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SOIL BIOLOGICAL QUALITY UNDER CHEMICAL AGENTS OF PLANT PROTECTION USAGE. ASSESSMENT OF PEDOFAUNA BIODIVERSITY

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ABSTRACT

This study, carried out under natural conditions, aims to understand the effect of the long-term use of phytosanitary treatments on the pedofauna biodiversity. Our results show that the influence of pesticides was clearer on the total abundance of the pedofauna in autumn than in spring. In total, we caught 620 individuals in the treated site and 868 individuals in the untreated site for the two work months October 2014 and April 2015. And the abundance of pedofauna was higher in the fall and lower in the spring for the untreated site. A total of 11 orders were identified for the site treated against 13 orders for the untreated site for the month of October. The impact of pesticides was more evident in the mesofauna where there was a total absence of springtails in the site treated, compared with only 5 individuals for the untreated site.

Keywords: biodiversity; pesticides; Berlese apparatus; pitfall traps; soil fauna.

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1. INTRODUCTION

The balance of the land seems to be maintained by ecological processes in which biodiversity plays a central role [1]. The agricultural space is home to a considerable part of the biodiversity of the pedofauna. This latter plays a key role in the functioning of ecosystems. These soil organisms are an integral part of agricultural ecosystems [2], which are essential parts of many soil functions [3], and are among the most species-rich compartments of terrestrial ecosystems [4].

Microorganisms and invertebrates play an essential role in maintaining and improving soil fertility, in detoxifying pesticides and other pollutants [5]. Earthworms, ants and termites are ecosystem engineers because they modify or create habitats for small soil organisms by constructing aggregates and resistant soil pores [6]. Oberholzer and Höper, [3] report that soil organisms and their diversity are part of soil quality. Reduction or disturbance of these can therefore influence the quality of the soil. Several factors influence the decrease of pedofaunic biodiversity in agricultural ecosystems, mainly agricultural practices that are summarized in the use of pesticides, fertilizers, plowing ... Biodiversity loss is one of today's greatest challenges and is currently occurring at an alarming rate [7]. Davis et al. [8], indicate that it is imperative to understand the impacts of anthropogenic and natural disturbances on these communities. Ponge [9], recalls that the massive use of pesticides and intensive tillage in conventional agriculture results in a significant reduction in the diversity and abundance of wildlife. The term pesticides cover herbicides, fungicides and insecticides [10]. Many studies question the use of pesticides in the collapse of biodiversity. Bengtsson et al. [11] indicate that organic farming usually increases species richness. Zarea [12], assumes that often many pesticides are toxic to earthworms or have adverse effects on them, however, most herbicides have little direct effect on earthworms; although, triazine-based herbicides are slightly toxic. Pesticide application leads to changes in biodiversity and loss of species [13]. Potter et al. [14], noted that some insecticides reduced populations of earthworms; whereas, Farenhorst et al. [15], indicated that most pesticides commonly used on farms do not affect populations of earthworms. These pollutants act silently for years and their effects are indirect and long-term. Intensive agriculture, characterized by a massive use of fertilizers, herbicides, pesticides, etc… and practices to maximize harvest, has negative local, regional, and global consequences on above and below-ground biodiversity [16] Cristina et al. (2017) [17] affirm that the land use had the greatest impact on soil micro arthropod community.

Our study is an approach to disclose the impact of long-term use of pesticides on the biodiversity of soil fauna at the agricultural plot of technical institute of market gardening and Industrial culture (ITCMI) in Bir -Rogaa center in Oum El Bouaghi, which practices conventional and integrated agriculture in its plots.

2. MATERIAL AND METHODS

2.1. Study area and sampling sites

Our study was carried out at the Technical Institute of market gardening and Industrial Crops (ITCMI), the regional station of Oum El Bouaghi (Algeria). This latter is located at Bir Rogaa, 16 km to the east of the chief place of the wilaya whose altitude varies from 950-1000 m (fig. 1). For our study we chose to work on two plots cultivated in cereals: wheat, mentioned by TS and UTS in the figure (1) the parcel TS is considered as site treated for a long time with different phytosanitary products especially fungicides (Milor, Mancozebe, Ridomil) and the UTS is the untreated site the latter has never received a phytosanitary treatment.

The climate is continental semi-arid Mediterranean. The summers are warm and dry and the winters cold. The precipitation and monthly, maximum and minimum temperatures of the Bir-Rogaa region for the 11 years are shown on table (1).

