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ESTIMATION OF THE ENTOMOLOGICAL DIVERSITY OF A PEAR ORCHARD (*PYRUS COMMUNIS* L.) IN NORTH-WESTERN ALGERIA

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Abstract: The entomofauna is the object of important attention of protectionist ecologists in order to evaluate their population, a faunistic estimation of the entomofauna population of the two pear orchards located in north-western Algeria was carried out in the spring period following the cultural works and maintenance monitoring of the orchards. The 797 individuals sampled have highlighted 91 species, 46 families, and 9 orders. 68 species were noted for the orchard with east-west exposure and 55 species for the orchard with north-south exposure. The Shannon index (H') values are almost similar in both orchards, H'= 4.37 bits for the north-south orchard and H'= 4.38 bits for the east-west orchard, presenting a species composition that differs from each orchard. The beneficial functional groups are well maintained in the study station, reporting a high number of taxa (Pear orchards N/S: 24, Pear orchards E/W: 35) compared to predators and indifferent species. In our study, we have used the pitfall trapping that is one of the most commonly used methods to survey surface-active arthropods, but it showed certain limitation in capturing flying insects. Through this modest work, we reported for the first time in Algeria a parasitoid *Exallonyx microserus* (Hymenoptera, Proctotrupidae) sampled in the east-west orchard. No significant impact of the cultural and maintenance works effects was observed on the entomic population of the pear orchards studied.

Keywords: northwest Algeria, diversity, entomofauna, auxiliary, *Exallonyx microserus*.

INTRODUCTION

The agricultural production of pears has, in fact, an essential economic interest in Algeria. The surface occupied by the pear orchards represents 21.490 ha with a yearly production and an average of 1.098.000 quintals (Alili, 2008 and Sidouni, 2012). According to the DSA (2016), productivity always remains weak and irregular compared to the European norms, and it fails in fulfilling the consumers' demands. At the level of orchards, huge amounts of the harvest are directly consumed by the pest insects, either in the field or the storage (Souvion et al., 2013), just like the psyllids which cause important economic losses in the pear cultivation (Civolani et al., 2012); furthermore, it also represents one of the major enemies to this cultivation (Lyoussoufi, 1988). In the neighboring regions such as France, for instance, five groups of arthropods were classified as being the main enemies of the apple tree orchards as well as the pear orchards. The previously mentioned groups include the codling moth *(Cydia pomonella* L.), the tortrix moth, Aphids, pear Psylla *(Psylla pyri* L.), and phytophagous mites (Milaire, 1984). On the other hand, it is also crucial to note that at the level of the orchards, the presence of the auxiliaries is marked by their agro system utility in regulating the destructive populations as well as in reducing the damages that they cause to the crops. Other insects such as the Apoidae have a leading role in the pollination of the flowers. In reality, 80% of the savage plants depend on the pollinator insects (Nuruzzaman et al., 2016) and 75% of the crops used for nourishment depend in certain cases on the pollination insects (Klein et al., 2007). Because of different depredator attacks, the use of phytosanitary treatments has become prevalent affecting thus the auxiliary procession and it could also cause the extinction of certain useful species (Juste et al., 1990; Xiao et al., 2010 and Aidoo et al., 2016). Several studies have shown the unintended effects of pesticides on arthropod-fauna depending not only on the molecules used but also on the phases of the organism's life cycle (Kramarz and Stark, 2003; Langhof et al., 2003 and Gonzalez-Zamora et al., 2004). Therefore, in order to limit the harmful effects of chemical control alternative methods have been developed, such as integrated chemical control, which retains the most selective pesticides while respecting the use rates and intervening only at the most favorable moment of the pest cycle.

Many studies on pear trees orchards focused mainly on harmful insects and their control, notably, on pear tree psyllid *Cacopsylla pyri* L. as in Spain (Garcia Chapa and al., 2005), in Italy (Civolani, 2012 and Civolani et al. 2015), in France (Armand et al. 1991; Lyoussoufi et al. 1994a; Lyoussoufi et al., 1994b, Lenfant et al., 1994, Bues and Touban, 2000 and Debras, 2007), in Turkey (Erler, 2004) and the North of America (Horton, 1999). In Algeria, few pieces of research were realized on pear trees among the few works conducted there is the study of Yacoub (1998) about the psyllid in the Mitidja's meadow on some bio-ecological parameters and another study about populations dynamics of *Cacopsylla pyri* in relation to its natural enemies and with associated entomofauna by Alili (2008).

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The present study was conducted in the region of Khemis Miliana, located in north-western Algeria. This area is known as a favorable zone for pome fruit growing. The entomological biodiversity that hosts these arboreal ecosystems is captivating. However, nowadays no research has been carried out on the entomological diversity of pear trees in northwestern Algeria. It is in this context that we have considered it important to study the richness and structure of the entomological population on pear trees after maintenance works.

MATERIAL AND METHODS

Study area

The study was conducted in two pear orchards located in north-western Algeria, precisely in Khemis Miliana city (Ain Defla) (Latitude 36°14'9.5''N – Longitude 2°11'44.49''E). It is about 120 km far away from Algiers, delimited in the north by the city of Miliana, in the north-east by the city of Ben Allal, from the west by two cities, Ain Torki and Ain Soltane, from the east by Sidi Lakhder and in the south by Oued Chelif and the city of Bir Ouled Khelifa. The plain of Khemis Miliana has an agricultural vocation, characterized by a semi-arid continental climate with dry summers and rainy winters (Fig. 1).

