomurus palustris	37.8	6.46	2.02	14.1	6.04	2.27	6.1	5.77	2.37
9-Entomobrya musatica	-	-	-	-	-	-	-	-	-
10-Seira traegaardhi	-	-	-	-	-	-	-	-	-
11-Lepidocyrtus cyaneus	-	-	-	-	-	-	-	-	-
12-Cyphoderus bidenticulatus	0.7	7.5	0	-	-	-	14.6	6.26	3.38
13-Sminthurides pumilis	14.3	3.99	2.29	-	-	-	0.4	2.5	0
14-Sminthurus multifasciatus	-	-	-	-	-	-	-	-	-

Table 7b: Data of the Collembola Sampling show the mean number of Collembola collected in Summer (N), the mean depth (M) and the depth deviation (S).

Species	Treatment								
	Grazing			Recovery			Control		
	N	M	S	N	M	S	N	M	S
1-Hypogastrura denticulata	11.0	6.13	2.22	22.0	5.45	2.15	32.0	6.09	2.25
2-Hypogastrura inermis	11.8	6.65	1.87	20.2	6.23	2.17	66.3	5.99	2.29
3-Friesea claviseta	-	-	-	-	-	-	-	-	-
4-Onychiurus absoloni	18.5	7.90	4.11	30.6	6.09	2.74	33.5	5.11	3.55
5-Tullbergia callipygos	10.4	10.8	2.34	22.3	11.98	1.51	34.4	11.2	2.14
6-Folsomides parvulus	58.0	3.29	1.88	37.7	3.51	2.01	22.3	3.46	2.01
7-Isotomina thermophila	18.1	11.36	2.09	21.5	12.1	1.27	26.2	11.31	2.12
8-Isotomurus palustris		-	-	-	-	-	-	-	-
9-Entomobrya musatica	14.7	5.89	2.33	-	-	-	3.1	2.5	0
10-Seira traegaardhi	-	-	-	-	-	-	-	-	-
11-Lepidocyrtus cyaneus	18.5	8.17	3.88	12.7	7.22	3.62	3.0	5.83	3.35
12-Cyphoderus bidenticulatus	5.7	7.76	4.02	18.7	6.77	3.33	30.1	8.81	2.58
13-Sminthurides pumilis	14.5	4.49	2.42	-	-	-	3.70	4.79	3.77
14-Sminthurus multifasciatus	64.0	7.03	3.61	-	-	-	-	-	-

Table 7c: Data of the Collembola Sampling show the mean number of Collembola collected in Autumn (N), the mean depth (M) and the depth deviation (S).

Species	Treatment								
	Grazing			Recovery			Control		
	N	M	S	N	M	S	N	M	S
1-Hypogastrura denticulata	15.0	6.16	2.21	22.0	5.45	2.45	37.0	5.91	2.34
2-Hypogastrura inermis	-	-	-	12.5	5.28	2.48	33.5	4.47	2.43
3-Friesea claviseta	3.3	12.5	0	12.1	11.21	2.18	19.9	11.77	1.76
4-Onychiurus absoloni	22.6	8.69	3.21	42.4	7.23	3.62	95.5	7.24	2.56
5-Tullbergia callipygos	8.8	10.9	2.32	15.8	10.66	2.45	26.6	11.25	2.15
6-Folsomides parvulus	2.9	3.13	1.66	38.3	3.58	2.06	70.0	3.93	2.25
7-Isotomina thermophila	17.2	10.39	2.86	25.4	11.41	2.04	50.0	10.50	2.44
8-Isotomurus palustris	38.4	6.36	2.06	10.3	5.89	2.33	7.5	5.80	2.35
9-Entomobrya musatica	-	-	-	-	-	-	-	-	-
10-Seira traegaardhi	-	-	-	-	-	-	-	-	-
11-Lepidocyrtus cyaneus	14.0	12.5	6.42	-	-	-	0.8	2.5	0
12-Cyphoderus bidenticulatus	12.5	7.6	3.77	20.2	7.45	3.55	31.6	9.48	3.48
13-Sminthurides pumilis	-	-	-	-	-	-	-	-	-
14-Sminthurus multifasciatus	52.0	3.65	2.11	14.5	4.22	2.37	-	-	-

