Effects of agricultural practices and abiotic factors on woodlice diversity across two agroecosystems in Tunisia

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EFFECTS OF AGRICULTURAL PRACTICES AND ABIOTIC FACTORS ON WOODLICE DIVERSITY ACROSS TWO AGROECOSYSTEMS IN TUNISIA

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TERRESTRIAL ISOPODS
DIVERSITY
MAJERDA PLAIN
REGUEB PLAIN
CROP TYPE
ABIOTIC FACTORS

ABSTRACT. – There are evidences that agricultural practices are important drivers of the soil biota structure, but the mechanism is far from being fully understood, especially on the regional scale. In order to evaluate the impact of agricultural practices and abiotic factors on the community of terrestrial isopods (Isopoda: Oniscidea), a comparative study between two sampling sites belonging to two bioclimatic zones in Tunisia was carried out. The diversity and abundance of Oniscidea in eight crop types in each region were studied. We also tested the effect of environmental factors on the distribution of this group. Our findings highlighted a significant impact of crop type on the Oniscidean community and revealed that grassland harbored the highest diversity regardless of the sampling site. *Porcellio variabilis* (Lucas, 1846) and *Porcellionides pruinosus* (Brandt, 1833) were the most common species in the Majerda and Regueb plains, respectively, although *P. variabilis* represented the most recorded species across both sampling sites. Canonical Correspondence Analysis suggested that Oniscidean diversity is related to the crop type and environmental factors such as temperature and humidity, and soil properties.

INTRODUCTION

Among the soil faunal communities, terrestrial isopods play a crucial role in the nutrient cycling and the decomposition of leaf litter in agroecosystems (Hassall & Sutton 1978). They constitute an important element of soil food webs as sources of nutrients for other arthropods and vertebrates (Covaciu-Marcov *et al.* 2012). In general, agricultural landscapes provide the maintenance of soil fertility and structural properties. In addition, they constitute a reservoir for water and nutrient cycling (Dominati *et al.* 2010) considering that approximately 50 % of plant and animal species in Europe depend on agricultural areas (Stoate *et al.* 2009).

Several factors are involved in the dynamic structure of soil decomposer communities. Indeed, the diversity of soil fauna is decreased by agricultural intensification (Giller *et al.* 1997, Tsiafouli *et al.* 2015). In addition, environmental factors, such as soil humidity and temperature, influence the macroinvertebrate diversity (Hopkin & Read 1992, Souty-Grosset *et al.* 2005, Hassall *et al.* 2006, Fraj *et al.* 2010, Khemaissia *et al.* 2012, Khemaissia *et al.* 2017), as well as soil properties like pH, salinity, phosphorus (P), nitrogen (N) and carbon (C) content. Furthermore, the life histories of woodlice can be affected by natural environmental fluctuations (Jones & Hopkin 1998).

It has also been shown that landscape use and habitat structure (Vanbergen *et al.* 2007, Wu *et al.* 2015) contribute indirectly to the decomposition process of substrates via their chemical, physiological, quantitative and qualitative characteristics (Hättenschwiler & Bretscher 2001, Smith & Bradford 2003, Tripathi *et al.* 2013). Moreover, Paoletti & Hassall (1999) indicated that the specific diversity and abundance of Oniscidea are altered by agricultural practices such as tillage, drainage, fertilizers and pesticides.

The terrestrial isopod diversity varies between woodland and agricultural ecosystems where a drastic decrease is marked due to the intensive use of insecticides and herbicides (Farkas *et al.* 1996). Hence, the biologically active compounds lead to a reduction of woodlice growth rate and fecundity, and also change the availability of food (Paoletti & Hassall 1999). In fact, soil detritivores react directly to the vegetation age, quality and composition (Rushton & Hassall 1983, David *et al.* 1999, Souty-Grosset *et al.* 2005, Laossi *et al.* 2008) which affects the decomposition process.

It has been ensured that understanding the interaction between abiotic and biotic drivers of soil fauna on multiple spatial and temporal scales constituted a key step to predict the organism performance in light of the environmental changes (Davis *et al.* 1998, Magurran 2013, Messina *et al.* 2014, 2016) and subsequently the ecosystem way of functioning (Birkhofer *et al.* 2011). Considering the scarcity of research focusing on the impact of agricultural intensification on the decomposer biota and the increasing effort of maximizing production, there is a need to establish a correlation between soil fauna and agricultural practice types (Beare *et al*. 1997). Among soil fauna decomposers, isopods constitute a suitable model to accomplish such goals, especially with the availability of data about morphological, physiological and behavioral (Hassall *et al*. 2002) adaptations to the terrestrial environment.