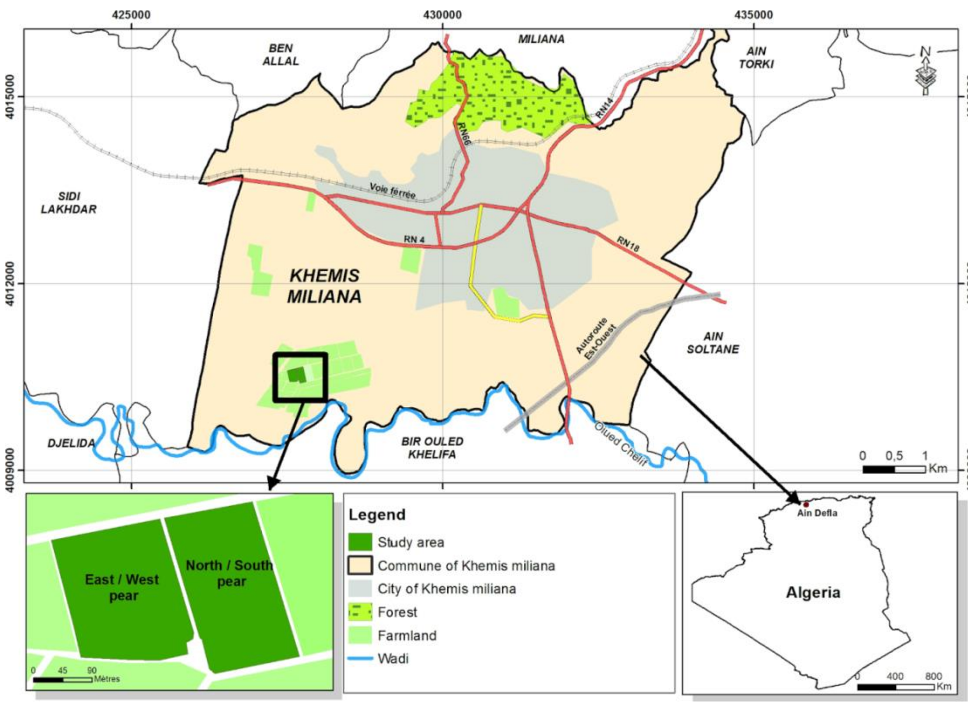

Fig. 1 Geographical location of the study area and sampling sites (north-western Algeria)

Methodology

The study of pear trees' entomofauna diversity was carried out on two parcels for the "Santa Maria" variety planted in two cardinal directions.

The orchard with east-west orientation is delimited by a field of olive trees and the orchard with north-south orientation is delimited by a field of cereals. The surface area of each parcel is 3 hectares containing 1200 trees planted in lines with a spacing of 1.5m. The parcels prospected are homogeneous and have benefited from regular cultivation work. Weeds between the trees were eliminated through grinding in order to enrich the soil with organic matter and thus create shelters for all species of terrestrial arthropods, which are often highly useful. For the phytosanitary monitoring of the orchards, the products used are precisely deficiency correctors, fungicides, acaricides, and insecticides. The choice of the insecticides is often based on the main predator of the crop under study (Table 1).

The sampling was realized during the spring season of the year 2018 within the period of the two months of May and June, using the pitfall traps. This type of trapping is the most used method in capturing the insects that move to the soil surface as well as in capturing the flying insects attracted by humidity (Blondel, 1979). Ten pitfall traps were planted in each orchard with a placement distance of 15 meters between the consecutive traps, and 30m between the traps of two different lines. The pitfall traps were opened and filled to two-thirds (2/3) with a solution saturated with salt and few scentless soap drops and they were sheltered from the rain. The records were accomplished four times each 15 days from their implementation in order to encompass the entomofauna of the study station.

In the zoological laboratory of the Higher National Veterinary School El –Harrach, Algiers, Algeria, the insects collected were sorted and conserved in pillboxes containing alcohol at 70 % in order to be identified later at the highest taxonomic rank possible, mainly, until the genus and species using a binocular magnifier with a magnification of (*10/20) times. The identification was carried out according to taxonomic

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 31, issue 1, 2021, pp. 34 - 46

keys described by Perrier (1937), Chopard (1943), Antoine (1955), Auber (1971), Du Chatenet (1986), Roger et al. (2013).

Concerning the results of the analysis, we have used ecological indexes of composition and structure. The first indexes were represented by the total richness S which corresponds to the number of different species identified during the sampling in the field. The centesimal frequency FC (%) = ni * 100/N in which (ni) is the individual number of species found in an environment, and (N) is the total individual number of all the mixed-up species (Dajoz, 1985). The frequency of occurrence FO (%) = Px100/N in which (P) is the number of the record containing the species I, and (N) is the total number of the records (Dajoz, 1970, 1982). Regarding the ecological indexes of the structure, we have calculated the diversity index of Shannon H'= -Σ Pi ($\log_2$ Pi) bits in which (Pi) is the proportion of the total number of the individuals which were counted for one species I. It gives much information about both the richness and the species' abundance (Barrantes and Sandoval, 2009), Furthermore, the equitability index which represents the ratio of Shannon index calculated and the maximum theoretical index in the population E= H' / H'max., in which H'max.= LOG_2 S and (S) is the total richness. This index varies between 0 and 1 (Blondel, 1979). The values shift to 0 when nearly all the species' numbers correspond to only one species of the settlement, and they tend to shift to 1 when each of the species is illustrated by the same individual number (Ramade, 1984). A Principal Component Analysis (PCA) was conducted on trophic groups of the entomofauna listed in the prospected parcels in order to better explain the species' organization in their environment, and bring out the interspecific interactions which could exist. This analysis was put forward using R 4.0.2 (Facto MineR, Rcmdr).

