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Biotechnol. Agron. Soc. Environ. 2014 **18**(1), 11-18

Hierarchization of factors driving soil macrofauna in North Algeria groves

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Received on March 14, 2013; accepted on January 6, 2014.

The current study gathers new data on soil macro-invertebrates in North Algerian orchards in order to evaluate their seasonal dynamics. Invertebrate samples were collected from three sites in Kabylie: two from sub-humid areas (Nezla and Guendoul) and one from a semi-arid area (Bouira). The objectives were to determine levels of soil macrofauna abundance and to rank the factors controlling their distribution in order of importance. We particularly focused on the effects of site (climate), season and type of orchard (*Ficus carica* L. and *Olea europaea* L.). We collected 24 taxa, of which 70% were ants and 16% earthworms. Site and seasonal factors as well as the interaction between these two elements were found to significantly influence total soil macro-invertebrate abundance. In particular, earthworms were found to be highly sensitive to aridity. In contrast, the type of grove explained only a small part of earthworm variance, whereas it had a significant influence on ant abundance. In order to be able to say whether these conclusions are typical for other comparable orchards in North Africa, more studies of this kind are needed.
Keywords. Soil fauna, physico-chemical characteristics of soil, *Olea europaea*, *Ficus carica*, climate, Algeria.

Hiérarchisation des facteurs déterminant la macrofaune du sol de vergers du nord de l'Algérie. Cette étude a pour but de rassembler des données sur la macrofaune du sol et d'évaluer sa dynamique saisonnière dans les vergers du nord de l'Algérie, peu étudiés sur ce thème. Les invertébrés ont été recueillis dans trois régions de Kabylie sous climat subhumide (Nezla et Guendoul) et semi-aride (Bouira). L'importance est de déterminer les niveaux d'abondance de la macrofaune du sol et de hiérarchiser les facteurs qui contrôlent leur distribution. Les effets de site (climat), de saison et de type de verger (*Ficus carica* L. et *Olea europaea* L.) ont été étudiés en particulier. Parmi 24 taxons identifiés, les fourmis et les vers de terre sont dominants et représentent respectivement 70 % et 16 % des individus. Les facteurs « site » et « saison » ainsi que leur interaction influencent l'abondance totale des macro-invertébrés du sol, en particulier les vers de terre qui sont très sensibles aux climats plus secs. Par contre, le facteur « type de verger » influence peu l'abondance des vers de terre, mais bien significativement l'abondance des fourmis. Il apparait que les macro-invertébrés sont principalement influencés par le climat et la saison. Afin de mieux statuer sur nos résultats et nos conclusions, il est nécessaire d'élargir ce type d'étude à différents sols et vergers sous d'autres variantes du climat de l'Afrique du Nord.
Mots-clés. Faune du sol, propriétés physico-chimiques du sol, *Olea europaea*, *Ficus carica*, climat, Algérie.

1. INTRODUCTION

Although soil fauna is known to influence soil function (Lavelle et al., 2001), invertebrate communities in North African soils are still poorly described. In Mediterranean soil ecosystems, climatic conditions have been shown to have great influence on soil macrofauna, which are often particularly sensitive to temperature (Sharon et al., 2001; Antunes et al., 2008), precipitation (Morón-Ríos et al., 2010) and soil humidity (Dodd et al., 1997; El-Sharabasy et al., 2008). The dominant climatic and pedological characteristics of this region favour soil erosion and salinity, both of which may have a negative impact on soil biodiversity (Pueyos et al., 2007; Errouissi et al., 2011). These factors also constrain soil community dynamics (Véla et al., 2007; Fadda et al., 2008). In arid conditions the presence of macrofauna improves nitrogen nutrition and the availability of water for the horticultural plants (Ouédraogo et al., 2006). Apart from providing fruit and bioenergy, orchards in Southern Mediterranean regions also contribute to the mitigation of soil erosion (Martins da Silva et al., 2011; Ramos et al., 2011).