To accomplish this comparative study we aimed to test the following hypotheses: 1) the cropping systems and the vegetative cover affect the distribution of isopods in both studied sites, 2) the diversity and abundance of Oniscidea are driven by soil properties and local environmental conditions, 3) the intensification of agricultural activities acts on isopods community.

MATERIALS AND METHODS

Sampling sites: The first sampling site was the Majerda low valley. It is located in the North East of Tunisia, between Tunis and Bizerte cities, and extends on 33000 ha (Chabchoub 2011). This site is of a great socioeconomic importance in Tunisia. The agricultural activities marking this area are arboriculture, cereal and vegetable farming. The annual cultivation occupies 80 % of the total cultivated area (Abbes *et al*. 2005). The Majerda low plain is also home to almost a quarter of the irrigated areas in Tunisia. Herein, the climate is semi-arid and the annual precipitation average can reach 433 mm.

The second studied site was the Regueb plain which is located in the center of Tunisia and is surrounded by Sidi Bouzid, Sfax and Kairouan. Arboriculture and cereal farming dominate the agricultural activities in this region covering 39 % and 8 % of the total area, respectively (SCDCGE 2012). The Regueb plain is characterized by an arid climate with an annual precipitation average of 197 mm (Fig. 1).

Sampling methods: The collection of terrestrial isopods was carried out in ten crops. For each crop, two replicates were made. For each replicate, three quadrats of 0.25 m² were randomly placed with an interval of 20 m respecting the same sampling effort.

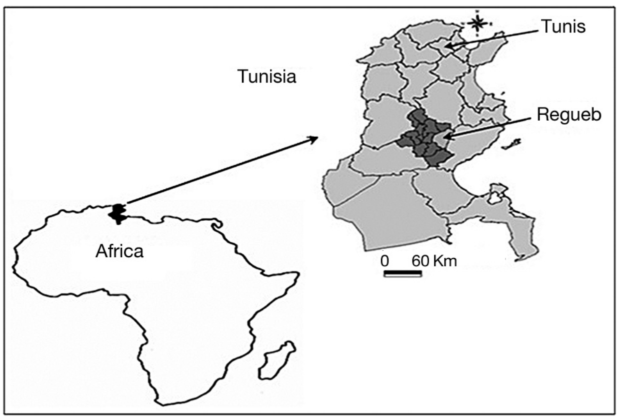

Fig. 1. – Location of the two sampling sites.

The sampling was performed between March 1st and April 30th except for the melon crop which was done between June 5th and 30th, 2016. During each sampling, the humidity and the temperature of soil and air were taken using a thermohygrometer. Specimens were preserved in 70 % ethanol in order to identify them using a stereomicroscope Leica MS 5.

Soil analysis: Three samples from each plot were mixed in order to obtain a composite sample of soil. Soil pH was measured with a pH meter (WTW Series). Soil conductivity was measured using a conductivity meter (wtw LF521). Soil sodium, carbon and humus contents were determined using an elemental analyzer Cecil CE 2021 UV/Vis Spectrophotometer.

Data analysis: Ecological indices were computed to estimate the Oniscidea diversity across the different types of crop in both sites. Species richness was expressed by the total number of species collected in each crop type. Relative abundance (%) (i.e., the number of individual species i (ni)) was expressed in terms of total number of detected isopods (N). Species diversity was analyzed using the Hill index (Hill = N2/N1) and the Pielou's evenness index (J' = H'/log2 S) where N1: exponential of Shannon index (H'), N2: the inverse of Simpson index, S: the total number of species. The similarity of isopod communities between the eight crop types in each region was carried out using the Bray-Curtis index taking into account the relative abundance. The aforementioned analysis was applied using the PRIMER 5.0 software package (Clarke & Warwick 1994). The Kruskal-Wallis test was used to compare ecological indices and environmental factors across crop types. To examine environmental factors and ecological indices between sites, Mann-Whitney test was performed. To find the correlation between species relative abundance and environmental factors, multivariate analysis was carried out using canonical correspondence analysis (CCA) with the free version of XLSTAT 2016 software (http://www.xlstat.com).