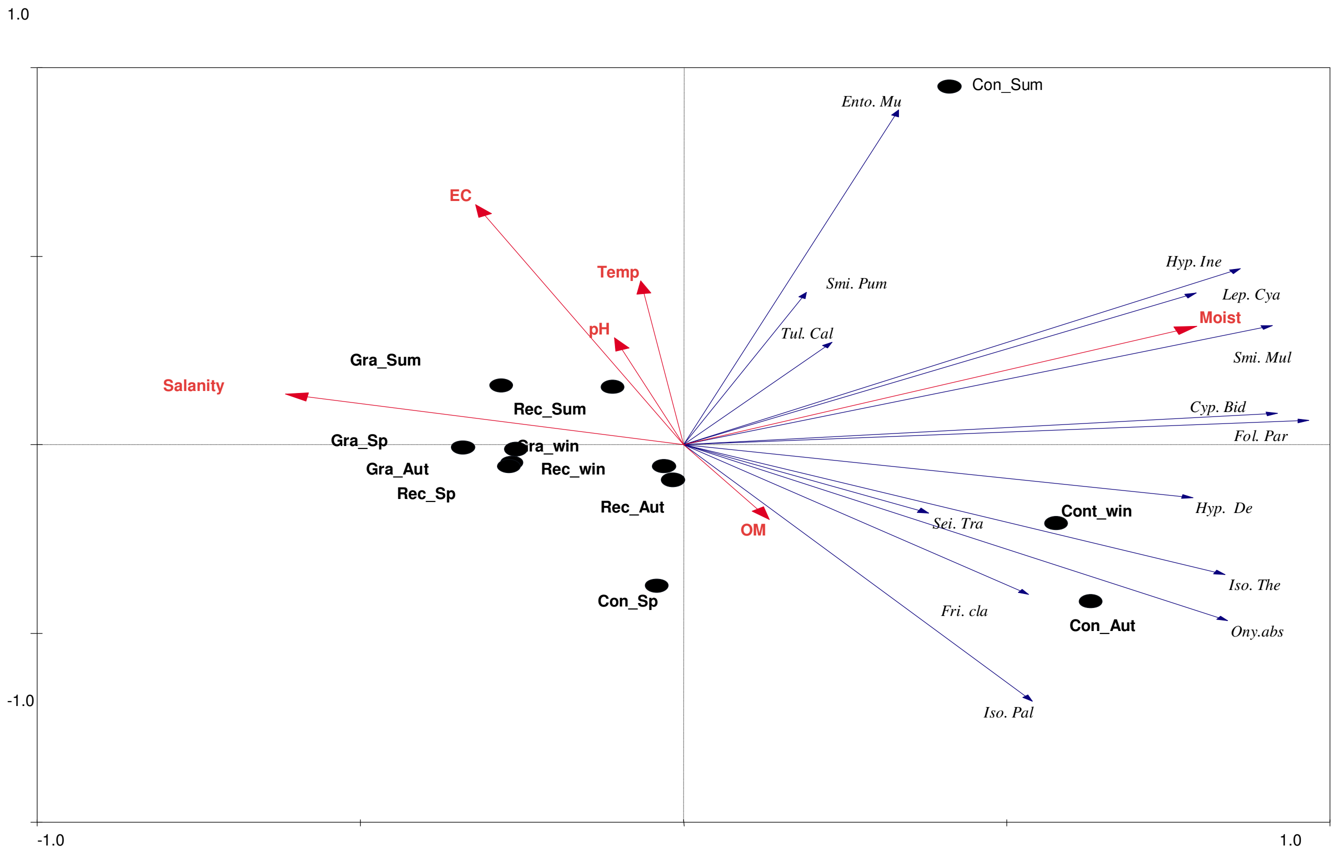
Table 7d: Data of the Collembola Sampling show the mean number of Collembola collected in Winter (N), the mean depth (M) and the depth deviation (S).

