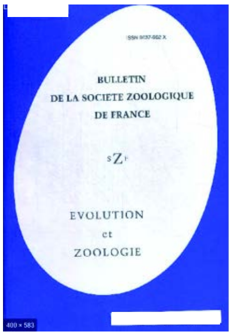
Bulletin de la Société Zoologique de France
2021, volume 146 (1), pages 1 à 7
ISSN : 0037-962X
http://societe-zoologique.fr/



Bio-ecology of the Diplopoda: *Cylindroiulus punctatus* (LEACH, 1815), *Ommatoiulus* sp. (LATZEL, 1884) and *Nematozonium* sp. (VERHOEFF, 1939) in Theniet El Had National Park

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Manuscrit reçu le 01/12/2020, accepté le 02/02/2021, mis en ligne le **13/05/2021**

Abstract Diplopoda are one of the essential components of soil fauna. Diplopoda playa role as soil engineers in material-cycling and energy-flow, but also act as sensitive bioindicators of soil characteristics and environmental change. However, little information has been available on the Diplopoda in the forest of Theniet El Had. In order to understand the seasonal dynamics of Diplopoda at 7 sites under different canopies, we have studied the impact of the quality of the litter and the chemical-physical properties of soil and climatic conditions on the density and the distribution of three species (*Ommatoiulus* sp., *Cylindroiulus punctatus*, *Nematozonium* sp.). The density varies between sites, with a density of 52.35 ind/m^2 in the cedar (*Cedrus atlantica*) forest and 17.66 ind/m^2 in the green oak (*Quercus ilex*) forest. The highest density of diplopods was observed in autumn, while the lowest content was detected in summer. The environmental conditions, compactness and low quality of litter, physicochemical properties of soil, determine the density, diversity and spatial distribution of Diplopoda. The results suggested that diplopod populations were significantly affected by the variation of the biotic and abiotic conditions, which provided important scientific evidence for understanding the ecological processes in the soil of Theniet El Had forest.

Keywords Theniet El Had, Diplopoda, Density, Litter, Soil.

Titre français : **Bio-écologie des Diplopodes : *Cylindroiulus punctatus* (Leach, 1815), *Ommatoiulus* sp. (Latzel, 1884) et *Nematozonium* sp. (Verhoeff, 1939) dans le Parc National de Theniet El Had**

Résumé Les Diplopodes sont l'une des composantes essentielles de la faune du sol par leur rôle d'ingénieurs du sol dans le cycle des matériaux. Ils agissent également comme bio-indicateur, sensibles aux caractéristiques du sol et aux changements environnementaux. Peu d'informations sont disponibles sur les diplopodes de la forêt de Theniet El Had. Afin de comprendre la dynamique saisonnière des diplopodes dans 7 stations sous les forêts de cèdres d'atlas (*Cedrus atlantica*) et de chênes verts (*Quercus ilex*), nous avons étudié l'impact de la qualité de la litière et des propriétés physico-chimiques du sol et des conditions climatiques sur la densité et la répartition des trois espèces *Ommatoiulus* sp., *Cylindroiulus punctatus*, *Nematozonium* sp. Les diplopodes ont été étudiés par tri manuel direct. Un échantillonnage saisonnier a été effectué dans sept stations sélectionnées en fonction des différentes propriétés physico-chimiques du sol et des modifications du couvert végétal ainsi que de la quantité et de la composition de la litière. La densité varie d'une station à l'autre, une densité de 52,35 ind/m^2 dans la forêt de cèdres et de 17,66 ind/m^2 dans la forêt de chênes verts. La plus forte densité des diplopodes a été observée en automne et la plus faible en été. Les conditions environnementales, la compacité et la faible qualité de la litière, les propriétés physico-chimiques du sol, déterminent la densité, la diversité et la distribution spatiale des diplopodes. Les résultats suggèrent que les diplopodes, dans leurs structures, sont significativement affectés par la variation des conditions biotiques et abiotiques, ce qui fournit des preuves scientifiques importantes pour la compréhension des processus écologiques dans le sol de la forêt de Theniet El Had.

Mots-clés Theniet El Had, Diplopoda, Density, Litter, Soil.

Introduction

Diplopods are a major component of terrestrial ecosystems of the world, they are ecologically important as detritivores (consumers of dead plant material), and are important biogeographical indicators because of their profound diversity and geological age, as well as low vagility (HOPKIN & READ, 1992). Diplopoda play an important role in the decomposition of organic matter, and several species are adapted to subterranean life, (CULVER & SHEAR, 2012; GOLOVATCH & KIME, 2009; SENDRA & REBOLEIRA, 2012). BONKOWSKI *et al.* (1998) also found that the presence of millipedes significantly increased the decomposition of litter, much more so than endogenous earthworms. RUAN *et al.* (2005) found that millipede density explained 40 percent of the variance in leaf litter decomposition rates, while soil microbial biomass explained only 19 percent of the variance.

Although the millipede faunas of many national parks in Algeria are relatively well studied, this is not true of the National Park of Theniet El Had. The biodiversity of these animals is not well known in Algeria. The present work concerns the study of the density and diversity of diplopods, their spatial and temporal dynamics and the impact of litter quality and anthropization in a forest ecosystem in the National Park of Theniet El Had.