In Algeria, olive (*Olea europaea* L.) and fig (*Ficus carica* L.) orchards are widespread due to their socio-economic importance and their robustness (Ruano et al., 2004; Fayez et al., 2011). However, over the last few decades these orchards have been progressively neglected in favour of more high yielding horticultural systems. Such policies have led to a deterioration of agro-ecosystems in these areas, which has resulted in recent attempts to restore their functionality (Santos et al., 2007).

The aim of the present work was to understand the relative importance of three factors recognized as being important for soil invertebrate communities: the climate (sub-humid *vs* semi-arid), the season (winter *vs* summer) and the orchard type (fig *vs* olive groves). We hypothesized that macro-invertebrate abundance would be controlled by interactions between these three factors. This study, carried out in traditional rural fig and olive orchards, beside more intensively cultivated orchards in the same region, should constitute a reference for future assessments of soil biological activity in orchard systems in this geographical area.

2. MATERIALS AND METHODS

2.1. Study sites

Three sites were selected on a 52 km North-South transect in Kabylie in northern Algeria: Nezla (36°47'4" N; 4°36'40" E), Guendoul (36°44'20" N; 4°13'5" E) and Bouira (36°23'43" N; 3°53'14" E). Some characteristics of these sites are given in **table 1**. The Djurdjura Mountains separate Bouira from Nezla and Guendoul. The climate is sub-humid in Nezla and Guendoul and semi-arid in Bouira, with De Martonne indices of 26.6 and 19.3 respectively. Both fig and olive groves were studied at each site. The mean age of trees ranged between 30 and 60 years and mean density was about 100-120 trees per hectare. Also, in both fig and olive groves studied, the composition of the plant cover is similar and composed by same species notably *Avena sterilis*, *Inula viscosa*, *Oxalis pes-caprae*, *Daucus carota*, *Galactites tomentosa*, *Scolymus hispanicus*. The productivity of these groves is irregular and mainly for local consumption. Management is very low-intensity, with no use of phytosanitary products, fertilization or irrigation. Fructification and thinning cuts were made during the harvest, but this is neither a systematic nor an intensive procedure (M.A.D.R., 2009). This kind of agro-ecosystem is currently still the dominant orchard management type in the region.

Table 1. Characteristics of the three studied sites — *Caractéristiques des stations étudiées*.

	Nezla	Guendoul	Bouira
Altitude (m)	492	446	373
Mean annual precipitations (mm)*	826	826	560
Mean annual temperature range (°C)*	5.7 - 37.7	5.7 - 37.7	4.2-39
Grove age (years)	40	30	60
Slope	5%	5%	10%
Type (WRB)	Cambisol	Calcisol	Calcisol

*: Data were measured respectively at the Boukhalfa and Ain-Bessam meteorological stations between 1996 and 2006 — *Les données ont été mesurées respectivements aux stations météorologiques de Boukhalfa et Ain-Bessan entre 1996 et 2006*.

2.2. Soil sampling and characterisation

The soils were Calcisols at Guendoul and Bouira and Cambisols at Nezla (WRB, 1998). Soils were sampled in January 2007 with a boring sampler (4 cm in diameter, 20 cm depth). We collected five soil samples randomly from each plot. Soil characteristics were determined on three replicates from the composite samples according to standard methods described in Jackson (1967). Particle size distribution was measured according to the Robinson pipette method (*i.e.* organic matter oxidation by H_2O_2, shaking in a sodium hexametaphosphate solution). Soil pH was measured in a 1/5 soil distilled water suspension. The $CaCO_3$ content was determined using the HCl 1 M volumetric method. Cation exchange capacity (CEC) was measured according to the ammonium acetate method. Organic C was determined by sulfochromic oxidation. Bioavailable phosphorus was extracted by shaking soil samples in $NaHCO_4$ 0.5 M solution at pH = 8.5 (soil/solution ratio of 1/10) during 1 h (Olsen et al., 1977). The suspension was then filtered and phosphorus concentration in the solution was determined by colorometry. Exchangeable-K was extracted by shaking soil samples in an ammonium acetate 1 M solution at pH 7 (soil/solution ratio of 1/10) for 1 h (Quemener, 1979). The suspension was then filtered and K+ concentration in the solution was determined by flame spectrometry.