Species	Treatment								
	Grazing			Recovery			Control		
	N	M	S	N	M	S	N	M	S
1-Hypogastrura denticulata	19.0	5.56	2.41	33.0	6.59	1.93	30.0	6.20	2.28
2-Hypogastrura inermis	6.1	5.83	2.31	13.0	6.34	2.10	49.3	5.54	2.44
3-Friesea claviseta	18.4	11.50	1.94	24.0	11.66	1.90	30.1	10.80	2.90
4-Onychiurus absoloni	21.7	7.12	3.59	40.0	6.87	2.99	60.3	6.97	2.47
5-Tullbergia callipygos	-	-	-	-	-	-	-	-	-
6-Folsomides parvulus	66.6	4.49	2.44	25.0	3.93	2.24	15.6	4.29	2.40
7-Isotomina thermophila	18.2	10.24	2.48	28.0	11.07	2.25	77.0	11.39	2.07
8-Isotomurus palustris	27.0	6.20	2.19	2.0	7.50	0.0	-	-	-
9-Entomobrya musatica	-	-	-	-	-	-	-	-	-
10-Seira traegaardhi	6.5	8.65	3.99	-	-	-	14.7	7.60	4.14
11-Lepidocyrtus cyaneus	14.5	6.63	3.27	0.90	2.50	0.0	-	-	-
12-Cyphoderus bidenticulatus	5.3	5.10	2.24	17.0	6.02	3.32	32.4	5.89	2.96
13-Sminthurides pumilis	-	-	-	-	-	-	-	-	-
14-Sminthurus multifasciatus	45.0	3.60	2.08	22.0	3.63	2.09	8.0	4.30	2.41

Friesea claviseta, Tullbergia callipygos and *Isotomina thermophila* are concentrated in the third soil horizon (10-15) in all seasons. While *Friesea claviseta* disappear in spring and summer from all studied plots. The remaining species are concentrated in the second soil horizon (5-10).

The Multivariate analysis (Fig 3) showed that species communities of most collembolan species differed significantly by season. Positive influence of moisture and organic matter content on the abundance of the collembolan species, *Hypogastrura inermis, Lepidocyrtus cyaneus* and *Sminthurus multifasciatus* was observed. The opposite pattern of environmental variables (temperature, pH, Ec, and salinity) has positive effect on collembolan species in grazing and recovery plots during summer season.

Figure 3: Multivariate analysis of collected collembolan species with different environmental variable during the four seasons of study.



Arrows illustrate the correlation between collembolan community development and the statistically significant environmental variables,circular dots representing plots at all seasons of the year i.e. (Gra) grasing; (Rec) recovery; (Con) control; (Aut) autumn; (Sum) summer; (Win) winter; (Sp) spring. (Tem) temperature; (Moist) moisture; (OM) organic matter; (EC) electrical conductivity. (Hyp. De) Hypogastrura denticulate; (Hyp. Ine) Hypogastrura inermis; (Fri. Cla) Friesea claviseta;(Ony. abs) Onychiurus absoloni; (Tul. cal) Tullbergia callipygos; (Fol. par) Folsomides parvulus; (Iso the) Isotomina thermophila; (Iso. pal) Isotomurus palustris; (Ento. mu) Entomobrya musatica; (Sei. tra) Seira traegaardhi ; (Lep. cya) Lepidocyrtus cyaneus; (Cyp. bid) Cyphoderus bidenticulatus; (Smi .pum) Sminthurides pumilis and (Smi. mul) Sminthurus multifasciatus. **Scale for supplementary variables = 1 x samples scale.**