Material and Methods

Study area

The study was performed in Theniet El Had National Park, on the El Oursins mountain at Tissemsilt in the west central area of Algeria (150 km west of Algiers, figure 1), at

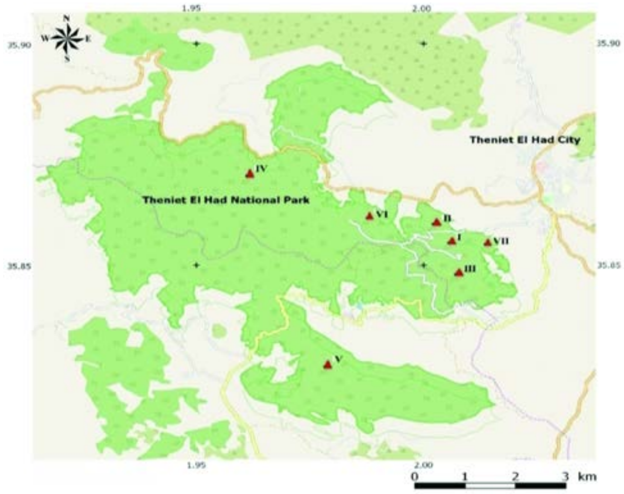

Fig. 1.- Geographical location of the study site.
Localisation des Stations d'étude.

an altitude of 858 to 1786 m. The national park is on the subhumid climate region (cool variant) with an average annual temperature of 11.3°C, and a total annual precipitation of about 792 mm (SARI, 1977; OUNADI *et al.,* 1990).

Methods

Diplopods were sampled during the four seasons from March 2018 to March 2019. Seven stations were chosen according to the vegetal cover, the type of soil and to include a site with anthropized soils (Tables 1 and 2).

The method used is hand sorting, according to the criteria suggested by LAVELLE (1988) and ANDERSON & INGRAM (1993). The hand sorting is very relevant for the extraction of diplopods (BLANCHARD, 1990; DECAËNS,

Table 1.- Description of study sites with latitude, longitude, and type of habitat.
Description des sites d'étude avec la latitude, la longitude et le type d'habitat..

Study site	Site number	Latitude	Longitude	Habitat
canton pépinière	I	N 35.856108	E 002.0045 65	Cedar (*Cedrus atlantica*) dense
canton pépinière	II	N 35.857413	E 002.0030 20	Cedar forest for the picnic (anthropized)
canton Sidi Abdoune	III	N 35.845658	E 002.01 2947	Holmoak (*Quercus ilex*)
canton Djouareb	IV	N 35.868589	E 001.964113	Cedar
canton Fercîouan	V	N 35.840766	E 001.963119	Holmoak
canton Guerouaou	VI	N 35.861583	E 001.990806	Holmoak
canton Kefsachine	VII	N 35.847379	E 002.012017	Holmoak dense

Table 2.- Soil properties in the sampled forests at different stations.
Propriétés des sols dans les stations d'étude.

Station	pH	C (mg.g^{-1})	N (mg.g^{-1})	P_2O_5 (mg.g^{-1})	Litter composition	Litterthickness(cm)		
						OL	OF	OH
I	7.17 ± 0.2	3.72 ± 0.42	11.65 ± 1.7	5.6 ± 0.3	Cedar needles	5	8	17
II	7.18 ± 0.3	3.78 ± 0.26	12 ± 2.0	6.6 ± 0.3	Cedar needles	0.4	0.2	1.6
III	7.25 ± 0.3	4.95 ± 0.66	37.86 ± 2.6	9.3 ± 0.2	Green oak leaves	4.2	0.6	3.4
IV	7.07 ± 0.3	5.5 ± 0.48	27.75 ± 3.1	14.3 ± 1.0	Cedar needles	3.6	6.5	12.7
V	7.2 ± 0.3	4.86 ± 0.30	38.4 ± 2.8	8.3 ± 0.3	Green oak leaves	6.1	1.5	5
VI	7.02 ± 0.2	5.2 ± 0.58	25 ± 2.3	17.5 ± 0.6	Green oak leaves	8.7	2.3	6.6
VII	7.03 ± 0.3	5.74 ± 0.46	26.5 ± 1.4	16.2 ± 0.8	Green oak leaves	12.8	4.9	10

Organic horizons (**OL**: Dead Leaves, whole and perfectly recognizable. **OF**: Dead Leaves, fragmented, but still recognizable. **OH**: unrecognizable organic matter) are formed by dead organic matter (OM).

Table 3.- The density of the three species at the different sites.
La densité des trois espèces dans les différentes stations.