2.3. Invertebrate sampling and identification

Invertebrate sampling was carried out in winter (January) and summer (June)

2007 following the methodology outlined in Coineau (1974). In each selected orchard, six sampling zones of 30 x 30 cm, at least 10 m distance from each other, were set up. Two depth profiles were sampled at each sampling site. Large invertebrates were then hand-sorted in the laboratory. Remaining invertebrates were then extracted from the soil using the Berlese-Tullgren method (Pesson, 1971). After extraction, all invertebrates were preserved in 70° alcohol for later identification. Due to the still currently very incomplete taxonomic catalogue of Algerian soil fauna, invertebrates were only identified to order level in most cases. Taking account of their social behavior and the resulting aggregated distribution, ants were analyzed separately from other macro-invertebrates. Hence, total density referred to the density of all invertebrates but excluding ants.

2.4. Statistical analyses

The Kruskal-Wallis rank sum test was used for looking at soil differences between sites and orchards. Afterwards, multiple comparisons were done to identify groups that differed (Siegel et al., 1988). We also tested for the influence of the factors “site”, “season” and “orchard” and their interactions on both the overall population density and the diversity of invertebrates. For this, analyses of variance were performed on log-transformed data. Tukey’s “Honest Significant Difference” method was used to test for multiple comparisons of means.

3. RESULTS

3.1. Soil characteristics

Soil characteristics are detailed in **table 2**. No differences in pH and organic C, $CaCO_3$, exchangeable K and clay contents were observed between orchards from any one of the three sites. At Nezla and Guendoul, the CEC was higher in fig than in olive orchard soils. In Bouira soils, the soil available phosphorus content was slightly higher in fig than in olive groves. Regarding differences between the three sites, it appeared that Guendoul presented higher pH, organic C and $CaCO_3$ contents and lesser available P content than Nezla, with intermediate values in Bouira. The available phosphorus content separated Bouira and Nezla from Guendoul. Clay content was twice as high at Bouira than at Guendoul, with 25.6% and 13.7% respectively. Finally, no differences in exchangeable K content and CEC were recorded between sites.

3.2. Macro-invertebrate density and diversity

A total of 2,620 individuals were collected and 24 taxa identified. Ants and earthworms dominated the communities, representing 70% and 16% of total individuals, respectively. Total macro-invertebrate density was highly influenced by the factors “site”, “season” and their interaction but not by the type of grove (**Table 3**). Maximum population values were recorded during winter in Nezla and Guendoul (sub-

Table 2. Means (standard error) soil characteristics of the six studied groves — *Moyennes (erreur standard) des caractéristiques des sols des six vergers étudiés.*

	Nezla		Guendoul		Bouira	
Grove	**Fig**	**Olive**	**Fig**	**Olive**	**Fig**	**Olive**
pH water	7.44 (0.07)	7.00 (0.15) ns, [b]	7.46 (0.01)	7.62 (0.11) ns, [a]	7.41 (0.04)	7.41 (0.03) ns, [ab]
Org C (%)	0.33 (0.04)	0.40 (0.08) ns, [b]	1.25 (0.11)	1.29 (0.69) ns, [a]	0.89 (0.06)	0.71 (0.2) ns, [ab]
$CaCO_3$ ($g \cdot kg^{-1}$)	3.7 (0.09)	2.4 (0.07) ns, [b]	26.7 (0.9)	25.0 (1.61) ns, [a]	15.4 (0.48)	11.8 (0.66) ns, [ab]
Tot N ($g \cdot kg^{-1}$)	0.910	0.910	1.260	0.630	1.720	1.260
CEC	15.26 (0.19)	12.24 (0.4) *, [a]	14.5 (0.33)	13.46 (0.31)*, [a]	14.16 (0.11)	13.35 (1.35) ns, [a]
P assi	1.34 (0.16)	1.51 (0.17) ns, [a]	0.78 (0.16)	0.93 (0.15) ns, [b]	1.57 (0.06)	1.43 (0.04)*, [a]
K assi	20.83 (1.48)	26.13 (1.92) ns, [a]	29.15 (1.88)	26.70 (7.33) ns, [a]	21.66 (0.88)	21.73 (0.76) ns, [a]
Clay (%)	20.37 (2.18)	16.53 (0.84) ns, [ab]	13.75 (0.55)	13.68 (0.63) ns, [b]	25.60 (1.08)	23.4 (1.53) ns, [a]