RESULTS

Abiotic factors

Physico-chemical variables were determined for each crop type in the Majerda low plain (Table I). The maximum and the minimum mean air temperature were recorded in melon (28.4 ± 0.1 °C) and grassland (18.5 ± 4.3 °C), respectively. In the same plot, the mean values of C/N, air and soil humidity were high (12.4 ± 1.4, 54.4 ± 12 %, 58 ± 12.7 %, respectively). Mean soil temperature was equal to 24.4 ± 0.4 °C in melon and 21.2 ± 0.2 °C in wheat. Soil conductivity and $CaCO_3$ were high in artichoke; they were respectively equal to 42.3 ms/cm and 0.41 %. Humus showed an irregular distribution with a maximum in wheat (3.16 %) and a minimum in almond (0.29 %).

Table I. – Isopod diversity indices and soil properties across different types of crop in the Majerda low plain.

	Grassland	Olive	Almond	Wheat	Barley	Artichoke	Alfalfa	Melon
P. variabilis (%)	37	48	36	0	80	0	17	25
A. officinalis (%)	3	0	11	13	0	0	0	0
A. tunisiense (%)	5	0	0	7	0	0	0	0
C. elongata (%)	14	12	0	0	0	0	0	0
P. laevis (%)	36	40	42	80	20	0	83	42
A. pelagicum (%)	5	0	11	0	0	0	0	33
P. pruinosus (%)	0	0	0	0	0	100	0	0
Mean species number	6	2.66 ± 0.6	3	2.66 ± 0.6	1.5 ± 0.7	1	2	2.33 ± 0.57
Abundance	521	161	72	147	92	16	298	384
Hill index	0.82 ± 0.02	0.95 ± 0.02	0.95 ± 0.006	0.82 ± 0.04	0.97 ± 0.03	1	0.92 ± 0.04	0.93 ± 0.03
Evenness (J’)	0.77 ± 0.01	0.95 ± 0.04	0.95 ± 0.001	0.62 ± 0.04	0.91	–	0.81 ± 0.1	0.87 ± 0.1
Air temperature (°C)	18.5 ± 4.3	20.6 ± 0.2	20.3 ± 0.3	20.4 ± 0.1	20.5 ± 0.2	19.4 ± 0.07	19.23 ± 0.1	28.4 ± 0.1
Air humidity (%)	54.4 ± 1.2	54.6 ± 1.5	49 ± 2	52.6 ± 1.5	56 ± 2.8	50.5 ± 0.7	52.3 ± 2.5	53 ± 2.6
Soil temperature (°C)	21.9 ± 4.2	21.4 ± 0.3	23.5 ± 0.3	21.2 ± 0.2	21.4 ± 0.2	22.7 ± 0.2	21.7 ± 0.1	24.4 ± 0.4
Soil humidity (%)	58 ± 12.7	54.03 ± 0.5	51 ± 0.4	51.6 ± 1.5	51 ± 1.4	54.5 ± 0.7	48.6 ± 1.5	52.6 ± 2.5
Soil pH	7.95 ± 0.2	7.96 ± 0.5	7.96 ± 0.1	8.08 ± 0.1	8.06 ± 0.2	8.07 ± 0.2	7.99 ± 0.4	8.03 ± 0.2
Soil conductivity (ms/cm)	0.74 ± 0.4	2.36 ± 0.7	0.65 ± 0.2	19.87 ± 4.9	19.2 ± 3.7	42.3 ± 11.6	5.61 ± 3.1	4.3 ± 0.5
CaCO3 (%)	0.31 ± 0.04	0.23 ± 0.07	0.29 ± 0.1	0.3 ± 0.2	0.33 ± 0.04	0.41 ± 0.1	0.39 ± 0.1	0.31 ± 0.08
Humus (%)	1.46 ± 0.9	2.88 ± 0.2	0.29 ± 0.2	3.16 ± 1.4	2.78 ± 0.5	1.84 ± 0.9	1.92 ± 1.1	2.87 ± 0.3
C/N	12.4 ± 1.4	4.32 ± 1.9	9.23 ± 0.8	7.38 ± 2.1	8.04 ± 0.6	7.81 ± 2.4	11.1 ± 0.7	11.8 ± 2.3

Table II. – Isopod diversity indices and soil properties across different types of crop in the Regueb plain.