	Collected in						
	Cedar dense I	**Cedar anthro II**	**Holm oak III**	**Cedar IV**	**Holm oak 2 V**	**Holm oak 3 VI**	**Holm oak dense VII**
Cylindroiulus punctatus	32.53	17.6	3.83	26.6	5.23	10.2	12.6
Ommatoiulus sp.	7.5	2.66	10.27	12	16.4	15.2	18.5
Nematozonium sp.	12.32	9.96	3.56	8.6	2.9	09.33	13.8
Total average density	52.35	30.22	17.66	47.2	24.53	34.73	44.9

1999; BARROSE *et al.,* 2002). Ten blocks of soil, 25 cm x 25 cm by 30 cm deep, and the litter layer were collected and sorted manually at each site and season. Sampling is carried out during the months from December-January (winter season), May-June, (spring season) July-August (summer season) and October-November (autumn season).

Diplopods were kept in small bottles with 70% ethanol and sorted and identified in the Animal Ecobiology Laboratory at ENS KOUBA (Algeria), the Zoology Laboratory at INA El Harach (Algeria) and at the Natural History Museum, University of Florence (Italy).

Statistical analyses

In order to exploit the results by statistical analytical methods and to explain the diet by intake of several factors, we employed Factor Analysis of Correspondences (AFC) and analysis of Variances (ANOVA) using Xlstat (2009 Addinsoft, France).

Results

In total we observed 3908 individuals belonging to 2 families, Julidae and Siphonorhinidae. The Diplopoda density in ind/m^2 of each species is given in Table 3.

The density of diplopods in stations I (52.35 ind/m^2) and IV (47.2 ind/m^2) is greater than in other sites ($p<0.05$); on the other hand, the density at site III (17.66 ind/m^2) and II (30.22 ind/m^2) is low. Several factors can be highlighted to explain this difference. We can say that is due to the quality (cedar needles vs. green oak leaves) and quantity of the litter. The thickness of litter at site I is 30 ± 5.9 cm and only 2.2 ± 0.21 cm in station II (Table 2).

The potential influence of environmental factors on the structure of diplopod communities is evaluated in Table 4 ($p<0.001$). For *Ommatoiulus* sp. and *Cylindroiulus punctatus*, we observe a shift between T2 and T1 during the rainy season in autumn, stand migrant (*Ommatoiulus* sp. *Cylindroiulus punctatus*) [with the population migrating?] to the surface layer, and the contrary when the dry season arrives. We observe that the population density of *Nematozonium* sp. in layers T3 and T4 changes between seasons.

The structure of Diplopoda populations was assessed by the differences between Figs 2-6 ($p<0,001$) as a high density of Diplopoda is observed in the layer T1 (litter), followed by the layers T2 (0 to 10 cm) and T4 (20 to 30 cm) and the final one is the layer T3 (20 to 30 cm) according to Figure 2. The results of this analysis indicate that the

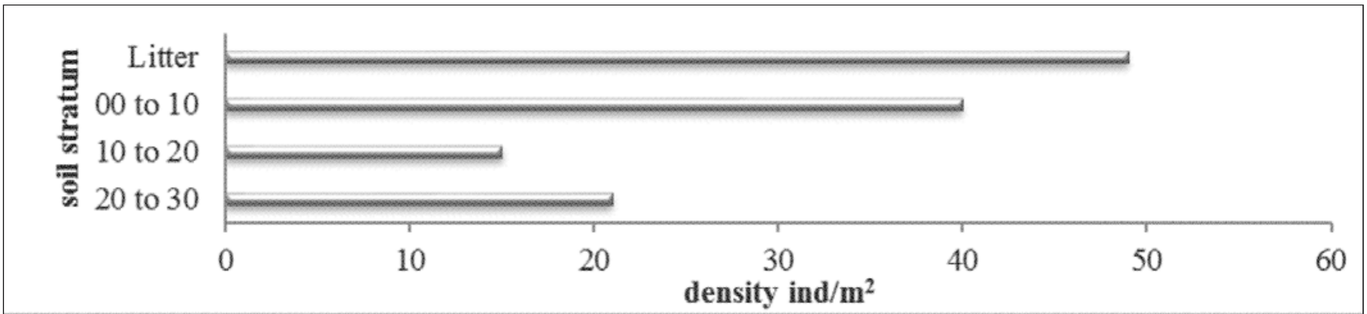

Fig. 2.- Annual distribution of diplopods in different soil stratums. (Litter = T1; 0 to 10 cm = T2; 10 to 20 cm = T3; 20 to 30 cm = T4).
Répartition annuelle des diplopodes dans les différentes strates de sol. (litière = T1 ; 0 à 10 cm = T2 ; 10 à 20 cm = T3 ; 20 à 30 cm = T4).