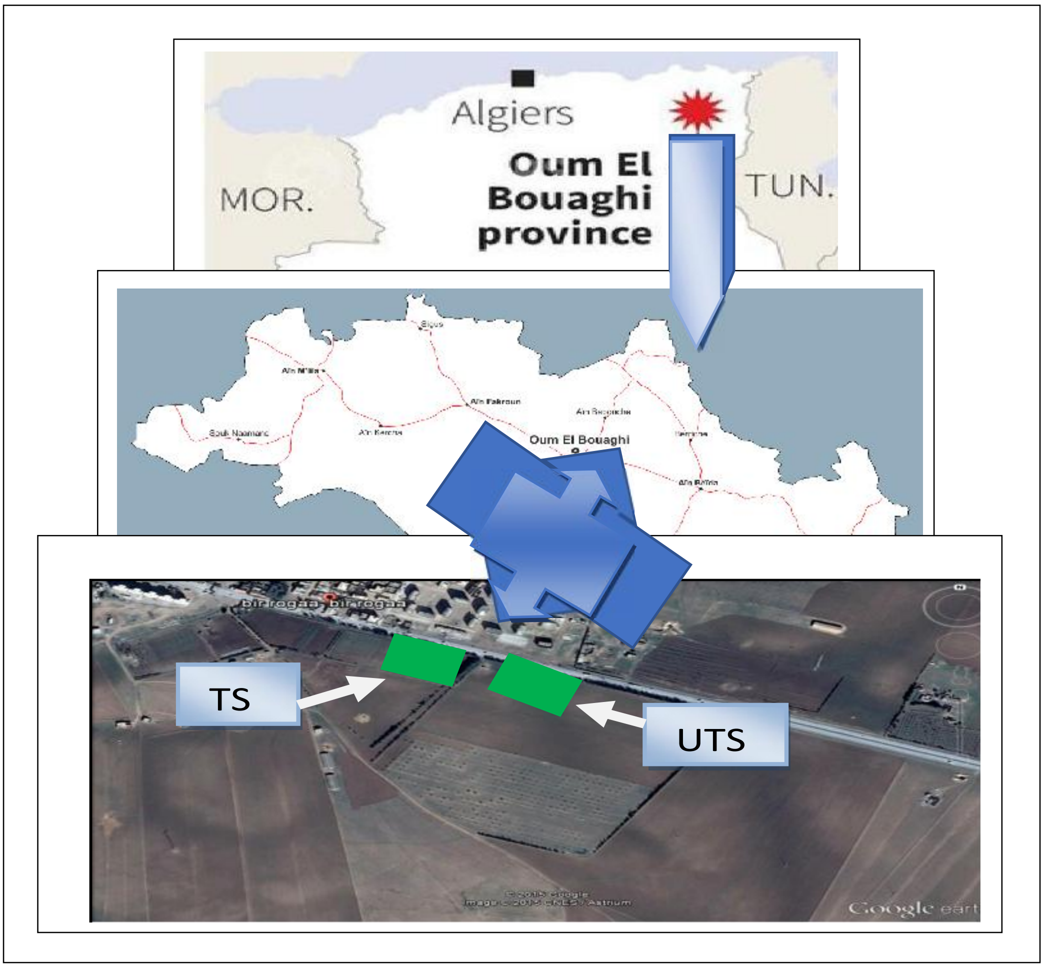

Fig.1. Localization of study site (experimental station ITCMI. in Bir-Rogaa). (Satellite image, Google Earth, 2018) TS: Treated site UTS: Untreated site

The last decade has been characterized by extreme thermal amplitudes, the lowest monthly averages are recorded for the months of December to March with the lowest in February at 4.95 °C, while the highest averages are recorded for the months of the summer season (June, July, August) (23.06 C °, 28.77 C ° and 30.72 C ° respectively).

For precipitation, we note that the highest monthly cumulative rainfall is recorded in March followed by May and December (55.48, 42.2 and 41.83mm), while July is the driest month when rainfall do not exceed a height of 11.5 mm. The mean annual cumulative rainfall is 368.9 mm.

Table 1. Mean monthly rainfall and thermal data for the 11-year study site (2003-2014)

2003/ 2014	Jan	Feb	Mar	Apr	May	Jun	July	Aug	sep	Oct	Nov	Dec
T C° max	10.3	8.78	11.94	17.8	20.84	30.59	36.03	36.86	31.72	30.43	16.95	10.56
T C°min	2.05	1.11	3.65	5.75	8.29	15.53	21.52	24.59	19.92	15.67	8.29	2.58
T C°mean	6.19	4.95	7.79	11.77	14.57	23.06	28.77	30.72	25.82	23.05	12.62	6.57
Rain (mm)	22.51	26.83	55.48	27.35	42.2	26.7	11.5	24.45	26.75	28.27	35.03	41.83

2. 2. Sampling of soil fauna

Methods of sampling insects are numerous and the choice of one or some of them is determined by the requirements of the field and by the type of insects sought.

For our study we chose to work with the methods used in the scientific literature: the pit fall trap method for surface insects and the Berlese apparatus for species that live deep, as well as the physical method for sampling of earthworms.