	Grassland	Olive	Almond	Wheat	Barley	Pea	Bean	Melon
P. pruinosus (%)	56	81	73	75	75	70	81	76
P. variabilis (%)	21	9	13	14	25	30	19	24
P. laevis (%)	2	10	14	11	0	0	0	0
L. panzerii (%)	7	0	0	0	0	0	0	0
A. sulcatum (%)	14	0	0	0	0	0	0	0
Mean species number	4.5 ± 0.5	2.66 ± 0.57	3	3	2	2	2	2
Abundance	483	367	214	195	90	175	166	413
Hill index	0.8 ± 0.03	0.84 ± 0.04	0.81 ± 0.009	0.85 ± 0.08	0.92 ± 0.04	0.95 ± 0.06	0.88 ± 0.008	0.91 ± 0.02
Evenness (J’)	0.78 ± 0.06	0.54 ± 0.1	0.69 ± 0.05	0.74 ± 0.1	0.81 ± 0.1	0.85 ± 0.2	0.68 ± 0.06	0.81 ± 0.07
Air temperature (°C)	38.7 ± 1.1	33.3 ± 0.9	34.6 ± 1	34.6 ± 1.8	32.2 ± 1.1	32.6 ± 1	34.6 ± 0.5	39.4 ± 1.2
Air humidity (%)	22 ± 1.1	19.1 ± 1	21.1 ± 1.6	22.1 ± 1	21.7 ± 1	20.5 ± 0.7	20 ± 1	22.1 ± 1.7
Soil temperature (°C)	38.8 ± 0.7	38.6 ± 0.4	39.6 ± 0.8	39.6 ± 0.6	39.6 ± 0.3	38.2 ± 1	39.1 ± 0.3	37.2 ± 1.8
Soil humidity (%)	20 ± 0.4	19.9 ± 1.2	21.1 ± 1.5	22 ± 0.4	22.2 ± 0.5	29.6 ± 2.1	22.4 ± 0.6	34.2 ± 2.3
Soil pH	7.66 ± 0.3	7.36 ± 0.2	7.38 ± 0.5	7.44 ± 0.8	7.46 ± 0.2	7.87 ± 0.2	7.87 ± 0.4	7.33 ± 0.7
Soil conductivity (ms/cm)	1.5 ± 0.6	1.50 ± 0.2	1.62 ± 1.1	6.23 ± 3.2	6.99 ± 0.6	7.76 ± 0.7	6.35 ± 2.6	6.29 ± 1.4
CaCO3 (%)	0.3 ± 0.08	0.4 ± 0.1	1.1 ± 0.2	0.8 ± 0.4	0.6 ± 0.4	1.3 ± 0.1	1.2 ± 1.1	0.9 ± 0.5
Humus (%)	0.75 ± 0.3	0.62 ± 0.4	1.12 ± 0.2	0.88 ± 0.4	0.92 ± 0.4	2.17 ± 1.6	2.09 ± 0.9	0.77 ± 0.6
C/N	6 ± 1	8.1 ± 2.4	3.9 ± 3.3	4.1 ± 0.4	4.1 ± 0.9	8.68 ± 2.5	8.46 ± 1.9	10.7 ± 3.7

In the Regueb plain, mean air temperature and humidity were maximal in the melon with 39.4 ± 1.2 °C and 22.1 ± 1.7 %, respectively (Table II). Mean soil temperature was relatively high in all cultivations (more than 37 °C). However, the maximum values of soil humidity and C/N were recorded in melon while humus and soil conductivity were high in pea (2.17 % and 7.76 ms/cm, respectively).

Air temperature and humidity in both sites and soil temperature and humidity in Regueb plain differed significantly between crops ($p = 0.014$, $H = 11.6$, $df = 7$). In the same line, air and soil temperature and humidity differed significantly between both studied areas (p = 0.0009). Soil pH exhibited a significant difference between sites (p = 0.0009) but not between crops types in each area (p = 0.99; H = 1.15; df = 7 in Majerda and p = 0.66; H = 4.94; df = 7 in Regueb). A significant difference of C/N and soil conductivity was highlighted between crop types in Majerda plain (p = 0.04; H = 14.72; df = 7 and p = 0.013; H = 17.78; df = 7, respectively) and Regueb plain (p = 0.04; H = 14.36; df = 7 and p = 0.05; H = 13.9; df = 7, respectively) but not between sampling sites (p = 0.053, p = 0.57, respectively).