ns: not significant — *non significatif*; *: indicates significant differences between fig and olive groves from one site — *indique les différences significatives entre les vergers de figues et d’olives d’un site*; Different letters indicate significant differences between sites — *les lettres différentes indiquent des différences significatives entre les sites*; Data between brackets are standard errors — *les données entre parenthèses sont les erreurs standard*.

shumid climate) with values ranging between 130 and 380 ind·m^{-2}. The lowest values were mainly found during winter in Bouira (semi-arid climate) and during summer in Nezla with more or less than 40 ind·m^{-2}.

This pattern was mainly driven by earthworm densities that reached high values (59 to 324 ind·m^{-2}) during winter in the sub-humid climate regardless of the orchard type (**Table 3**). In these orchards, earthworms dominated, accounting for 42% to 86% of soil macro-invertebrate density. In other conditions, communities were characterized by scarce or null density of earthworms (0 to 22 ind·m^{-2}). The population levels for ants depended significantly on the site and the type of groves (**Table 3**). This effect is highlighted by a difference between high densities in fig orchards at Bouira (about 750 to 1,800 ind·m^{-2} depending on the season), and low densities in olive orchards at Nezla whatever the season and in fig orchards at Bouira during winter (less than 10 ind·m^{-2}).

Invertebrates other than earthworms and ants were found at lower densities, *i.e.* always less than 40 ind·m^{-2}. Nevertheless, some groups represented up to 60% of the community. For instance, millipedes at Guendoul exhibited densities ranging from 9 to 33 ind·m^{-2}, representing 13% to 24% of the total population. Their density was almost stable between season and grove type. In all other conditions, millipedes were rare, except in Bouira olive groves during summer (11 ind·m^{-2}). Adult coleopterans also reached up to 30 ind·m^{-2} particularly during summer in all conditions (7 to 28 ind·m^{-2}) and at Guendoul during winter (30 ind·m^{-2}). Finally, snails were present only in Nezla although at very low densities (up to 6 ind·m^{-2} and to 9% of density).

The taxonomic richness ranged between 1 and 11. Among the three factors investigated, only the factor "site" significantly influenced the taxonomic richness of macro-invertebrates. The highest values were observed at Guendoul and Bouira, with diversity values of 2.5 and 4, respectively.

4. DISCUSSION

4.1. Hierarchy of factors

Our results showed that olive and fig trees have similar effects on soil characteristics – consistent with existing literature reports (Dodd et al., 1997; Ricarte et al., 2011). Significant differences were observed with respect to available phosphorus amounts, which were low in all orchards. The low available phosphorus content probably related to the nature of the calcareous parent material, which enhanced its precipitation (Darrah et al., 1994). The type of grove within a single site did not influence total density of soil invertebrates, which is to a large extent ascribed to the similarity of soil characteristics.