2.2.1. Pitfall trap

This type of trap is a tool for the study of medium and large arthropods. As a result, Baziz [18], indicates that this is the most appropriate method for capturing geophilic species. In our case, the traps used (28 in number) are cut plastic bottles, 9 cm in diameter and 10 cm high. These traps are buried vertically so that the opening is level with the ground. The soil is packed around the traps to avoid the barrier effect for small species [19], This is the type of trap most commonly used to collect invertebrates, including arthropods [20], as well as beetles, springtails, spiders, diplopods and a large number of flying insects that come to land or fall from the wind [19]. The pitfall traps are filled with water, vinegar, and iodized cooking salt to one third of their height [21]. Then they are covered with a plastic shelter to avoid anything else falling on the traps. In each site we installed 14 traps separated by intervals of about 10 m to represent the maximum of each plot. Invertebrate sampling is carried out at a rate of once a week for one month in October 2014 and April 2015 at both sites. The species collected each time are placed in boxes containing ethanol for identification.

2.2.2. The apparatus of Berlèse

The Berlese apparatus is used to recover hidden invertebrates of small size (ex: mites, collemboles ...). For both period’s fall 2014 and spring 2015, we sampled two sites per week for one month for each site. In each site and for both seasons, a pit with a depth of 30cm has been dug in order to look for earthworms and then a fraction of soil is taken and placed on the grid of the apparatus of Berlese.

Relative abundance (RA), expressed by the ratio between numbers of specimens of a species i and the total number of specimens caught in the site ×100 [22].

Constancy (C) is the ratio of the number of surveys containing the species studied (Pi) to the total number of surveys (P), expressed as a percentage [23].

C: Frequency (%)

Pi: Number of records containing species i

3. RESULTS

Biodiversity of Pedofauna

Using the methodology described, sampling was carried out at each site to characterize the present biodiversity of the macro and mesofauna of the soil.

3.1. Soil Macrofauna

Wildlife trapping using the pitfall traps method revealed a total of 743 individuals through both sites during the month of October, the latter being morphologically identified.

For this autumn sample, we counted a total of 225 arthropod species in the treated parcel belonging to four classes (arachnida, crustacea, Insecta and myriapoda) and 13 orders (tab. 2) Insecta dominates largely in order number (09 orders), followed by the class of arachnida with two orders, and the two classes crustacea and myriapoda with only one order for each.

At the level of the untreated parcel, we counted 518 individuals. Distributed into three classes (arachnida, insecta, myriapoda) and 13 orders (tab. 2). Even for this site the class of the insecta dominates, but with 10 orders followed by the class of arachnida with two orders then the class of the myriapoda with a single order. The activity of Arthropods is conditioned by a combination of several factors: soft temperatures, humidity, soil type and conditions (heavy soils, clayey soils, clammy or rich in organic matter), tillage (in the absence of work of the soil the Arthropods are not disturbed), history of the parcel and previous crops [24].

Figure (2) clearly shows the biodiversity of the pedofauna caught in both treated and untreated sites. A total of 13 orders were identified for both sites, which means that phytosanitary treatment had not influenced the biodiversity of the soil fauna for the month of October.

The same figure shows that pesticides have no effect on the abundance of beetles and Diptera where we have counted a higher number in the treated site; this is due to the characteristics of these two orders. But the impact of the pesticides is well revealed concerning the total number of pedofauna trapped where we counted in the untreated site twice what is counted in the treated site. This indicates that for this month of October the use of pesticides has an impact on total abundance. According to Drapela et al. [25].

On arable land, the use of pesticides is an important factor influencing arenas communities. At sites with increased pesticide ratios, wild insect and honeybee communities were more uniform, revealing less exchange between communities in intensive farming areas [26].

From a relative abundance point of view (Figure 3), the order of Hymenoptera dominates in both sites, but with an enormous difference, where we have a relative abundance of 73.36% and 11% for the orders of Hymenoptera and Araneae, Respectively for the untreated site. While for the treated site the relative abundance recorded is 43.56% and 20.89% respectively for the two orders hymenoptera and coleoptera.

The results of the frequency of occurrence calculations presented in Figure (4) show that for the treated site the orders of: Araneae, Coleoptera, Diptera and Hymenoptera are ubiquitous (C = 100%) according to Bigot's classification and Bodot (1973); whereas, Isopoda, Isoptera, Lepidoptera, Trichoptera and Diplopoda (C = 25%) are accessory individuals.