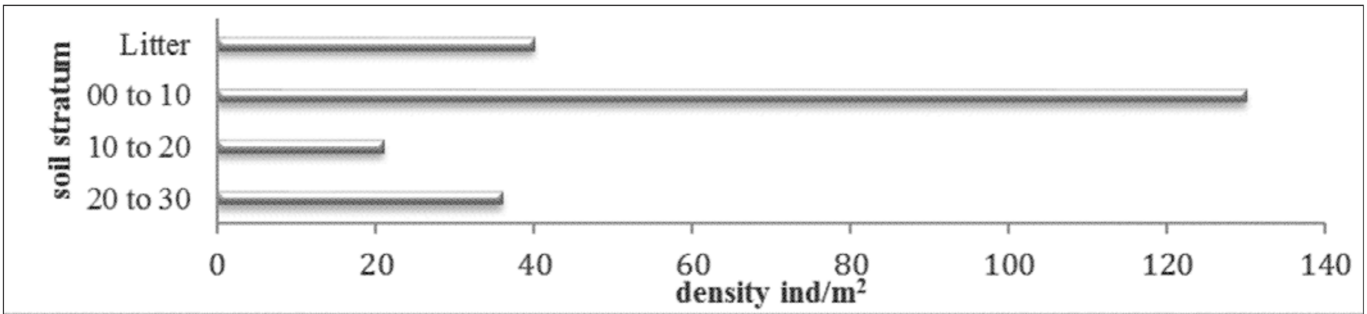

Fig. 3.- The spring distribution of the diplopods in different stratums. (Litter = T1; 0 to 10 cm = T2; 10 to 20 cm = T3; 20 to 30 cm = T4).
Répartition au printemps des diplopodes dans les différentes strates. (litière = T1 ; 0 à 10 cm = T2 ; 10 à 20 cm = T3 ; 20 à 30 cm = T4).

Table 4.- The seasonal dynamics of diplopods in the different soil stratums at three sites.
La dynamique saisonnière des diplopodes dans les différentes strates du sol dans trois stations.

Stations	Seasons	Layer	*Cylindroiuluspunctatus*	*Ommatoiulus* sp.	*Nematozonium* sp.
Cedar dense	Spring	litter	75.2 ± 9.3	11	0
		00 to 10 cm	185.6 ± 16.4	0	0
		10 to 20 cm	29 ± 3.1	0	7.3
		20 to 30 cm	0	0	24 ± 0.78
	Autumn	litter	265.3 ± 24.2	14.8	0
		00 to 10 cm	05	0	0
		10 to 20 cm	0	0	17
		20 to 30 cm	0	0	12
	Winter	litter	198.4 ± 17.2	12	0
		00 to 10 cm	8	0	6.6
		10 to 20 cm	0	0	21
		20 to 30 cm	0	0	17
	Summer	litter	4.2	6.4	0
		00 to 10 cm	339.2 ± 30.1	0	0
		10 to 20 cm	29	0	15
		20 to 30 cm	0	0	16
Cedar anthropized	Spring	litter	7.6	2	0
		00 to 10 cm	125.2 ± 6.3	0	0
		10 to 20 cm	11	0	6.4
		20 to 30 cm	0	0	24 ± 0.6
	Autumn	litter	85 ± 0.8	6.4	0
		00 to 10 cm	9.2	0	12
		10 to 20 cm	0	0	15
		20 to 30 cm	0	0	26
	Winter	litter	33	2.4	0
		00 to 10 cm	0	0	8
		10 to 20 cm	0	0	19
		20 to 30 cm	0	0	20
	Summer	litter	0	3	0
		00 to 10 cm	144 ± 7.4	0	0
		10 to 20 cm	22	0	5.2
		20 to 30 cm	0	0	32
Holmoak I	Spring	litter	6	16	0
		00 to 10 cm	11.4	53 ± 0.2	0
		10 to 20 cm	0	0	8
		20 to 30 cm	0	0	16
	Autumn	litter	19.4	36 ± 0.12	0
		00 to 10 cm	5	10	0
		10 to 20 cm	0	0	9.6
		20 to 30 cm	0	0	12
	Winter	litter	8	18.2	0
		00 to 10 cm	2	8	0
		10 to 20 cm	0	0	10.5
		20 to 30 cm	0	0	24
	Summer	litter	0	6.4	0
		00 to 10 cm	14.2	28 ± 0.9	0
		10 to 20 cm	0	0	21
		20 to 30 cm	0	0	40.2 ±1.2

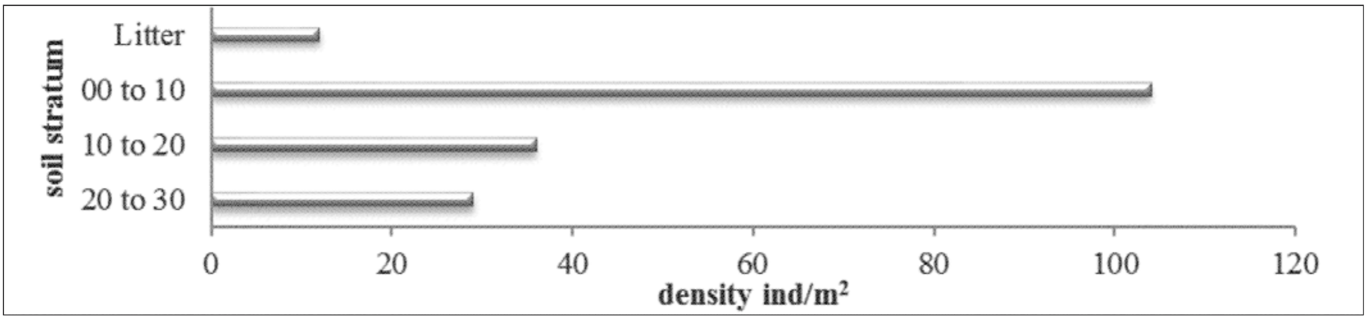

Fig. 4.- The summer distribution of diplopods in different stratums. (Litter = T1; 0 to 10 cm = T2; 10 to 20 cm = T3; 20 to 30 cm = T4).
Répartition en été des diplopodes dans les différentes strates. (litière = T1 ; 0 à 10 cm = T2 ; 10 à 20 cm = T3 ; 20 à 30 cm = T4).