The main result of this work lies on the ranking of factors by importance driving invertebrate communities in Kabylien soils. It clearly emerged from the results that the factors "site" and "season" profoundly affected the total density of soil invertebrates. These results agreed with Sharon et al. (2001). These authors showed that climate was the main factor influencing abundance and diversity of soil macrofauna in Middle East Mediterranean forests. Similar results have been reported for woodlice by Warburg et al. (1984) and Huerta et al. (2012). However, Santos et al. (2007) showed ant density to be controlled by site characteristics and orchard type. To our knowledge, the present work provides the first results from soil invertebrate communities under fig trees in Mediterranean soils. Otherwise, fig tree impacts on soil communities have been described by Merlim et al. (2005) for a tropical climate. Although we did not observe any effects of orchard type (except for ants, **table 3**), the type and age of vegetation have been reported to drive both abundance and diversity of soil fauna (Neirynck et al., 2000; Woodcock et al., 2005). However, the simplified structure of vegetation in orchards has been found

Table 3. Results (F values) of 3-factor analyses of variance performed on log transformed macro-invertebrate densities — *Résultats d'analyse de variance de l'effet des trois facteurs sur la densité des macro-invertébrés après transformation logarithmique (valeurs F)*.

	Df	Total	Earthworms	Millipedes	Coleopterans	Snails	Ants
Site	2	5.4**	18.0***	24.4***	0.6	4.1*	4.6*
Season	1	10.3**	68.3***	< 0.1	3.1	1.0	3.7
Orchard	1	1.1	2.4	1.6	8	0.1	4.1*
Site x season	2	6.6**	16.9***	2.0	0.2	0.3	0.5
Site x orchard	2	0.2	2.5	0.8	1.3	0.2	1.7
Season x orchard	1	0.5	0.6	2.4	< 0.1	3.2	0.1
Site x season x orchard	2	0.5	0.5	1.1	4.0*	1.6	0.1

* : $p < 0.05$ — *$p < 0{,}05$*; ** : $p < 0.01$ — *$p < 0{,}01$*; *** : $p < 0.001$ — *$p < 0{,}001$*; Df: degree of freedom — *degré de liberté*.

to act negatively on abundance and diversity of soil arthropods (Van der Wal et al., 2009; Martins da Silva et al., 2011). The tree species can also influence soil biota through the interactions between their roots and the soil, such effects being apparently more important when soil organic matter content is low (Eo et al., 2008; Ivask et al., 2008). Furthermore, it has also been found elsewhere that the type of orchard influenced *e.g.* organic matter dynamics and pH (Cesarz et al., 2007; Carrillo et al., 2011). Some studies have also mentioned that soil fauna composition can interact with vegetation to modify soil characteristics (Jones et al., 1997 ; Jacob et al., 2009).

Our results also showed that there were clear differences in the densities of soil invertebrates between Nezla and Guendoul on the one hand, and Bouira on the other hand, during the winter. Differences could be due to climate rather than to soil type. Indeed, Nezla and Guendoul, both situated in a similar sub-humid climatic zone, differ from each other for soil characteristics in terms of pH, organic C, $CaCO_3$ and available P contents. During the summer, densities were lower, with the highest values recorded in Nezla (109 ind·m^{-2}) but most of them ranged between 15 and 74 ind·m^{-2}. Surprisingly, Nezla soils hosted the highest densities during winter (> 250 ind·m^{-2}) and the lowest during summer (< 40 ind·m^{-2}). Soil characteristics probably explain this result (Lavelle et al., 2001), particularly in terms of the fact that organic C content is three times less in Nezla soils compared to those at Guendoul. Finally, in addition to the warm summers of Kabylie, soil invertebrates in Bouira were also exposed to cold winters with, for instance, 25 days of frost during winter 2007.

4.2. Effects on macrofaunal groups

Among the studied communities, taxa exhibited different responses to various environmental factors. For instance, earthworms were significantly numerous in Nezla and Guendoul soils during the winter, while millipede densities were high at Guendoul whatever the season. In the following section, responses to such factors are discussed taxon by taxon.