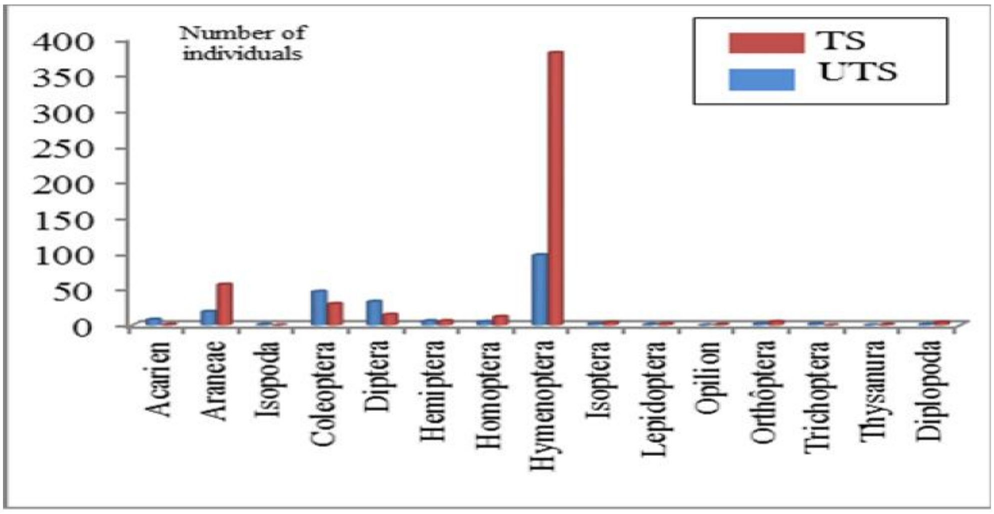

Fig.2. Orders of individuals caught by pitfall traps during the month of October. TS: treated site, UTS: untreated site

The Araneae, Coleoptera, Homoptera and Hymenoptera orders are considered ubiquitous (C = 100%), while the individuals of the orders: Acarien, Opilion, Thysanura and Diplopoda are classified as accessory (C = 25%).

For the second period (spring) (Tab. 3) of our study, Barber's traps were installed in April, the period when the temperature is slightly above 20 ° C. For this spring month we have captured a total of 745 individuals.

395 specimens of arthropods are captured in the April simpling (spring), belong to three classes (Arachnida, Insecta and myriapoda) and 8 orders, of which the insecta class dominates with 05 orders, followed by the Arachnida class with 2 orders, and the myriapoda class with a single order.

At the untreated site, 350 individuals are counted, divided into three classes (Arachnida, crustacea, and Insecta) and eight orders (Table 3).

Similarly, the class of the Insecta dominates with 05 orders followed by the class of the Arachnida with two orders and the class of Crustacea with a single order.

So, for the month of April, there is no impact of pesticide residues on total abundance of soil fauna, as we counted fewer individuals in the untreated site.

Figure (5) shows well the dominance of the order of the hymenoptera in the treated site and the order of the beetles in the untreated site.

It is important to mention that there was no treatment with pesticides this year in the site treated so that at the level of the ITCMI, the use of pesticides is only for vegetable crops and not on cereals.

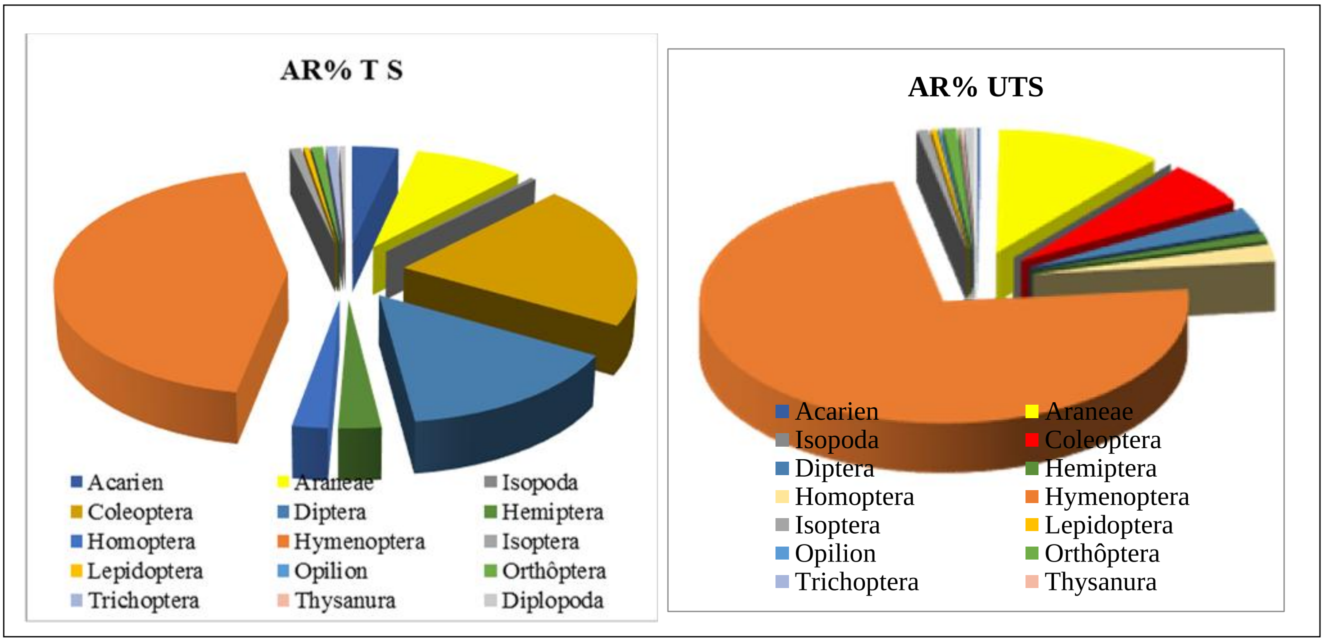

Fig.3. Centesimal frequency in% of pedofauna collected in October at both sites. TS: treated site, UTS: untreated site