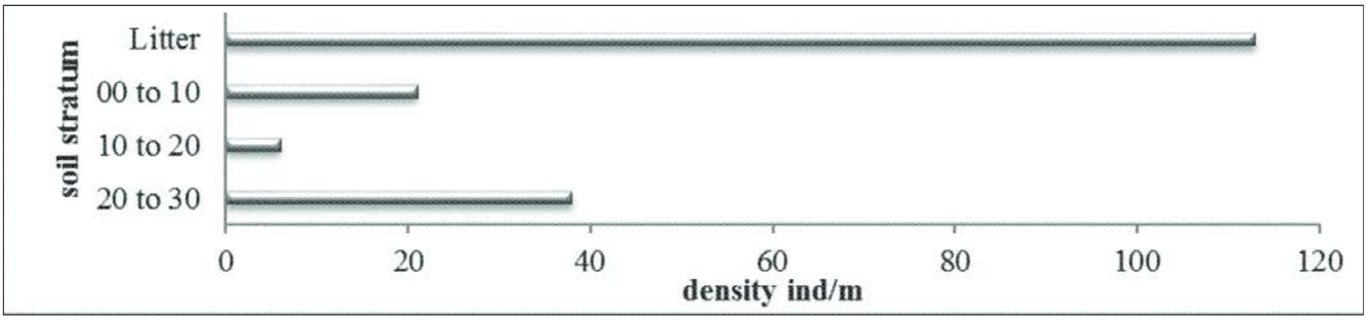

Fig. 5.- The autumn distribution of diplopods in different stratums. (Litter = T1, 0 to 10 cm = T2, 10 to 20 cm =T3; 20 to 30 cm = T4).
Répartition en automne des diplopodes dans les différentes strates. (litière = T1 ; 0 à 10 cm = T2 ; 10 à 20 cm = T3 ; 20 à 30 cm = T4).

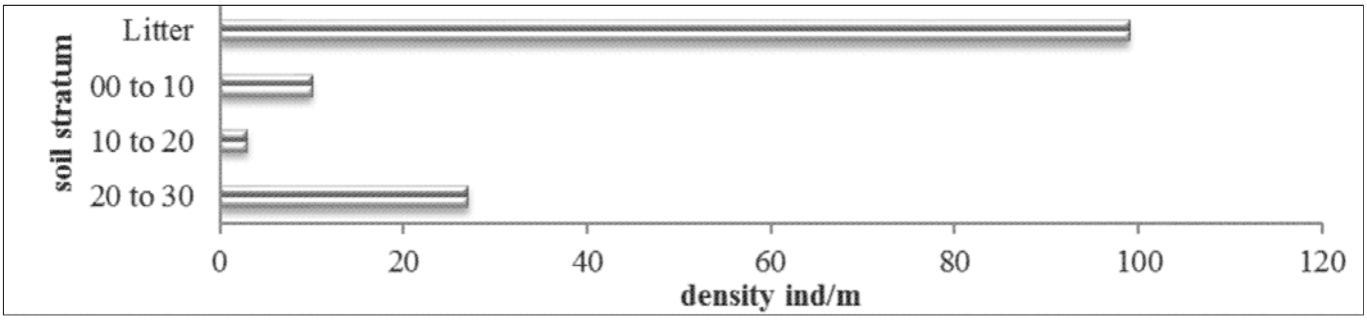

Fig. 6.- The winter distribution of diplopods in different stratums. (Litter = T1; 0 to 10 cm = T2; 10 to 20 cm = T3; 20 to 30 cm = T4).
Répartition en hiver des diplopodes dans les différentes strates. (litière = T1 ; 0 à 10 cm = T2 ; 10 à 20 cm = T3 ; 20 à 30cm = T4).

diplopods are distributed differentially in the layers of soil. The axes of analysis are shown in Figure 7. Soil stratums with a similar density of diplopods are closest together. We observe the species distribution between layers and stations.