DISCUSSION

In the present study we reported low abundances of total Collembolan species under the effect of the grazing regimes when compared with control. Salamon et al. (2008) stated that, Collembola responds little to changes in vegetation structure and appears to be more influenced by biotic factors such as water content. The obtained results appeared that the population of hemiedaphic collembolan species *Isotomurus palustris, Entomobrya musatica, Sminthurides pumilis* and *Sminthurus multifasciatus* had increased in grazing plots followed by recovery plot and decreased in control plots despite the favorable physiochemical conditions. In contrast all euedaphic species decreased in grazing plots and slightly increase in recovery when compared with their densities in control plots which reach their optimum population size in winter. In other studies Collembola generally show discriminatory associations with agronomic disturbance as the relative response to different treatments varies, depending on the year (Wardle et al. 1999). An interesting observation is that the relative abundance of euedaphic Collembolan species (*Friesea claviseta, Isotomina thermophila, Seira traegaardhi* and *Cyphoderus bidenticulatus*) from the grazing plots was lower than the relative abundance from the recovery and control plots during the whole period of study. These results are in accordance with that reported by

Clapperton et al. (2002) and Lindo and Visser (2004) who suggested that the difference in relative abundances and consequently in diversity are related to the soil compaction as a result of livestock grazing. Vannier (1987) found that Collembola from the Isotomidae family are less tolerant to desiccation than oribatid mites in addition, the lower reproduction and higher mortality are the result of low moisture content (Butcher et al. 1971).

Significant differences in species richness of Collembola were not evident in the grazing, recovery and control plots. Control plot may be considered to have slightly higher species richness than heavily grazed plot due to a total number of species recorded. Aguilar (2011) stated that, grazing has enhanced significantly the species richness of Oribatida but not that of Collembola and suggesting a relationship between oribatid richness and grazing disturbance. A strong grouping pattern was observed in the Control as opposed to the Recovering and heavily grazed regimes which presented no distinct group pattern having similar species composition of Collembola.

These results showed that grazing regimes is an important characteristic to determine the species composition of Collembola in the soil layer of cultivated rangelands. The analysis of the collected data reflects the differences between grazing and Control areas, frequently reported by other authors (Bonnet et al., 1977 and Ponge, 1993). However, differences in species composition among the several land-use units are not explained only by this division; as we documented, the proportion of each soil-use type within each land-use unit, plus the different management practices adopted also have a share in conditioning community composition.

In the case of grazing some species *Isotomurus palustris, Entomobrya musatica, Sminthurides pumilis* and *Sminthurus multifasciatus* are able to adapt their dynamics to cope with this disturbance. However, when pulse and press disturbances coexist, community composition can be affected which usually results in a reduction of species number and/or abundance. In this case, and despite the slight difference in the average number of taxa between grazed and control areas in the species contributing to the decrease of that difference have a low abundance in comparison to more common species. These results coincide with that reported by other authors (Bonnet et al., 1977 and Ponge, 1993). Control plot was clustering a part from Recovering and grazed plots indicating that it has a different species composition as previously demonstrated by differences in species richness and diversity from those of the grazed plots when analyzed multivariate methods. When using Collembola as bioindicators to monitor the community changes, multivariate methods gives strong results, allowing the detection of small changes in the community composition. This is in accordance with Van Straalen, (1997, 1998) who stresses the importance of the type of data to collect when using bioindicators to assess changes at landscape level.