Table 1.

The pesticides used in the two pear orchards studied

Trade name	Active ingredient	Chemical family	Field rate (L or Kg /Ha)	Target
INSEGAR	FENOXYCARBE	Carbamate	0.4	Psylla eggs: (second-generation eggs) Codling moth: (first generation egg-laying)
BORAMIN Ca	CaO + B + ACIDES AMINES	Foliar fertilizer	3	Bio-stimulant, helps fruit setting
MANCO 80 RIVA + DIVISOL 250 EC	MANCOZEBE + DIFENOCONAZOLE	Dithiocarbamates + Triazole, systemic, unitary	2 + 0.2	Scab prevention + Scab Healer
NOMOLT + CAPTAN 50 VALLES	TEFLUBENZURON + Captan	Benzylurea + Phtamilides	0.33 + 3	Codling moth: (First generation larvae) + Scab prevention
KRISTA STOP	Potassium Sulfate	Fertilizers	8	Drying the honeydew of the psyllids + Foliar nutrition
ENVIDOR	SPIRODICLOFEN	Tetronic acids	0.6	From the egg stage to the first larval stages of the psyllid
ABAMECTIN	ABAMECTINE	Avermectine	0.75	Psylla: Larvae (L1 and L2)

RESULTS

A total of 797 individuals were sampled in the station of the study. 91 species were registered and were distributed upon 46 families and nine orders. The east-west pear orchard revealed the presence of 545 individuals represented through 68 species. Whereas, at the level of a north-south pear orchard, a total of 252 individuals were collected indicating the presence of 55 species (Tab.01).

In the pear orchard direction north-south, the best-represented orders of insects are the Hymenoptera with a centesimal frequency of 52.38 % followed by the Coleoptera (20.24 %), the Diptera with (13.89 %), and finally the Orthoptera (6.75 %). Also, at the level of the east-west orchard, the Hymenoptera always keeps the first position with a frequency of 63.85 % followed by the Diptera (14.5 %) then the Coleoptera (12.48 %). The remaining orders showed inferior frequencies of 5 % in the two orchards explored (Table 2).

Table 2.

The total richness (S) and the centesimal frequency (FC %) of the orders of the insects identified in the study's station

Taxa	Pear orchard N/S			Pear orchard E/W			Total		
	S	ni	FC %	S	Ni	FC %	S	ni	FC %
Orthoptera	4	17	6.75	4	17	3.12	4	34	4.27
Hemiptera	4	12	4.76	3	6	1.10	6	18	2.26
Coleoptera	24	51	20.24	32	68	12.48	45	119	14.93

Hymenoptera	14	132	52.38	15	348	63.85	22	480	60.23
Diptera	7	35	13.89	9	79	14.50	9	114	14.30
Lepidoptera	-	0	0	2	4	0.73	2	4	0.50
Entomobryomorpha	1	5	1.98	1	20	3.67	1	25	3.14
Neuroptera	-	0	0	1	2	0.37	1	2	0.25
Thysanoptera	-	0	0	1	1	0.18	1	1	0.13
Total	54	252	100	68	545	100	91	797	100

S: total richness, ni: number of the individuals, FC %: centesimal frequency.

The Centesimal frequency (FC %) of entomological species identified in the station of the study

The results obtained show a huge heterogeneity of the frequencies for each listed species. *Messor barbarus* is the most represented among the entomological communities sampled at the level of two pear orchards with 24.60 % in the direction north-south (N/S) and 26.79 % in the direction east-west (E/W). The classification of the species at more than 2 % of frequency by a descending order has brought out two lists. The first list is relative to the N/S pear orchard with *Messor barbarus* (FC=24.60 %) followed by *Plagiolepis schmitzii* (FC= 15.87%), *Tapinoma nigerrimum* and *Harpalus distinguendus* (FC= 3.97% for each), *Pezotettix giornae* and *Cacopsylla pyri* (FC= 2.78% for each) and finally, Carabid *Agriotes sputator* (FC= 2.3%). The second list concerns the E/W pear orchard always with *Messor barbarus* on top of the list (FC= 26.79%) followed by *Camponotus barbaricus xanthomelas* and *Pheidole pallidula* (FC= 10.09% for each), *Tapinoma nigerrimum* (FC= 4.59%), *Lasius* sp. and *Plagiolepis schmitzii* (FC= 4.22% for each), Entomobryidae sp. Ind. (FC= 3.67%), *Mayetiola destructor* (FC= 3.12%), *Harpalus* sp. (FC= 2.75%), *Liriomyza* sp. (FC= 2.39%) and finally *Liriomyza bryoniae* (FC= 2.20%) (Table 3).