Discussion

The diplopods are abundant at all sites. According to GOLOVATCH (2009), they succeeded in invading a considerable number of habitats, including difficult and extreme ones. The results show a difference in density of the Diplopoda between the sites, with a strong density at sites of Cedar (I, IV) and low density at sites of Holm oak (III,V) (Table 3). The consumption of cedar needles are favorable for the Diplopoda, compared to holm oak leaves. This result is consistent with previous observations by KHEIRALLAH (1979), DANGERFIELD (1994) and CÁRCAMO *et al.* (2000); millipedes are selective about which leaves they eat. According to STRIGANOVA & PRISHUTOVA (1990) and DAVID & CELERIER (1997), the quality of food is a significant factor in the dynamics of the populations of the diplopods, mainly on growth and reproduction. The diplopods show high rates of assimilation of macro-nutrients from selected litter and leaves in general (HOPKIN *et al.,* 1992). The reason for the difference in density of Diplopoda in Cedar dense I and Cedar anthropized II (Table 3) is the human trampling of litter at the second site (Table 2), which has been widely described in the scientific literature (CROUAU *et al.,* 1999; COLE *et al.,* 2001; MIGLIORINI *et al.,* 2005). According to BUCKERFIELD *et al.* (1997) and YEATES (2003), soil fauna are useful indicators of soil quality, because they are sensitive to changes in land management and are involved in many soil functions. Soil disturbance has detrimental effects on species and functional richness of Diplopoda assemblages (ZSOLT & ELISABETH, 2019).

The anthropogenic modification in station II does not affect the community of *Nematozoniumsp* (Table 4). According to ZSOLT & ELISABETH (2019), the species have different responses to anthropogenic habitat modification, depending on their ecological needs and tolerance.

Ommatoiulus sp. and *Cylindroiulus punctatus* do not dig very deeply during the dry season (Table 4), their population is distributed between the litter and 0 to 10 cm, while *Nematozonium* sp. are living underground from 10 to 30 cm (Figures

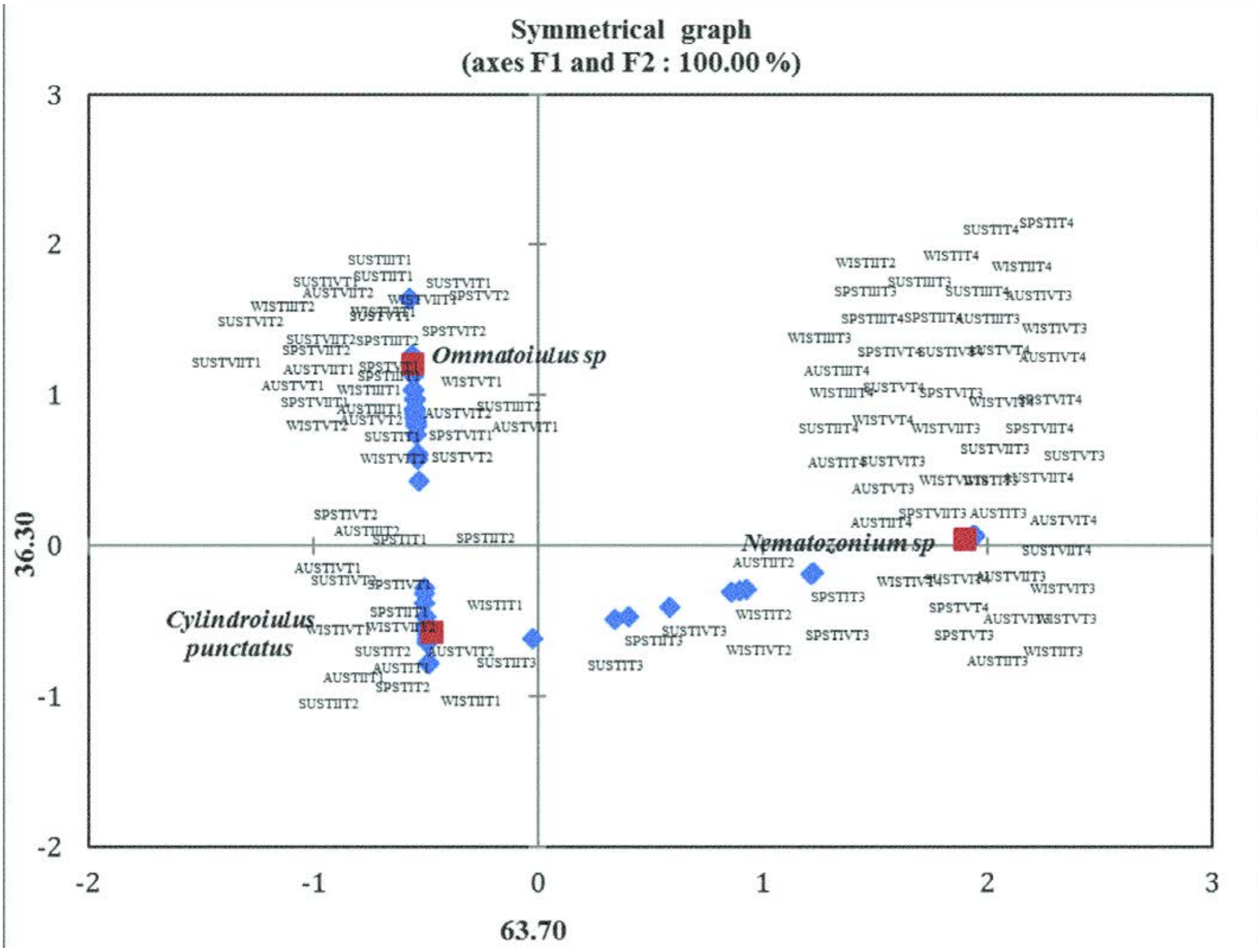

Fig. 7.- Correspondence analysis chart. Factors seasons, layers of the soil x species of diplopod.
Each species is plotted using its name at its coordinate on the first two axes produced by the analysis.
(SP: Spring, SU: Summer, AU: Autumn, WI: Winter, T1: litter, T2: 0 to 10 cm, T3: 10 to 20 cm, T4: 20 to 30 cm, (I, II, III, IV, V, VI, VII stations).
Numbers by each axis represent the percentage of data variability explained by the axis.