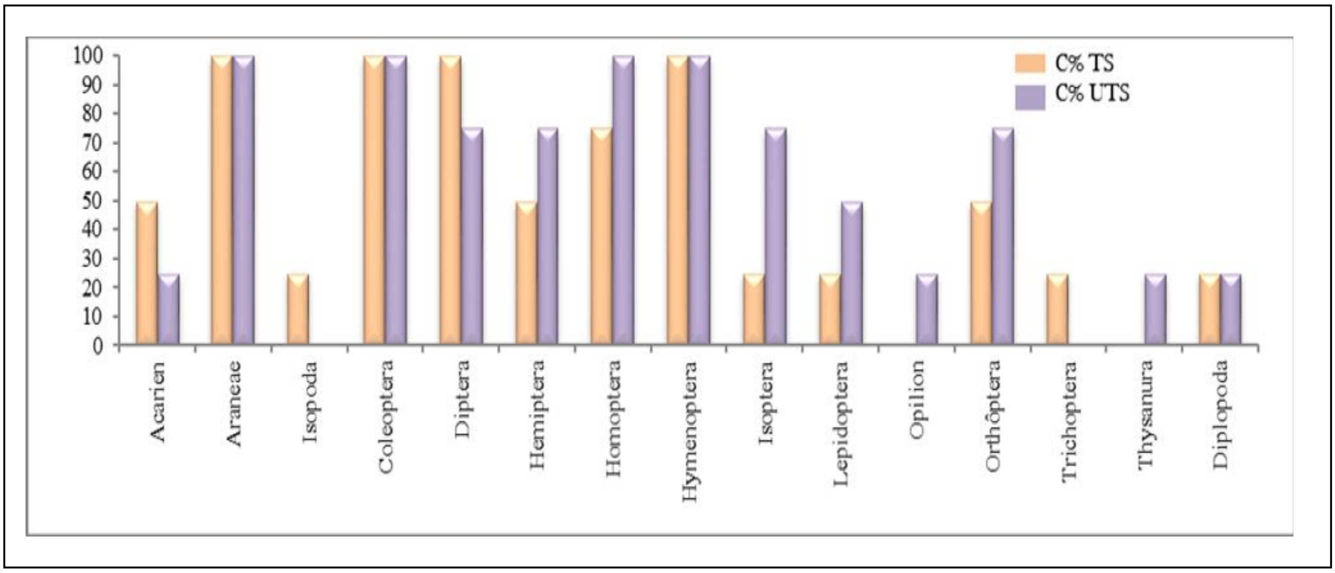

Fig.4. Frequency of Occurrence (C%) of Pedofauna at both sites during the month of October. TS: treated site, UTS: untreated site

Table2. Pedofauna caught using the pitfall traps at both sites during the month of October

Branch	Under Branching	Class	Order	Number of captured pedofauna							
				Treated plot				Untreated plot			
				S1	S2	S3	S4	S1	S2	S3	S4
Arthropoda	Chelicerata	Arachnida	Acarien	05	03	-	-	-	01	-	-
			Araneae	04	03	05	07	17	18	12	10
	Mandibulata	Crustacea	Isopoda	01	-	-	-	-	-	-	-
		Incecta	Coleoptera	11	24	02	10	03	11	06	10
			Diptera	02	28	02	01	07	03	05	-
			Hemiptera	01	05	-	-	03	02	01	-
			Homoptera	02	01	-	02	02	03	05	02
			Hymenoptera	19	45	25	09	86	112	81	101
			Isoptera	-	-	-	02	02	-	01	01
			Lepidoptera	-	01	-	-	01	01	-	-
			Opilion	-	-	-	-	01	-	-	-
			Orthôptera	01	-	01	-	03	01	01	-
			Trichoptera	-	02	-	-	-	-	-	-
			Thysanura	-	-	-	-	01	-	-	-
		Myriapoda	Diplopoda	-	-	01	-	-	-	-	04
Total	02	04	15	46	112	36	31	126	152	112	128
						225				518	

For this month of April, the highest relative abundance (Figure 6) is recorded by Hymenoptera (AR = 47.6%), Followed by Coleoptera specimens (AR = 33%) for the treated site; whereas, for the untreated site dominance is recorded by the same orders but with an inverted ranking (Coleoptera AR = 52.6% and Hymenoptera AR = 22%).