The occurrence frequency (FO %) of the entomological species listed in the study station

The entomological settlement collected during the sampling period is gathered in several categories. The pear orchard direction N/S encompasses ten common species which are present in 30 % to 40 % of the samples. The latter consists mainly of *Aiolopus strepens*, *Pezotettix giornae*, *Aphis illinoisensis*, Staphylinidae sp. ind., *Messor barbarus*, *Plagiolepis schmitzii*, Agromyziidae sp. ind., *Mayetiola destructor*, *Harpalus distinguendus, and Tapinoma nigerrimum*. The rest of the species are supplements that exist in 10 % to 20 % of the samples. However, the results of the frequency of occurrence calculated for the entomofauna of the pear orchard direction E/W, reveal the existence of four diverse categories. *Messor barbarus* is a constant species; it is present in 90 % of the samples. Two species are regular with different percentages. Respectively, there are the *Plagiolepis schmitzii* (FO= 70%) and *Pheidole pallidula* (FO= 60%). 11 species are common and exist in 30 % to 40 % of the samples. Namely, *Tapinoma nigerrimum*, *Calliphora* sp., *Harpalus* sp., *Poecilus cupreus*, Tenebrionidae sp. ind., *Camponotus barbaricus xanthomelas*, *Lasius* sp., *Messor* sp., Agromyziidae sp. ind., Phoridae sp. ind. Entomobryidae sp. ind. All the remaining species are subsidiaries and present in 10 % to 20 % of the samples. In addition, a significant difference in the entomological categories formed was noted between the two directions of the sampled orchards (Table 3).

Table 3.

The specimen numbers (ni), centesimal frequency (FC %), occurrence frequency (FO %), and the functional groups of different species in the two agroecosystems (U: useful, P: Pests, I: Indifferent)

Orders	**Taxa**	**Codes**	**Pear tree N/S**	**Pear tree E/W**	**Functional groups**				
			ni	**FC%**	**FO%**	**ni**	**FC%**	**FO%**	**U/P/I**
Orthoptera	**Acrididae**								
	Aiolopus strepens (Latreille, 1804)	Astr	5	1.98	40	3	0.55	10	P
	Pezotettix giornae (Rossi, 1794)	Pgi	7	2.78	40	9	1.65	20	P
	Anacridium aegyptium (Linnaeus, 1764)	Aae	3	1.19	20	2	0.37	10	P
	Tetrigidae								
	Paratettix meridionalis (Rambur, 1838)	Pmer	2	0.79	10	3	0.55	10	P
Hemiptera	**Anthocoridae**								
	Anthocoris nemoralis (Fabricius, 1794)	Ane	-	-	-	1	0.18	10	U
	Aphididae								
	Aphis gossypii (Glover, 1877)	Ago	1	0.40	10	-	-	-	P

	Aphis illinoisensis (Shimer, 1866)	Ail	1	0.40	10	0	-	-	P
	Sitobion avenae (Fabricius, 1794)	Sav	-	-	-	1	0.18	10	P
	Cicadellidae								
	Cicadellidae sp. ind.	Cisp	3	1.19	20	-	-	-	P
	Psyllidae								
	Cacopsylla pyri (Linnaeus, 1761)	Pssp	7	2.78	40	4	-	-	P
Coleoptera	**Anthicidae**								
	Cyclodinus humilis (Germar, 1824)	Chu	1	0.40	10	-	-	-	P
	Apionidae								
	Perapion sp.	Pesp	-	-	-	1	0.18	10	P
	Biphyllidae								
	Diplocoelus sp.	Dipsp	1	0.40	10	1	0.18	10	U
	Carabidae								
	Brachinus crepitans (Linnaeus, 1758)	Bcr	-	-	-	1	0.18	10	U
	Brachinus efflans (Dejean, 1830)	Bef	1	0.40	10	1	0.18	10	U
	Calathus opaculus (Leconte, 1854)	Copa	2	0.79	20	1	0.18	10	U
	Calathus piceus (Marsham, 1802)	Cpi	1	0.40	10	-	-	-	U
	Calathus sp.	Casp	-	-	-	2	0.37	20	U
	Harpalus cupreus (Dejean, 1829)	Hcu	1	0.40	10	2	0.18	10	U
	Harpalus distinguendus (Duftschmid, 1812)	Hdi	10	3.97	30	3	0.55	20	U
	Harpalus fuscipalpis (Sturm, 1818)	Hfu	-	-	-	2	0.37	10	U
	Harpalus rufipes (De Geer, 1774)	Hru	-	-	-	3	0.55	20	U
	Harpalus siculus (Dejean, 1829)	Hsi	2	0.79	10	-	-	-	U
	Harpalus sp.	Hasp	-	-	-	15	2.75	30	U
	Microlestes negrita (Wollaston, 1854)	Mne	-	-	-	1	0.18	10	U
	Microlestes sp.	Misp	-	-	-	1	0.18	10	U
	Nebria brevicollis (Fabricius, 1792)	Nbr	-	-	-	2	0.37	10	U
	Ophonus sp.1	Opsp1.	-	-	-	1	0.18	10	U
	Ophonus sp.2	Opsp2.	-	-	-	2	0.37	10	U
	Ophonus sp.3	Opsp3.	-	-	-	1	0.18	10	U
	Poecilus cupreus (Linnaeus, 1758)	Pcu	2	0.79	20	5	0.92	30	U
	Poecilus sp.	Posp	-	-	-	4	0.73	20	U
	Polistichus sp.	Polsp	1	0.40	10	-	-	-	U
	Pterostichus melas (Creutzer, 1799)	Pme	3	1.19	20	-	-	-	U
	Siagona sp.	Sisp	-	-	-	1	0.18	10	U
	Trechus sp.	Trsp	-	-	-	1	0.18	10	U
	Chrysomelidae								
	Chrysomellidae sp. ind.	Chrsp	1	0.40	10	-	-	-	P
	Cryptophagidae								
	Atomoria sp.	Atsp	1	0.40	10	-	-	-	U
	Curculionidae								
	Bothynoderes punctiventris (Schoenherr, 1834)	Bpu	1	0.40	10	-	-	-	P
	Sitona sp.	Sitsp	1	0.40	10	-	-	-	P
	Dermestidae								
	Dermestes frischii (Kugelann, 1792)	Dfr	-	-	-	4	0.73	10	I
	Elateridae								
	Agriotes sputator (Linneus, 1758)	Aspu	2	0.79	10	-	-	-	P
	Agriotes sp.	Agsp	6	2.38	10	2	0.37	10	P
	Nitidulidae								