*Représentation graphique de l'analyse factorielle des correspondances Facteurs saisons, strates du sol x espèces de diplopodes du sol.
SP : printemps, SU : été, AU : automne, WI : hiver, T1 : litière, T2 : 00 à 10 cm, T3 : 10 à 20 cm, T4 : 20 à 30 cm.*

2-7). According to BRÖLEMANN (1923), VANDEL (1964) and GINET & DECOU (1977), diplopods are very largely represented in the various compartments of the basement of soil. The distribution of *Nematozonium* sp. is discussed by PAUL (2012) like many other colobognath millipedes, the Siphonophorida often occur in cryptic subterranean habitats and shun light where they are infrequently encountered.

For our study, the seasonal dynamic of *Ommatoiulus* sp. And *Cylindroiulus punctatusis* well marked by displacement between the litter and the layer of 0 to 10 cm (Table 4), with the arrival of the rainy season, these two species move from layer 0 to 10 cm (T2) to the litter (T1) in Autumn, according to GOLOVATCH (1994) these animals are generally very sensitive to the water deficit. For GILLON (1976), the migration of Julidae in depth coincides with the last rains, and our results are similar to those of GILLON & YVES (1979). The distribution of Julidae in depth varies according to the season. Temperature and humidity of soils are the main factors influencing the structure of Diplopoda (BRANQUART *et al.*, 1995; MEYER *et al.*, 1997; GAVA, 2004).

The population remains in the litter and reproduces: we found larvae and even eggs of Diplopoda in spring in the litter, and breeding of *Ommatoiulus* sp, and *Cylindroiulus punctatus* occurs in Autumn and Spring.

Conclusion

We sampled two families of diplopods (Julidae and Siphonorhinidae) and assessed the distribution of Julidae between the litter and the layer 0 to 10 cm, and their vertical displacement according to climatic conditions. The life-cycle of Julidae appears to be influenced mainly by the summer drought. Diplopoda are sensitive to changes in the quality and quantity of the litter and in land management of soil. The Siphonophoridae often occur in subterranean habitats, where they are found between 10 and 30 cm below the surface. This study will be followed by a taxonomic study of diplopods in the park.

Acknowledgments

We are highly thankful to the ENS Kouba, Algiers, for providing us with laboratories and equipment and the Zoology Laboratory at INA El Harach for helping us in identifying the species. We also thank all members of the animal eco-biology laboratory.

Références

ANDERSON, J.M. & INGRAM, J. (1993).- *Tropical soil biology and fertility programme: Methods Handbook*. 2nd edition, CAB International, Wallingford.

BARROS, E., PASHANASI, B., CONSTANTINO, R. & LAVELLE, P. (2002).- Effects of land-use system on the soil macrofauna in western Brazilian Amazonia. *Biol. Fertil. Soils,* **35**, 338-347.

BLANCHART, E. (1990).- *Rôle des vers de terre dans la formation et la conservation de la structure des sols de la savane de Lamto (Côte d'Ivoire)*. Thèse d'Etat, Université de Rennes I, 263 p.

BONKOWSKI M., SCHEU, S. & SCHAEFER, M. (1998).- Interactions of earthworms (*Octolasion lacteum*), millipedes (*Glomeris marginata*) and plants (*Hordelymus europaeus*) in a beechwood on a basalt hill: implications for litter decomposition and soil formation. *Applied Soil Ecology,* **9**, 161-166.

BRANQUART, E., KIME, R.D., DUFRENE, M., TAVERNIER, J. & WAUHTY, G. (1995).- Macroarthropod-habitat relationships in oak forest in South Belgium. 1. Environments and communities. *Pedobiologia*, **39**, 243-263.

BRÖLEMANN, H.W. (1923).- Biospeologica XLVIII. Blaniulidae Myriapodes (Première Série). *Archives de Zoologie expérimentale et générale,* **61** (2), 99-453.

BUCKERFIELD, J.C., LEE, K.E., DAVOREN, C.W. & HANNAY, J.N. (1997).- Earthworms as indicators of sustainable production in dry land cropping in Southern Australia. *Soil Biology and Biochemistry,* **29**, 547-554.

CÁRCAMO, H.A., ABE, T.A., PRESCOTT, C.E., HOLL, F.B. & CHANWAY, C.P. (2000).- Influence of millipedes on litter decomposition, N mineralization, and microbial communities in a coastal forest in British Columbia, Canada. *Canadian Journal of Forest Research,* **30**, 817-826.