Concerning vertical distribution of Collembola, the recorded results reveal that *Folsomides parvulus, Entomobrya musatica, Lepidocyrtus cyaneus, Sminthurides pumilis,* and *Sminthurus multifasciatus* inhabit the top 5 cm of soil in all investigated plots in all seasons except in summer in some cases where they escape to the deepest layers from hot and dry conditions. Collembolan species *Friesea claviseta, Tullbergia callipygos* and *Isotomina thermophila* inhabit deeper soil layer (10-15 cm depth) in all investigated plots in all seasons except in some cases but their population density tended to decrease in comparison to more common species. The remaining recorded species were recorded at the soil depth from 5-10 cm. Most workers are of the opinion that most abundant soil inhabiting Collembola are usually abundant near the surface up to the layer of 10 cm deep which are characterized by favorable moisture conditions, adequate living space, aeration ratio and accumulation of organic debris (Wallwork 1970, Holt 1985 and Badejo et al., 1998). The finding of the present investigation also agrees with their findings. Reduction in the abundance and aggregation of individuals in deeper layers may be due to the reduction of pore space, less available food sources and corresponding unfavorable microclimatic conditions (Hagvar 1983, Holt 1985 and Culic et al., 2002). Muturi et al., (2009) and Maribie, (2009) reported that, the presence of organic manure resulted in an increase in the abundance and diversity of total collembolan species.

CONCLUSION

The study has demonstrated the potential of grazing regimes amendments in enhancing Hemiedaphic soil Collembola as well as diversity due to the increased of organic matter contents and substrate niche. However the disturbance due the removal of the vegetation cover as a result of heavily grazing negatively affects most Collembolan species which are important in nutrient cycling. .It can be concluded that, negative and positive effects were found in different collembolan species. According to that study, grazing appears not to affect Collembola as a group.

References

Adams, BW., Ehlert, G., Stone, C., Alexander, M., Lawrence, D.,Willoughby, M., Moisey, D., Hincz, C., and Burkinshaw, A., (2009). Rangeland Health Assessment for Grassland, Forest and Tame Pasture. Public Lands and Forests Division, Alberta Sustainable Resource Development. Pub. No. T/044. ISBN 0- 7785 – 2848 - 0.

Aguilar, ID., (2011). Impact of grazing on soil mesofauna diversity and community composition in deciduous forested rangelands of northwest Alberta. Ph.D Carcey Hincz, P.Ag Rangeland Management Branch. Alberta Sustainable Resource Development. 20 pp.

Al Assiuty, AI. and Bayoumi, BM., (1983). Distribution of soil mites and collembolans under pine trees in Riyadh region, Saudi Aribia. Acta Acrachnol. 32: 27-36.