Oniscidean affinities

In both studied sites, 3794 individuals belonging to nine species of terrestrial isopods were collected from ten crop types. *Porcellio variabilis* Lucas, 1849, *Armadillo officinalis* Duméril, 1816, *Armadillidium tunisiense* (Hamaïed & Charfi-Cheikhrouha, 2007), *Chaetophiloscia elongata* (Dollfus, 1884), *Porcellio laevis* Latreille, 1804, *Armadillidium pelagicum* Arcangeli, 1957 and *Porcellionides pruinosus* (Brandt, 1833) were found in the Majerda low valley. We sampled the species *P. pruinosus, P. variabilis, P. laevis, Leptotrichus panzerii* (Audouin, 1826) and *Armadillidium sulcatum* Milne-Edwards, 1840 in the Regueb plain (Tables I, II).

In the Majerda low plain, among the 2103 individuals captured, *P. laevis* and *P. variabilis* were almost encountered in all plots. In the Regueb plain, *P. pruinosus* and *P. variabilis* were the most common species unlike *L. panzerii* (7 %) and *A. sulcatum* (14 %), which were found only in the grassland. Hence, a significant difference of abundance was established between plots in the Majerda and Regueb plains (p = 0.038; H = 14.82; df = 7 and p = 0.041; H = 14.63; df = 7, respectively) but not between sites (p = 0.061).

In the Majerda low plain, the highest species richness was recorded in grassland (S = 6) whereas the artichoke exhibited the lowest one (S = 1). Hence, the statistical analysis showed a significant difference between crop types (p = 0.029; H = 15.56; df = 7). Similarly in the Regueb plain, we found a clear difference of species richness between plots, which ranged from 2 in barley, pea, beans and melon to 5 in grassland. Mann-Whitney test revealed no significant difference of species richness between sites (p = 0.12).

In Majerda, the Hill index ranged from 0.8 in grassland and wheat, to 1 in artichoke where only *P. pruinosus* was recorded. In Regueb, the Hill index varied between 0.8 and 0.95 in grassland and pea, respectively. A significant difference relating to crop types was observed within each plain (p = 0.043; H = 14.5; df = 7) and between both sites (p = 0.037).

Terrestrial isopods were not evenly distributed across different crop types in both sites. In the Majerda low plain, the evenness index fluctuated between 0 in artichoke (only one species collected) and 0.95 in almond and olive trees. In the Regueb plain, the evenness index ranged from 0.54 in olive trees to 0.85 in pea. Herein, in each sampling site, a highly significant difference of

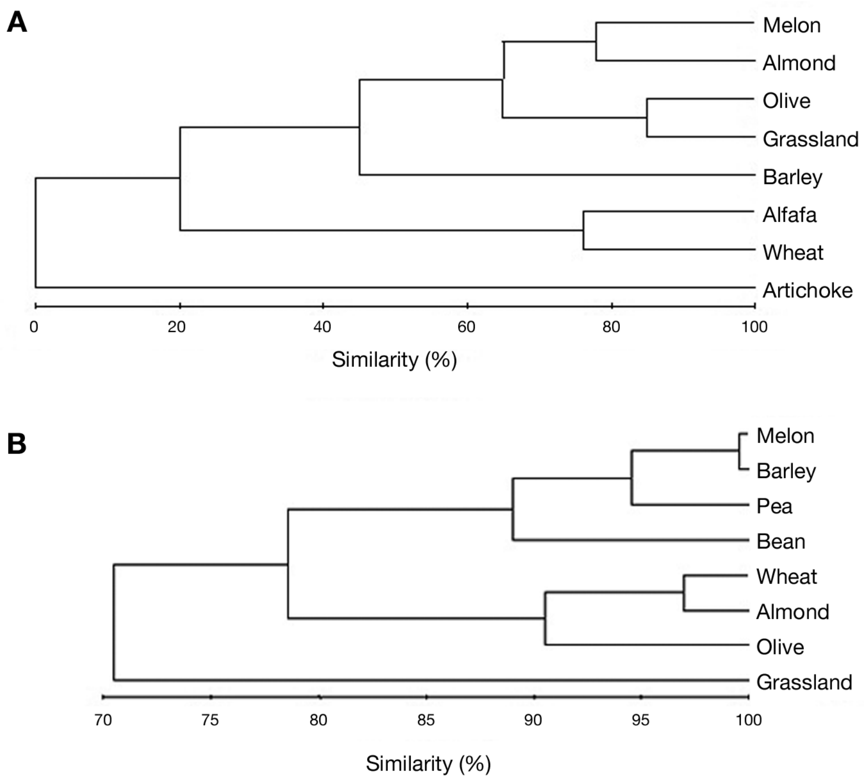

Fig. 2. – **A**: Clustering of sampling crop types based on relative abundance of Oniscedea species in Majerda plain (Bray-Curtis index – complete linkage). **B**: Clustering of sampling crop types based on relative abundance of Oniscedea species in Regueb plain (Bray-Curtis index – complete linkage).