	Carpophilus sp.	Carsp	1	0.40	10	1	0.18	10	I
	Pselaphidae								
	Euplectus sp.	Eusp	1	0.40	10	-	-	-	U
	Silphidae								
	Silpha tyrolensis (Laicharting, 1781)	Sty	-	-	-	1	0.18	10	I
	Staphylinidae								
	Aleochara sp1.	Alsp1	-	-	-	1	0.18	10	U
	Aleochara sp2.	Alsp2	-	-	-	1	0.18	10	U
	Atheta sp.	Athsp	5	1.98	20	2	0.37	10	U
	Lithocaris sp.	Lisp	1	0.40	10	-	-	-	U
	Platystethus cornutus (Gravenhorst, 1802)	Pco	-	-	-	1	0.18	10	U
	Staphylinidae sp. ind.	Stsp	4	1.59	40	1	0.18	10	U
	Tenebrionidae								
	Gonocephalum sp.	Gosp	1	0.40	10	-	-	-	P
	Tenebrionidae sp. ind.	Tensp	1	0.40	10	3	0.55	30	P
	Tribolium castaneum (Herbst, 1797)	Tca	-	-	-	1	0.18	10	P
Hymenoptera	**Apidae**								
	Apis millifera (Linnaeus, 1758)	Ami	-	-	-	1	0.18	10	U
	Andrenidae								
	Andrena flavipes (Panzer, 1799)	Afl	-	-	-	3	0.55	20	U
	Braconidae								
	Aphidius ervi (Haliday, 1834)	Aer	1	0.40	10	2	0.37	20	U
	Opius sp.	Opisp	1	0.40	10	1	0.18	10	U
	Ceraphronidae								
	Ceraphron sp.	Cesp	-	-	-	1	0.18	10	U
	Encyrtidae								
	Encyrtidae sp. ind.	Ensp	-	-	-	3	0.55	10	U
	Figitidae								
	Leptopilina heterotoma (Thomson, 1862)	Lhe	1	0.40	10	-	-	-	U
	Formicidae								
	Camponotus barbaricus xanthomelas (Emery, 1905)	Cba	-	-	-	55	10.09	30	I
	Lasius sp.	Lasp	3	1.19	10	23	4.22	30	I
	Messor barbarus (Linnaeus, 1767)	Mba	62	24.60	40	146	26.79	90	I
	Messor sp.	Mesp	-	-	-	7	1.28	30	I
	Pheidole pallidula (Nylander, 1849)	Ppa	-	-	-	55	10.09	60	I
	Plagiolepis schmitzii (Forel, 1895)	Psc	40	15.87	40	23	4.22	70	I
	Tapinoma nigerrimum (Nylander, 1856)	Tni	10	3.97	30	25	4.59	40	I
	Ichneumonidae	-	-	-	-	-	-	-	U
	Diadegma sp.	Disp	1	0.40	10	2	0.37	10	U
	Venturia canescens (Gravinhorst, 1829)	Vca	4	1.59	20	-	-	-	U
	Diapriidae								
	Trichopria basalis (Thomson, 1859)	Tba	1	0.40	10	-	-	-	U
	Proctotrupidae								
	Exallonyx microserus (kieffer, 1908)	Emi	3	1.19	20	-	-	-	U
	Pteromalidae								
	Asaphes sp.	Assp	2	0.79	20	-	-	-	U
	Pteromalidae sp. ind.	Ptsp	-	-	-	1	0.18	10	U
	Roproniidae								
	Roproniidae sp. ind.	Rosp	2	0.79	10	-	-	-	U
	Vespidae								
	Vespula germanica (Fabricius, 1793)	Vge	1	0.40	10	-	-	-	I
Diptera	**Agromyzidae**								