Orders: Araneae, Coleoptera, Hymenoptera were omnipresent and had the highest distribution because of their high frequency of occurrence (C = 100%) in both treated and untreated sites (Fig. 7).

The lowest frequency was recorded for the orders of Acarien and Hemiptera for the two sites and the Diplopoda order for the treated site and the order of the Dermaptera for the untreated site that were captured only once (C = 25%), which makes individuals accessory

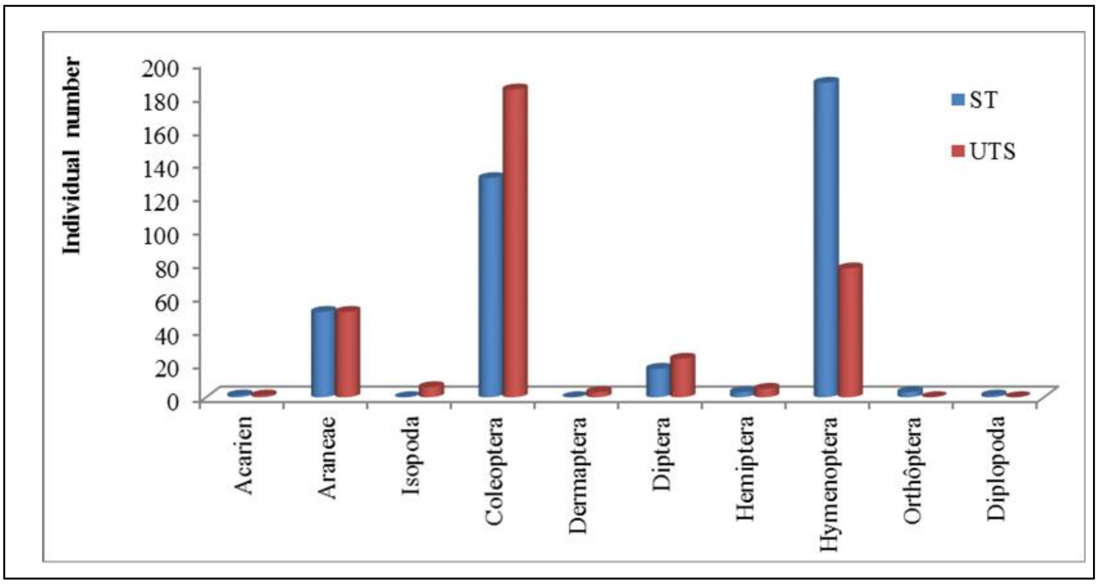

Fig.5. Orders of individuals captured by pitfall traps during the month of April

Table 3. Pedofauna caught using the pitfall traps at both sites during the month of April

Branch	Under Branching	Class	Order	Number of captured pedofauna – Treated plot S1	S2	S3	S4	Untreated plot S1	S2	S3	S4
Arthropoda	Chelicerata	Arachnida	Acarien	-	-	-	1	-	-	-	1
			Araneae	6	23	13	9	9	10	19	13
	Mandibulata	Crustacea	Isopoda	-	-	-	-	-	1	1	4
		Insecta	Coleoptera	11	44	37	39	12	34	78	60
			Dermaptera	-	-	-	-	-	-	-	3
			Diptera	1	-	14	2	-	12	10	1
			Hemiptera	-	3	-	-	-	5	-	-
			Hymenoptera	18	36	90	44	3	3	17	54
			Orthôptera	-	-	2	1	-	-	-	-
		Myriapoda	Diplopoda	-	-	1	-	-	-	-	-
Total				36	106	157	96	24	65	125	136
	2	4	10				395				350

3.2. Soil mesofauna

The search for the mesofauna was carried out using the Berlese extractor. The device of Berlese apparatus helped us to collect the springtails. In the soil, these small critters are involved in the cycle of decomposition of organic matter. For the autumn period, several samples of the soil were taken for the extraction of the mesofauna, but nothing was found, and the following results concern only the April sampling.

For the site that received phytosanitary treatments, no individual was found.

For the untreated site, in the samples taken, we counted only five collembola, which is considered a very low abundance. This may be justified by the lack of moisture and low organic matter content or the presence of collembola predators. This total absence of these microarthropods in the treated site indicates the effect of phytosanitary treatments on springtails even after nine months of the last treatment (Fig.8).