Pielou's evenness values was recorded between crop types (p = 0.04; H = 14.14; df = 7).

Similarities between crop types

The dendrogram of similarity between crop types, obtained by calculating the Bray-Curtis index based on relative abundance species, revealed the presence of two clusters in the Majerda low plain. The first included the artichoke assembly and the second included all the remaining crop types, which can itself be divided into three subgroups: the first included the crop of alfalfa and wheat, the second included only barley, and the third was represented by grassland, olive trees, almond trees and melon that shared more than 70 % of similarities (Fig. 2A).

In the Regueb plain, the degree of similarity between isopod communities fluctuated between 74 % and 99 %. Hence, two clusters were found: the first composed only by grassland and the second divided into two groups: the first including olive trees, almond trees and wheat, and the second including pea, beans, barley and melon. The two latter shared almost 99 % of species communities (Fig. 2B).

Distribution of Oniscidean species according to abiotic factors

Canonical correspondence analysis (CCA) (Ter Braak 1986) was applied to assess the relationships between abundance of Oniscidean species, abiotic factors and the crop types in the Majerda low plain and the Regueb plain.

In the CCA Majerda low plain data (Fig. 3A), the cumulative eigenvalue represented 85.96 % of which more than 71 % for the first axis alone. *P. laevis* and *P. pruinosus*, associated with melon and artichoke, respectively, were positively correlated with soil calcium, conductivity and pH. *A. pelagicum*, abundant in the almond trees, was positively correlated with humus and C/N. However, among the second group of Oniscidean species, which were associated with the rest of the crop types, *A. officinalis*, *Porcellio variabilis*, *A. tunisiense* and *C. elongata* seemed to be negatively correlated with soil humidity.