	Agromyzidae sp. ind.	Asp	19	7.54	40	10	1.83	30	P
	Liriomyza bryoniae (Kaltenbach, 1858)	Lbr	3	1.19	10	12	2.20	10	P
	Liriomyza sp.	Lysp	1	0.40	10	13	2.39	20	P
	Calliphoridae								
	Calliphora sp.	Csp	2	0.79	10	7	1.28	40	I
	Cecidomyiidae								
	Mayetiola destructor (Say, 1817)	Mde	7	2.78	40	17	3.12	20	P
	Chloropidae								
	Chlorops sp.	Chsp	-	-	-	1	0.18	10	P
	Drosophilidae								
	Drosophila sp.	Drsp	-	-	-	1	0.18	10	P
	Muscidae								
	Musca domerstica (Linnaeus, 1758)	Mdo	1	0.40	10	7	1.28	30	I
	Phoridae								
	Phoridae sp. ind.	Phsp	2	0.79	10	11	2.02	30	I
Lepidoptera	**Pieridae**								
	Pieris brassicae (Linnaeus, 1758)	Pbr	-	-	-	3	0.55	10	P
	Tineidae								
	Tineidae sp.	Tesp	-	-	-	1	0.18	10	P
Entomobryomorpha	**Entomobryidae**								
	Entomobryidae sp. ind.	Entsp	5	1.98	20	20	3.67	30	I
Neuroptera	**Chrysopidae**								
	Chrysoperla carnea (Stephens, 1836)	Cca	-	-	-	2	0.37	20	U
Thysanoptèra	**Thripidae**								
	Frankliniella occidentalis (Pergande, 1895)	Focc	-	-	-	1	0.18	10	P

Shannon Diversity Index and Equitability

The two specific total richness of both 54 species and 68 were noted respectively for the two pear orchards direction north-south and east-west. The values of the Shannon index (H’) are adjacent, 4.37 bits for the north-south pear orchard and 4.38 bits for the east-west pear orchard. This latter denotes that both environments present a rate of diversity that is crucial and homogeneous with a specific variation marked for both of the sampled orchards. Species evenness (E) reveals that the registered values for both of the study environments are near to one which, in turn, shows that the entomofauna listed is equally distributed (Table 4).

Table 4.

The values of the Shannon diversity index calculated for the two sampled orchards

Orchards / Indexes	Ni	S	H'	H' max.	E
N/S	252	54	4.37	5.75	0.76
E/W	546	68	4.38	6.09	0.72

Ni: the number of individuals, S: total richness. H’: the diversity of Shannon, H’max: the maximum diversity, E: equitability.

The functional groups of the entomological species listed

Table 5.

The functional groups (trophic) of the two sampled orchards

Functional groups	Pear orchards N/S			Pear orchards E/W		
	S	Ni	% Pear	S	ni	% Pear
Useful insects	24	52	20.63 %	35	73	13.37 %
Pest insects	20	73	28.97 %	19	88	16.12 %
Indifferent insects	10	127	50.40 %	14	385	70.51 %
Total	54	252	100 %	68	546	100 %

Ni: the number of the individuals, S: total richness % pear: percentage of the functional groups.

The analysis of the collected entomofauna at the level of the study station highlighted the presence of three functional groups. There exist precisely, useful species represented at the level of the north-south pear orchard by a total richness of 24 taxa, 52 individuals and a frequency of 20.63 %, and 35 taxa, 73 individuals and 13.37 % for the east-west pear orchard. The second functional group is composed of pest insects which are principally the phytophagous gathering 20 taxa, 73 individuals, and a frequency of 28.97 % for the north-south pear orchard and 19 taxa, 88 individuals, and 16.12 % for the east-west pear orchard. The third functional group is formed of indifferent species with ten taxa, 127 individuals, and a frequency of 50.40 % for the north-south pear orchard, in addition to 14 taxa, 385 individuals, and 70.51 % for the east-west pear orchard (Table 5).

The principal component analysis (PCA) of the listed entomofauna and the types of interactions that exist between the species

The principal component analysis carried out, allowed to represent graphically the organization of the entomofauna species of the study station through three observed functional groups. Each graduate is formed by a range of species, mainly, to represent each functional group. Two dimensions are issued from three chosen variables containing an inertia rate of 76.26 % either 40.44 % and 35.32 % respectively for Axis 1 and Axis 2. The most frequent species are legible on the graph and retreat from the rest of the cloud points, and they mark their high correlation with the two Axes through contributing positively to their inertia. It occurs for the indifferent species, *Messor barbarus* with (40.62 %) and *Plageolepis schmitzii* with (12.30 %). and for the pest species, Agromyzidae sp. ind. with (18.01 %), *Mayetiola destructor* (14.90 %), and finally *Harpalus distinguendus* (10.40 %) and *Harpalus* sp. (12 %) for the useful species (Fig. 2).

The second graph presents another distribution of the entomofauna species of the study station depending on the specific interaction between the different functional groups. The Axis 1 and 2 released upon the second matrix composed of three functional groups and 91 species that reveal a total rate of inertia of 59.56 %, either 35.82 %, and 23.74 % respectively for the Axis 1 and 2. It is seen from the formed graph that the two groups are positively related. It is precisely about pest species and useful ones in which their trophic interaction is importantly marked between these two functional groups. The third group tends to be independent and does not mark any interaction between the first groups, it is an exclusively indifferent species (Fig. 3).