Al-Assiuty AI., Bayoumi BM., Khalil MA. and Van Straalen NM. (1998). Egg number and abundance of ten Egyptian oribatid mite species (Acari: Cryptostigmata) in relation to habitat quality. Eur J. Soil. Biol. 29:59–65.
Badejo,MA., Nathaniol TI. and Tian G., (1993). Abundance of springtails (Collembola) under four agro forestry tree species with contrasting litter quality, Biol, Fertel, Soil. 27:15-20.
Benito, JCS. and Sanchez, MJL.,(2000). Ecology of soil springtails (Collembola, Insecta) from pine woods and Rhododendron scrublands in the Central and Eastern Pyrenees (North Spain). Pedobiologia 44:430–441.
Bonnet, L., Cassagnau, P. and Deharveng, L., (1977). Influence du de´boisement et du reboisement sur les bioce´noses de Collemboles dans quelques sols Pyre´ne´ens. B. Ecol. 8: 321–332.
Butcher, JW., Snider, R. and Snider, RJ., (1971). Biology of edaphic Collembola and Acarina. Annu. Rev. Entomol. 16, 249–288.
Chagnon, M., Hebert, C., Pare, D., (2000). Community structures of Collembola in sugar maple forests: relations to humus type and seasonal trends. Pedobiologia 44:148–174.
Clapperton MJ, Kanashiro DA, Behan-Pelletier VM., (2002). Changes in abundance and diversity of microarthropods associated with Fescue Prairie grazing regimes. Pedobiologia 46:496-511.
Culic MP., Souza de JL. and Ventura JA., (2002). Biodiversity of Collembola in tropical agricultural environment of Espirito, Santo, Brazil. Applied Soil Ecology. 21: 49- 58.
Dekinesh SI., (1991). Systematic and morphological studies on some soil collembola from three governorates in the North-Eastern district of Egypt. Alex. J. Agriculture Research. 36:77-95.
Detsis V., (2000). Vertical distribution of Collembola in deciduous forest under Mediterranean climatic condition. Belgium Journal of Zoology 130:57-61.
Dombos M., (2001). Collembola of loess grassland: effects of grazing on community composition. Soil Biology & Biochemistry, 33: 2037-2045.
Dunger W., (1983). ‘Tiere im Boden’. (Ziemsen Verlag: Lutherstadt Wittenberg).
Engelmann HD. (1978). Zur Dominanzklassifizierung von Bodenarthropoden. Pedobiologia. 18:378–80.
Fischer SF., Poschlod P. and Beinlich B. 1996. Experimental studies on the dispersal of plants and animals on sheep in calcareous grasslands. Journal of Applied Ecology 33:1206-1222.
Fjellberg, A., (1998). The Collembola of Fennoscandia and Denmark. Part I: Poduromorpha. Fauna ent. scand. 35. Brill, Leiden, 184pp.
Garay, I. and Nataf, L. (1982). Microarthropods as indicators of human trampling in suburban forests. Pages 201–207 in R. Borknkamm, J. A. Lee, and M. R. D. Seaward, eds. Urban ecology. The 2nd European ecological symposium, Berlin. 8–12 September 1980. Blackwell Scientific Publications, Boston, MA.
Gisin H. (1943). kologie und Lebensgemeinschaften der Collembolen im schweizeirischen Exkursionsgebiet Basels. Rev. Suisse de Zool., 50:131-224.
Hågvar, S. (1983). Collembola in Norwegian coniferous forest soils. II. Vertical distribution. Pedobiologia 25: 383–401
Hågvar, S. and Abrahamsen, G.(1984). Collembola in Norwegian coniferous forest soils. III. Relations to soil chemistry. Pedobiologia 27: 331–339.
Holt JA. (1985). Acari and Collembola in the litter and soil of the three north Qeensland Rainforst Australian Journal of Ecology 10:57-65.
Hopkin, SP. (2000). A key to the Springtails of Britain and Ireland, AIDGAP (Aids to Identification in Difficult Groups of Animals and Plants), test version. Field Studies Council, Preston Montford.
Klironomos, JN. and Kendrick, B. (1996). Palatability of microfungi to soil arthropods in relation to the functioning of arbuscular mycorrhizae. Biology and Fertility of Soils 21: 43-52.
Klute, A. (1986). Methods of soil analysis, Amer. Soc. Agronomi, Inc. Soil Soc. Amer. Inc. 3rd edition, Madison Wisconsin, USA.
Krzic, M., Broersma, K., Thompson, DJ. and Bomke, AA. (2000). Soil properties of grazed native and crested wheatgrass rangeland in southern interior of British Columbia. J. Range Manage. 53: 353–358.