As previously described by Rouabah et al. (2001), the warm and dry summer of Algeria leads to a widespread cessation of earthworm activity (in this study, except for the Guendoul olive orchards). Soil dryness leads directly to a drop in worm numbers. In Bouira however, worm density was always very low, probably also since in this semi-arid zone, winters are characterized by cold temperatures and low soil humidity. Comparing densities recorded in the present study with literature on Maghrebian soils is rather difficult considering the small number of studies on earthworms, most of which have been taxonomic studies (Omodeo et al., 2003). Moreover, even from this small sample size, some data are not considered to be reliable. For instance, Errouissi et al. (2011) reported densities of earthworms in agricultural plots, indicating that *Lumbricus terrestris* L. (1798) reached densities up to 50 ind·m^{-2}. However, an exhaustive review, Omodeo et al. (2003) showed that *L. terrestris* is not found in the earthworm fauna of Maghreb. This confusion can probably be explained by the paucity of taxonomic expertise for soil invertebrates in North Africa.

During the winter, which corresponds to the rainy season in Kabylie, earthworms were numerous in the topsoil at Guendoul and Nezla (59-141 and 202-324 ind·m^{-2}, respectively) (**Table 4**). These densities were rather higher than densities reported for other Mediterranean orchards. For instance, Morón-Ríos et al. (2010) found densities of 50 and 170 ind·m^{-2} during autumn 2002 and spring 2003, respectively. Kherbouche et al. (2012) recorded 150 ind·m^{-2} during springtime. However, in contrast to these groves, the Kabylien groves studied were not ploughed. The well-known negative impact of cultivation on earthworms probably explains this difference (Kherbouche et al., 2012).

In the orchards studied here, coleopteran densities were consistently low (2-30 ind·m^{-2}), especially in Bouira and Guendoul during winter (< 10 ind·m^{-2}). In comparison, Santos et al. (2007) found 250-909 ind·m^{-2} under olive groves in April and July, respectively, in Iberian Mediterranean orchards. Coleopterans in groves have been demonstrated to be influenced by year-round climate variations and management regimes (Ruano et al., 2004) or by soils (Martins da Silva et al., 2011). Coleopterans play important roles in orchard ecosystems such as these: in particular, they are recognized as regulators since some soil larvae are rhizophagous and other species are predators either at larval or imaginal stage (Ruano et al., 2004). Therefore, they are well documented and established as bio-indicators of soil quality (Shanas et al., 2011).

In contrast to the other groups, ant populations varied significantly according to site and grove type but not with season (**Table 3**). Aridity does not seem to reduce their abundance (Delsinne et al., 2010). Ants generally had very high densities on the sites studied here (**Table 4**), but were less abundant at Nezla during the two seasons, particularly under olive trees and they disappeared at Bouira in the wintertime. They were abundant in Guendoul (1,806-748 ind·m^{-2}) respectively in winter and summer under fig trees. The abundance of ants under olive trees was low and did not vary. This low density is striking compared to the results of Santos et al. (2007) who reported 1,182-3,120 ind·m^{-2}. Other studies have shown that ants play important ecological role in such groves (Castro et al.,

Table 4. Mean densities (standard error) of macro-invertebrates in studied orchards — *Densités moyennes (erreur standard) des macro-invertébrés dans les vergers étudiés*.