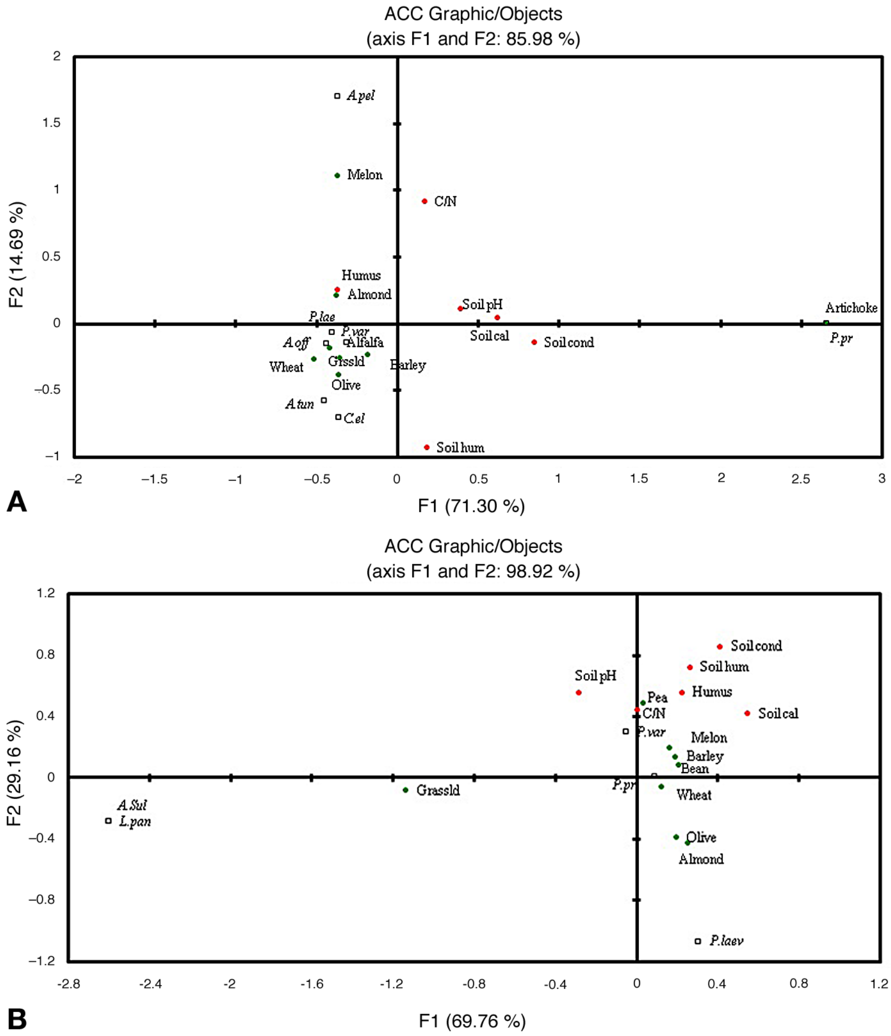

Fig. 3. – **A**: Canonical correspondence analysis performed on isopod species and abiotic factors in the Majerda low plain. **B**: Canonical correspondence analysis on isopod species and abiotic factors in the Regueb plain. *A.off: A. officinalis, A.pel: A. pelagicum, A.sul: A. sulcatum, A.tun: A. tunisiense, C.el: C. elongata, L. pan: L. panzerii, P.lae: P. laevis, P.pr: P. pruinosus, P.var: P. variabilis*, soil hum: soil humidity, soil cond: soil conductivity, soil Cal: soil calcium content, Humus, soil pH, Grssld: Grassland, ●: soil feature, ●: crop type, ◘: isopod species).

In CCA on the Regueb plain data (Fig. 3B), almost 70 % of the information was obtained through the first axis and more than 29 % was explained by the second axis. In contrast to *P. pruinosus*, *P. laevis* was clearly correlated with all soil factors. However, *P. variabilis*, abundant in olive and almond trees, was negatively correlated with soil pH. *L. panzerii* and *A. sulcatum* seemed to be negatively correlated with soil variables.

DISCUSSION

The individual abundance varied depending on the site and the type of crop. In the Majerda low plain, *P. laevis* and *P. variabilis* were the most encountered species in all crop types. In the Regueb plain, *P. pruinosus* exhibited the highest relative abundance regardless of the sampled plot, followed by *P. variabilis*. It is important to point out that the hand sampling method cannot be completely standardized because it informed on woodlice abundance to a certain degree (Souty-Grosset *et al.* 2005) unlike the pitfall trapping method which is selective for age, size and dispersal ability of macroinvertebrates including isopods (Tóth *et al.* 2016). With that being said, this method depends mainly on the arthropod activity (Thiele 1977) and does not allow to collect endogean and cryptozoic woodlice living under stones for instance, thus affecting the collection of samples (Antonović *et al.* 2012).

Armadillo officinalis, *A. tunisiense*, *C. elongata* and *A. pelagicum* were only collected in the low plain of Majerda in contrary to *A. sulcatum* and *L. panzerii* which were present only in the plain of Regueb reflecting their xerophilous trend (Messina *et al.* 2011). This confirms that species are more linked to site than to crop type as shown by Souty-Grosset *et al.* (2005). The high abundance of *P. pruinosus* and *P. variabilis* in the melon crop in Regueb could be explained by the availability of water and the moist environment created by the drip mode of irrigation. Hence, given their low capacity to regulate their body humidity and to excavate in depth compared to other taxa, Oniscidea abundance increased proportionally with water availability (Morón-Ríos *et al.* 2010).

Whatever the study site, plots of grassland (aged than two years) harbored the highest abundance and diversity of isopods compared to the annual crops like artichoke, wheat, alfalfa, etc. This result was in agreement with those obtained by Tóth *et al.* (2016), that have reported an increase of abundance and species richness of isopods with the age of the field. Souty-Grosset *et al.* (2005) have encountered less woodlice diversity in artificial grassland like clover and alfalfa. They have attributed this decline to the intensification of agricultural practices and the increasing disturbance which induce changes in available resources, substrate and physical environment. Warren *et al.* (1987) have also mentioned that the reduction or elimination of litter cover stimulated disturbance and reduction of microhabitat availability, decreasing the diversity of decomposer arthropods (Beare *et al.* 1997). Likewise, some data have attributed the decline of arthropods quantification in annual cropping compared to shrub succession and especially to the forest, to the rising disturbance and the reduction of organic matter in the agricultural plots (Tian *et al.* 1995).