Lindo, Z. and Visser S. (2004). Forest floor microarthropod abundance and oribatid mite (Acari:Oribatida) composition following partial and clear-cut harvesting in the mixedwood boreal forest. Canadian Journal of Forest Research 34:998-1006.
Maas, EV., and Hoffman GZ. (1977). Crop sals tolerance current assessment. Journal of irrigation and drainage division ASCE, 103:115-134.
Macfadyen A., (1953). Nots on methods for extracting of small soil arthropods. Journal of Animal Ecology. 22:65-77.
Magurran, AE., (1991). Ecological Diversity and its Measurement. Chapman & Hall, London.
Maribie, CW. (2009). Survey of soil mites (Acari) abundance and diversity in different land use types in Embu and Taita districts, Kenya Msc Thesis University of Nairobi.
Muturi, JJ., Mbugi, JP., Mueke, JM., Lagerlóf, J., Mungatu, JK., Nyamasyo, D. and Gikungu, M. (2009). Collembola density and diversity along a gradient of land-use types in Embu district, Eastern Kenya. Tropical and Subtropical Agroecosystems, 11, 361-369
Nielsen, UN.,. Osler, GHR, Campbell, CD., Neilson, R., Burslem, DFRP. and van der Wal. R. (2010). The enigma of soil animal species diversity revisited: The role of small-scale heterogeneity. PloS ONE 5(7): e11567. doi:10.1371/journal.pone.0011567
Page, AL. (1982). Methods of soil analysis Part 2: chemical and microbial properties. Amer. Soc. Agron. In, Soil Sci.Soc, Madison, Wisconsin, USA.
Pankhurst, CE., Hawke, BG., McDonald, HJ., Kirby, CA., Buckerfield, JC., Michelson, P., O’Brien, KA., Gupta, VVSR. and Doube, BE. (1995). Evaluations of soil biological properties as potential bioindicators of soil health. Aust. J. Exp. Agric. 35: 1015–1028.
Petersen H., Jucevica E. and Gjelstrup P. (2002). Long-term changes in collembolan communities in grazed and non-grazed abandoned arable fields in Denmark. Pedobiologia 48:559-573.
Pflug, A. and Wolters, V.(2001). Influence of drought and litter age on Collembola communities. Eur. J. Soil Biol. 37, 305–308.
Ponge JF. (1993). Biocenoses of Collembola in atlantic temperate grass-woodland ecosystems. Pedobiologia 37: 223-244
Ponge JF., Arpin P. and Vannier G. (1993). Collembolan response to experimental perturbations of litter supply in a temperate forest ecosystem. Eur J Soil Biol 29:141- 153
Ponge, JF. (2000). Acidophilic Collembola: living fossils? Contr. Biol. Lab. Kyoto Univ. 29:65–74.
Salamon, JA., Schew S. and Schaefer M. (2008). The Collembola community of pure and mixed stands of beech (Fagus sylvatica) and spruce (Picea abies) of different age. Pedobiologia 51:385-396.
Sousa, JP., Gama, MM., (1994). Rupture in a Collembola community structure from a Quercus rotundifolia Lam. forest due to the reafforestation with Eucalyptus globulus Labill. Eur. J. Soil Biol. 30:71–78.
Takeda H. (1995). Changes in the collembolan community during the decomposition of needle litter in a coniferous forest. Pedobiologia 39: 304-317.
Usher, MB. (1975). Seasonal and vertical distribution of a population of soil arthropods: Collembola. Pedobiologia, 10: 224-236
Van Straalen, NM., (1997). Community structure of soil arthropods as a bioindicator of soil health. In: Pankhurst, C.E., Doube, B.M., Gupta, V.V.S.R. (Eds.), Biological Indicators of Soil Health. CAB International, Wallingford, pp. 235–264.
Van Straalen, NM., (1998). Evaluation of bioindicator systems derived from soil arthropod communities. Appl. Soil Ecol. 9:429–438.
Vannier, G. (1987). The porosphere as an ecological medium emphasized in Professor Ghilarov’s work on soil animal adaptations. Biology and Fertility of Soils 3:39-44.
Verhoef, HA., Van Selm, AJ., (1983). Distribution and population dynamics of Collembola in relation to soil moisture. Holarct. Ecol. 6:387–394.
Wallwork, JA., (1970). Ecology of soil animals. McGraw- Hill, London, 283 pp.

Wardle, DA.; Nicholson, KS.; Bonner, KI.; Yeates, GW. (1999). Effects of agricultural intensification on soil-associated arthropod population dynamics, community structure, diversity and temporal variability over a seven-year period. Soil Biology biochemistry. 31:1691-1706

Wolters, V. (1983). .kologische Untersuchungen an Collembolen eines Buchenwaldes auf Kalk. Pedobiologia, 25: 73-85.