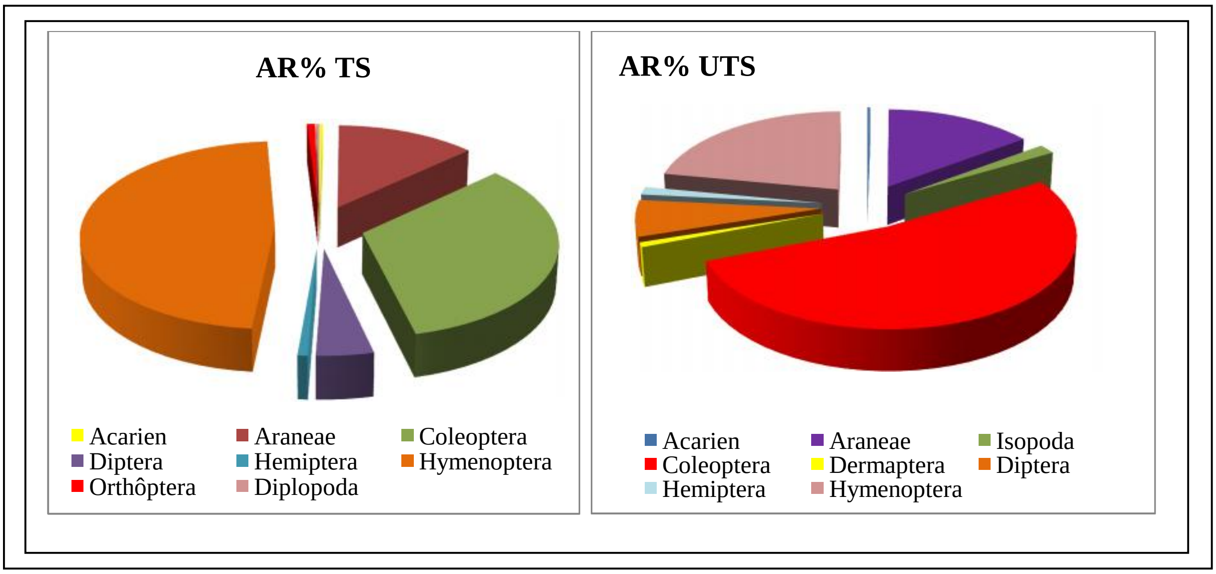

Fig.6. Centesimal frequency (%) of pedofauna collected in April at both sites. TS: treated site, UTS: untreated site

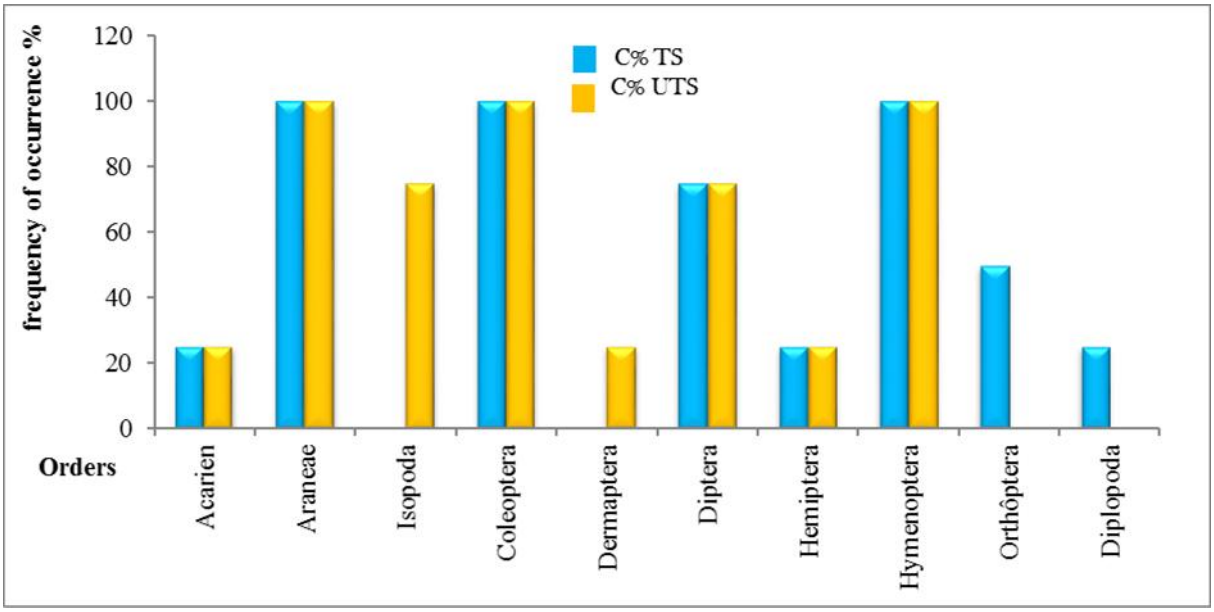

Fig.7. Frequency of Occurrence (C%) of Pedofauna at both sites during April. TS: treated site, UTS: untreated site