Variation in the distribution of Oniscidea in both sites could be controlled by the climatic conditions particularly temperature, precipitation and soil moisture which created an appropriate climate for survival in the Majerda low plain. Several reports have demonstrated the main effect of environmental conditions on the biology of isopods especially with the threats of desiccation and water loss (Paris 1963, McQueen & Carnio 1974, Kheirallah 1979, Dangerfield 1992, Zimmer 2004). Indeed, Zimmer *et al.* (2000) have reported that the isopod distribution is strongly affected by the annual mean temperature. Moreover, Khemaissia *et al.* (2017) have measured a variation of isopod abundance across bioclimatic zones.

In the Regueb plain, *P. pruinosus* was common in all crop types regardless the soil properties reflecting its large adaptive performance and ecological plasticity. In fact, Morgado *et al.* (2015) have confirmed the tolerance of this species for a wide array of environmental conditions compared to other Oniscidea species among which *Porcellio scaber* (Römbke *et al.* 2011) and *P. laevis* (Quinlan & Hardley 1983).

The invertebrate diversity could be affected by the floristic community. Several reports have mentioned the influence of the vegetation structure (David *et al.* 1999, Wu *et al.* 2015), productivity (Cole *et al.* 2005), and plant richness on macroinvertebrate diversity especially isopods. It has been shown that Oniscidea react to the grassland age and quality (Souty-Grosset *et al.* 2005) and the seasonal variation of associated plants (Achouri *et al.* 2008, Khemaissia *et al.* 2012, Messina *et al.* 2014). Furthermore, the feeding activities of the soil fauna such as terrestrial isopods are influenced by the legume and grass species richness (Birkhofer *et al.* 2011) and the litter quality (Gerlach *et al.* 2014).

It has been shown that the Oniscidea diversity reacted directly to the fluctuation of soil properties and plant communities (Souty-Grosset *et al.* 2005, Wu *et al.* 2015, Zimmer *et al.* 2000). Indeed, pH varied significantly between the two sampling sites. A plausible explanation for the difference in pH values between both sites was the sandy-calcic nature of soil (Smida *et al.* 2005) and the intensive use of organophosphorus and fertilizers in the Regueb plain. According to Van Straalen *et al.* (1997), the isopod abundance declined 10 times faster than the pH. Zimmer & Topp (1997) have also shown that the leaf litter pH level is mainly involved in the population life history (female mortality and juvenile longevity).

The abundance and species richness of Oniscidea varied clearly between crop types in both sites. Fraj *et al.*

(2010) have shown that *P. laevis* and *P. variabilis* reacted directly to the soil content of C and N and were most numerous when the soil C/N was equal to 0. However, according to our sampling data, these species seemed to be independent of this factor. The same authors have deduced a poor mineralization process if this result was equal to or greater than 12. However, in Majerda plain more woodlice were captured in the grassland plot where the C/N ratio was 12.4.

The highest values of C/N ratio were observed in grassland and melon for the Majerda plain, and in melon for the Regueb plain. Fraj *et al*. (2010) have found the same values in the melon crop in the Majerda plain, which coincided with the lowest species richness. Antonović *et al*. (2012) have mentioned that the C/N ratio varies between 13.6 and 17.2 in a non agricultural ecosystem.

The calcium content of soil in all cultivations ranged from 0.23 to 1.3 in both sites and ranged from 0.2 to 3.6 in a set of wetlands in the north of Tunisia (Khemaissia *et al*. 2017).

In the present study, a positive correlation was noted between *P. pruinosus* and the soil content of calcium and conductivity in the Majerda low plain. Ziegler *et al*. (2005) showed that isopods required a large amount of calcium as Ca^{2+} ions in order to regain the calcium lost during the molting process hence, a potential effect of the soil calcium content in the distribution of woodlice could be concluded. Khemaissia *et al*. (2012) have indicated that the calcium soil content has no effect on the distribution of terrestrial isopods in the supralittoral zone of Ghar El Melh lagoon (Tunisia).

In conclusion, our investigation in the two agroecosystems highlighted the effect of the cropping system and the vegetative cover on the Oniscidean community. Moreover, it appeared that the distribution of terrestrial isopods is dictated by climatic features of the studied areas and their soil properties like pH, C/N ratio, soil content of calcium, humus, etc. In accordance with previous results, we concluded that the Oniscidean dynamic is more linked to the sampling site than to the crop type. Herein the plain of Majerda revealed the most important diversity and abundance of terrestrial isopods. Plots of grassland seemed to be the preferred habitat which confirmed the influence of agricultural practices on isopod distribution. Further research is required to judge the combined effects of agricultural practices and climatic conditions on the Oniscidea distribution in Tunisia.

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