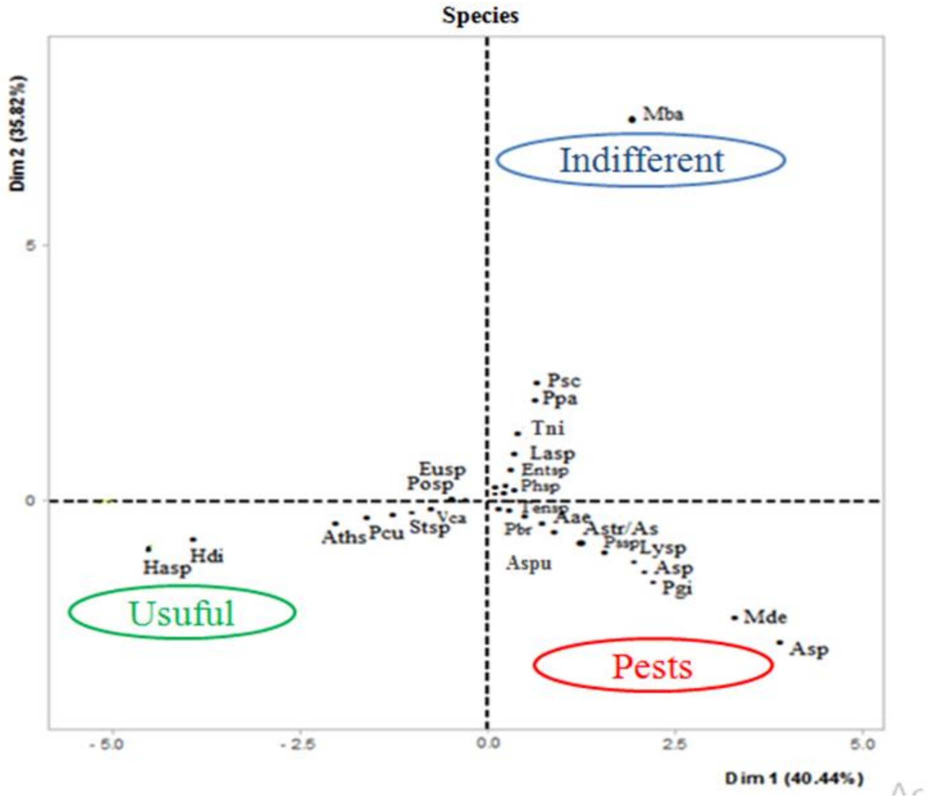

Fig. 2 Graphic representation of the listed entomofauna on the plan 1-2 of the PCA

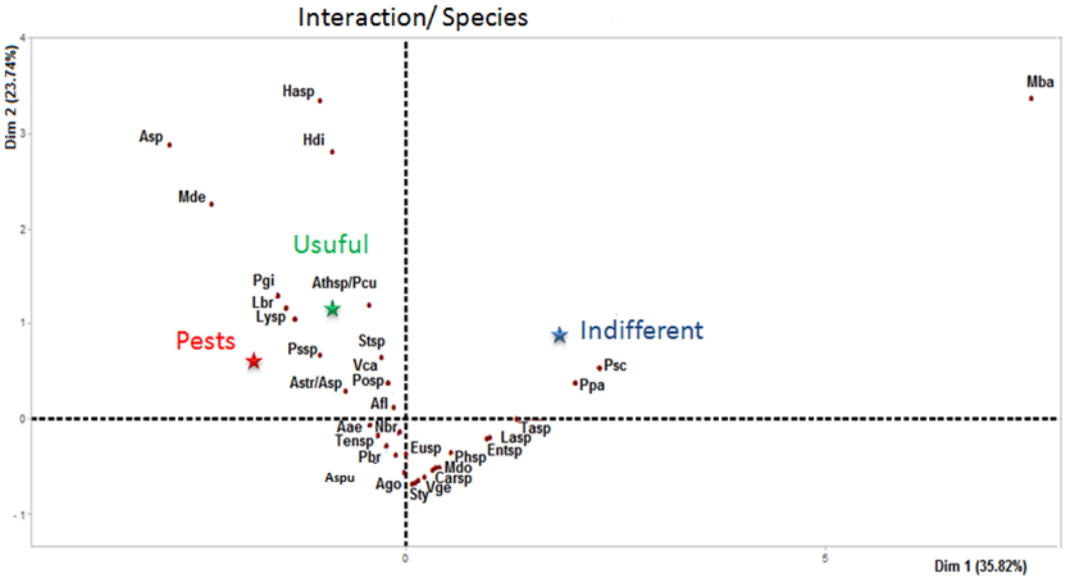

Fig. 3 A graphic representation of the specific interaction of the listed entomofauna on plans 1-2 of the PCA

DISCUSSION

The current research was realized within an agro-system located in the region of Khemis Meliana during the spring period. The study was carried out after a set of cultural and maintenance works at the level of the prospected parcels. The latter belong to two pear orchards of Santa Maria variety and are oriented towards two directions, north-south orchard and east-west orchard. In fact, the analysis of the descriptive parameters allowed to specify and to describe the available entomic fauna in the study field. A total of 91 species were listed even though the survey was realized during only two months. The latter led to the prediction of high entomological diversity in the study station. The specific diversity of each orchard depending on the cardinal directions is 55 species for the north-south orchard and 68 species for the east-west orchard. Based on these results, it is concluded that the east-west orchard hosts a diverse entomofauna. This is probably due to the phototropism, taking into account that the east-west parcel of our study station is exposed to the sun during the whole day, unlike the north-south parcel. So, we attend to the ordination of the species which is quite delicate depending on the particular needs of luminosity and warmth either in the morning (rising sides), in the afternoon, or at the end of the day (sunset side) (Boitier, 2004).