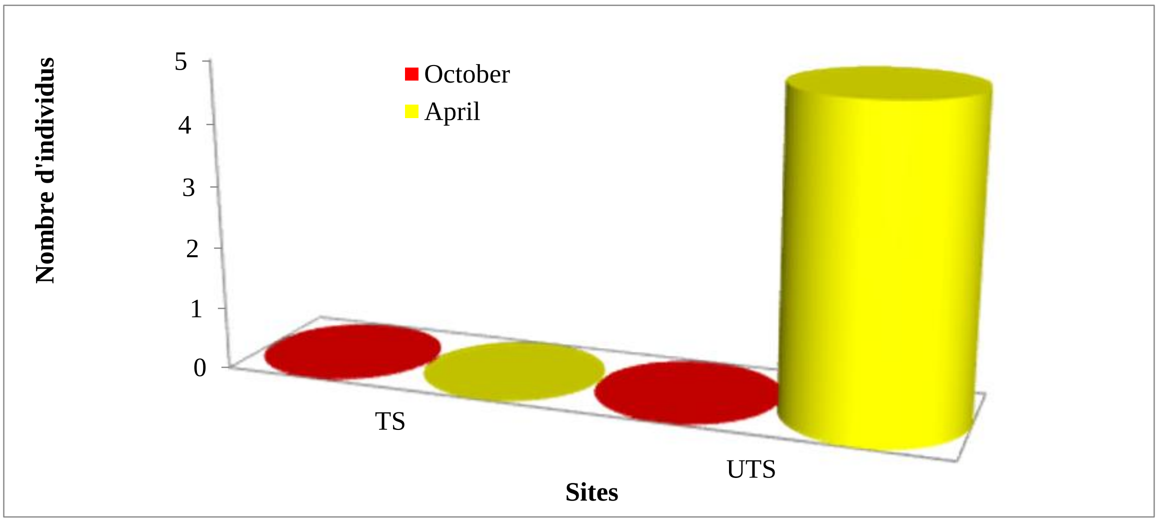

Fig.8. Springtails captured by the Berlese apparatus. TS: treated site, UTS: untreated site

4. DISCUSSION

Soil fauna provides several ecological functions in the ecosystem. Coleman et al. [27] reported that in the last decade of the twentieth century it became necessary to integrate studies of organic activities and biological diversity in a wide range of different ecosystems. In this study we trapped in October a total of 518 specimens for the site that has never received phytosanitary treatments belonging to 13 orders, where the order of Hymenoptera is the most represented with 380 individuals. This order has three important suborders, including the ants. Edward and Hölldobler [28], indicate that they constitute an important part of animal biomass. They are ubiquitous in agricultural ecosystems. Matlock and De La Cruz [29], have determined that ants have been widely used as biological indicators in invertebrate biodiversity assessments; whereas, for the site treated by plant protection products, a total of only 225 individuals was captured, still distributed on 13 orders, with Hymenoptera dominance, but with only 98 individuals, which represents a quarter of the number of individuals caught in the Untreated site.

These results indicate the harmful effect of plant protection products on this order.

The results of Mamadou and Mazih [30] study indicate that the relative abundance of ants fell sharply one day after pesticide applications (shock effect), while it increased in the control plots, and Significant reductions in ant populations of more than 98% in the presence of insecticides were noted at 12 days post-treatment.

Cortet et al**.** [31] report that fipronil (a pesticide) decreased the abundance of certain pedo-microarthropod taxa.

Concerning the second period of our study (April), a difference was recorded between the total number of specimens caughted in the two sites, with a superiority of individuals abundance recorded for the site treated (395 individuals against 350 individuals). These results indicate that after 9 months of the last treatment applied in the treated site, the pedofauna appears to be more abundant in this site than for the untreated site.

These findings are in agreement with those of Menhinick [32], who indicated that after application of pesticides, soil fauna tends to become more abundant, after a decrease of large organisms in favor of the small ones much more tolerant to the pesticides.

A complete absence was recorded for the month of October may be due to the dry state of the soil during this month, as well as to the rate of low organic matter of the soil which is a general character for the agricultural soils of the semi-arid zones. During the month of April, a very small number was recorded for the untreated site (5 individuals); whereas, for the treated site no individual was captured. These results reflect the quality of the soil because, according to Cortet, and Lebeaux, [33], springtails are valuable bio-indicators of the quality of the environment.

For earthworms during the two months where the study was carried out and in both sites no earthworms wer collected. Joko et al. [34] indicate that uncontrolled application of pesticides can contaminate soil and pesticides can damage soil biomass and microorganism such as bacteria, fungi, and earthworms. Low soil organic matter, low soil relative humidity and soil preparation may be among the causes of the absence of these soil engineers.

5. CONCLUSION

The results of this study show that the effect of pesticides was clearer on the total abundance of the pedofauna in October than in April. The abundance of soil fauna caught was higher in October 2014 and lower in April 2015 for the untreated site. In total, we caught 620 specimens in the treated site and 868 specimens in the untreated site during the two months of study that represent the two seasons (fall 2014 and spring 2015). The impact of pesticides was more clear with mesofauna where there was a total absence of springtails in the site treated, compared with only 5 specimens for the untreated site.

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