COLE, L.J., McCRACKEN, D.I., FOSTER, G.N. & AIT KEN, M.N. (2001).- Using collembola to assess the risks of applying metal-ritch sewage sludge to agricultural land in western Scotland. Agric. *Ecosyst. & Envir.,* **83**, 177-189.

CROUAU, Y., CHENON, P. & GISCLARD, C. (1999).- The use of *Folsomia candida* (Collembola, Isotomidae) for the bioassay of xenobiotic substances and soil pollutants. *Appl. Soil Ecol.,* **12**, 103-111.

CULVER, D.C. & SHEAR, W.A. (2012).- Myriapods. *In* White, W.B. & Culver, D.C., eds., Encyclopedia of Caves, Waltham, Massachusetts, Academic Press, **2**, 538-542.

DAVID, J. & CÉLÉRIER, M. (1997).- Effects of yeast on the growth and reproduction of the saprophagous millipede *Polydesmus angustus* (Diplopoda, Polydesmidae). *Biol. Fertil. Soils,* **24**, 66-69.

DECAENS, T. (1999).- *Rôle fonctionnel et réponses aux pratiques agricoles des vers de terre et autres ingénieurs écologiques dans les savanes colombiennes*. Thèse de Doctorat, Université Paris VI. 407 p.

GAVA, R. (2004).- Vertical distribution of Diplopoda populations from deciduous forests. *Arch. Biol. Sci., Belgrade*, **56** (1-2), 59-64.

GILLON, D. & GILLON, Y. (1979).- Estimation du nombre et de la biomasse des Iules (Myriapodes, Diplopodes) dans une zone cultivée au Sénégal. *Bull. Écologie,* **10**(2), 95-107.

GILLON, Y. & GILLON, D. (1976).- Comparaison par piégeage des populations de Diplopodes Iuliformes en zone de végétation naturelle et champ d'arachide. *Cah. ORSTOM. Biol.,* **11** (2), 121-127.

GINET, R. & DECOU, V. (1977).- *Initiation à la biologie et à l'écologie souterraines*. Paris, Éditions Universitaires J.-P. Delarge, 345 pp.

GOLOVATCH, S.I. & KIME, R.D. (2009).- Millipede (Diplopoda) distributions: A review. *Soil Org.,* **81** (3), 565-597.

HOPKIN, S.P. & READ, H.J. (1992).- *The Biology of Millipedes*. Oxford, Oxford University Press, 223 pp.

KHEIRALLAH, A.M. (1979).- Behavioural preference of *Julus scandinavius* (Myriapoda) to different species of leaf litter. *Oikos*, **33**, 466-471.

LAVELLE, P. (1988).- Assessing the abundance and role of invertebrate communities in tropical soils: aims and methods. *J. Afr. Zool.,* **102**, 275-283.

MEYER, E. & SINGER, A.(1997).- Verteilung, Aktivität und Besiedlungsdichte von Diplopoden in Wäldern Vorarlbergs (Österreich). *Naturwissenschaftlichmedizinischer Verein in Innsbruck,* **84**, 287-306.

MIGLI ORINI, P., PIGI NO, G., CARUSO, T., FANCIULLI, P.P., LEONZIO, C. & BERNINI, F. (2005).- Soil communities (Acari Oribatida; Hexapoda Collembola) in a clay pigeon shooting range. *Pedobiologia*, **49**, 1-13.

OUNADI, F. & ZERROUKI, K. (1990).- *Diagnostic Écologique et Aménagement Sylvo-pastoral du Djebel El Meddad « parc national de Theniet El Had »,* Thèse d'ingéniorat, USTHB, Alger, 51 p.

PAUL, E., WILLIAM, A. & SHEAR, E. (2012).- A redescription of the leggiest animal, the millipede *Illacme plenipes*, with notes on its natural history and biogeography (Diplopoda, Siphonophorida, Siphonorhinidae). *ZooKeys*, **241**, 77-112.

RUAN, H., LI, Y. & ZOU, X. (2005).- Soil communities and plant litter decomposition as influenced by forest debris: Variation across tropical riparian and upland sites. *Pedobiologia*, **49**, 529-538.

SARI, D. (1977).- *L'homme et l'érosion dans l'Ouarsenis (Algeria)*. NMCS, Algiers, 204.

SENDRA, A. & REBOLEIRA, A. (2012).- The world's deepest subterranean community Krubera-Voronja Cave (Western Caucasus). *International Journal of Speleology*, **2**, 221-230.

STRIGANOVA, B. & PRISHUTOVA, Z. (1990).- Food requirements of diplopods in the dry steppe subzone of the USSR. *Pedobiologia*, **34**, 37-41.

VANDEL, A. (1964).- *Biospéléologie. La biologie des animaux cavernicoles*. Paris, Gauthier-Villars éditeur, 619 pp.

YEATES, G.W. (2003).- Nematodes as soil indicators: functional and biodiversity aspects. *Biology and Fertility of Soils,* **37**, 199-210.

ZSOLT, T., & ELISABETH, H. (2019).-Taxonomic and functional response of millipedes (Diplopoda) to urban soil disturbance in a metropolitan area. *Insects*, **11**, 14-25.