Site	Season	Whithout ants						Ants
		Orchard	Total	Earthworms	Millipedes	Coleopterans	Snails	
Nezla	Winter	Olive	378 (119)[a]	324 (105)[a] 86%	2 (2)[b] 0%	4 (2)[b] 1%	6 (3)[a] 1%	2 (2)[b]
Nezla	Winter	Fig	263 (139)[ab]	202 (107)[ab] 77%	2 (2)[b] 1%	6 (3)[b] 2%	2 (2)[a] 1%	178 (162)[ab]
Guendoul	Winter	Olive	235 (58)[ab]	141 (45)[ab] 60%	33 (16)[a] 14%	30 (14)[a] 13%	2 (2)[a] 1%	41 (33)[ab]
Guendoul	Winter	Fig	139 (33)[b]	59 (25)[bc] 43%	26 (6)[a] 19%	30 (11)[a] 1%	0 (0)[a] 0%	1,806 (,1547)[a]
Bouira	Winter	Olive	4 (3)[c]	0 (0)[c] 0%	2 (2)[b] 50%	2 (2)[b] 50%	0 (0)[a] 0%	44 (41)[ab]
Bouira	Winter	Fig	22 (8)[c]	9 (7)[c] 42%	0 (0)[b] 0%	0 (0)[b] 0%	0 (0)[a] 0%	0 (0)[b]
Nezla	Summer	Olive	15 (6)[c]	0 (0)[c] 0%	0 (0)[b] 0%	7 (3)[b] 50%	0 (0)[a] 0%	7 (3)[b]
Nezla	Summer	Fig	41 (14)[c]	2 (2)[c] 5%	2 (2)[b] 5%	19 (9)[ab] 45%	4 (2)[a] 9%	39 (22)[ab]
Guendoul	Summer	Olive	109 (37)[b]	22 (13)[c] 20%	26 (8)[a] 24%	28 (12)[a] 25%	0 (0)[a] 0%	72 (47)[ab]
Guendoul	Summer	Fig	74 (26)[bc]	0 (0)[c] 0%	9 (3)[a] 13%	11 (3)[ab] 15%	0 (0)[a] 0%	748 (483)[a]
Bouira	Summer	Olive	61 (10)[bc]	0 (0)[c] 0%	11 (5)[a] 18%	28 (10)[a] 45%	0 (0)[a] 0%	33 (14)[ab]
Bouira	Summer	Fig	37 (8)[c]	2 (2)[c] 5%	0 (0)[b] 0%	22 (7)[ab] 60%	0 (0)[a] 0%	472 (429)[ab]

Different letters indicate significant differences between sites — *les lettres différentes indiquent des différences significatives entre les sites*; % : percentage with regard to the column "total" — *pourcentage par rapport à la colonne « total »*.

1996; Garrido-Jurado et al., 2011). Several authors have suggested their importance as bio-indicators for agro-ecosystems (Lobry de Bruyn, 1999), under fig trees (Merlim et al., 2005) and under olive trees with a very heterogeneous distribution and variable (Pereira et al., 2004; Santos et al., 2007). Despite this apparent ecological importance, ants are still inadequately studied in Mediterranean ecosystems (Ottonetti et al., 2008).

Snails were collected in very small numbers at Nezla, but nowhere else. These invertebrates are very sensitive to fluctuations in soil humidity (Pokryszko et al., 2011). Moisture has been shown to be the key determining factor of variation in their abundance and diversity in soils (Pennings et al., 2005; Cameron et al., 2006). This taxonomic group is also influenced by other soil properties and the nature of the vegetation (Omodeo et al., 2003; Ondina et al., 2004; Cameron et al., 2010).

Millipedes were mostly observed at Guendoul during both seasons, where they reached densities up to 33 ind·m^{-2} (**Table 4**). Millipedes also represented up to 50% of community density in Bouira demonstrating their characteristic abundance in semi-arid climates (Galanes et al., 2011).

5. CONCLUSION

This study allowed us to rank three factors (soil type, climate and fruit tree) influencing the abundance of macro-invertebrates in North African olive and fig groves. It appears for most of the macro-invertebrates studied that they are favorably influenced by humid climate and site. Moreover, it provides valuable data on the varying abundances and diversity of soil macro-invertebrates under traditional olive and fig groves in three regions of Kabylie. However, the results presented in this study may only be valid for this region. To make more general statements about the abundance of macro-invertebrates in traditionally maintained groves (in terms of soil management regime), this study should be extended to sites encompassing a wider range of different soils, orchard types, and climatic situations across North Africa. However, this study, reporting on conditions in traditionally managed fig and olive groves, which exist side-by-side with more intensively managed groves throughout the region, could constitute a valuable reference for soil biological activities in horticulture for this area.

Acknowledgements

We would like to thank Folkert van Oort for his very useful comments (UR251 PESSAC INRA Versailles). We are grateful to the owners of the orchards for having let us make our study in their groves. We thank all the students who took part in soil sampling.

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