The order of the Hymenoptera takes the first position with the centesimal frequency of 60.23 %, the Formicidae stays the most representative family at the level of two orchards in which *Messor barbarus* was registered with a frequency of 26.79 % and 24.60 % respectively for the east-west and north-south orchards, this is probably related to the social life which leads these insects. In fact, the family of the Formicidae is mentioned by several publications due to its abundance in the ecosystem and of its ubiquity (Abera-Kalibata et al., 2007) but also, of its diversity and its functional importance (Mc Geoch, 2007). Formicid species can also be abundant and omnipresent regardless of the level of disturbance of the studied habitat (Bailly Maitre et al., 2012). The noted values of the Shannon index are almost identical in the two orchards, H'= 4.37 bits for the north-south orchard and H'= 4.38 bits for the east-west orchard. Nevertheless, the component of each entomological settlement varies from one orchard to another. It is to consider that the used phytosanitary treatments are far from the organo-phosphorate, selective to the potential pests of pear aiming at the first generations of the codling moth and psyllid. Similarly, in the flowering stage, the used products are the growth regulators of the insects. These latter, proceed essentially on a determined stage of the present pests bringing forward a low to moderate toxicity on the useful organisms (Audemard, 1987). The results obtained corroborate with this statement, which is the fact that the entomic fauna remains important at the level of the two orchards studied. This can also be explained by the functional group of the auxiliaries, which present a high number of taxa in relation to the group of pest insects and the indifferent species. The density assessments estimated from the pitfall traps have revealed reduced densities for each species, perhaps due to the high diversity. Debras et al. (2007), reports that when the diversity is high, the majority of the species have a lower abundance.

It is necessary to specify that although the cultural and the phytosanitary follow-up of our pear orchards, the inventory of the entomofauna composition includes a significant diversity of the auxiliary species which seem well maintained at the level of the study station. The family of the Carabidae alone has presented 23 species that belong to ten genus. These latter are known to be a generalist and beneficial predators in the agricultural environments (Barbar et al., 2006; Tixier et al., 2006; Suenaga and Hamamura, 2001), because of their omnipresence and their action in the natural regulation of the pest insects (Dajoz, 1989; Kromp, 1999), in which *Harpalus distinguendus* (FC=3.97%) is the best represented for the north-south orchard and *Harpalus* sp. (FC=2.75%) for the east-west orchard. *Poecilus cupreus* is also one of the species which marked its presence in the study station. It was much more recorded at the level of the east-west orchard. It is a polyphagous generalist predator (Wallin and Ekbom, 1994; Lövei et al., 2006) which is reproduced mainly between May and June (Haschek et al., 2012). The Carabidae beetles are important environmental indicators (Rainio and Niemelä, 2003; Avgin and Luff, 2010; Koivula, 2011; Ricard et al. 2012) because of the strong sensibility of the majority of their species towards the phytosanitary products as well as with other elements related to the orchard management (Vonlanthen et al. 2015). We also consider this group of insects to be a suitable candidate, which justifies the good measures that have been taken in our follow-up of the pear orchards. The settlement of the auxiliaries associate as well the Staphylinidae with a total of 6 species and the higher frequency was marked by *Atheta* sp. (1.98%) and Staphylinidae sp. ind. (1.59%) at the level of the two prospected orchards. Some Staphylinidae beetles of the *Aleochara* genus can ensure regulation of the fly pupae through a combination of a predatory action at the adult stage with an ecto-parasitism at the larval stage (Fournet, 2000).

The results of this study highlighted the presence of two natural enemies of the common pear psyllid, *Cacopsylla pyri*, which is the most dangerous pest of the pear culture in Algeria. It is mainly about the bedbug predator *Anthocoris nemoralis* and *Chrysoperla carnea*. *A. nemoralis* is pertinent in the natural control of *Cacopsylla pyri* since it uses olfactive indexes in order to localize the infested pears of the psyllids (Scutareanu et al., 1997; civolani et al., 2007). In France, the species *A. nemoralis* (Fabricius, 1794) is considered an important agent of the natural fight in several programs of the integrated pest management upon the pear (Hassan et al. 1991). The data studied of Scutareanu et al. (1999), conveys that the predator behaves opportunistically, it seems that it reacts not only to the variable availability of the prey of the psylla genus but also to the characteristics of their host trees, it is more present in the hedges more than in the cultivated and uncultivated orchards. The species *Chrysoperla carnea* was trapped in the pitfall traps even though it often shows itself on the pear leaves. We also observed the pedunculated eggs of this species under the leaves of certain trees. It is a polyphagous predator which is reproduced naturally in the majority of agricultural cultures (Hassan et al., 1991), and it is used in the biological control of pest insects in the agro-ecosystems and the greenhouses (Corrales and Campos, 2004). In addition to that, their larvae are highly effective against the psyllids (Vilajeliu et al., 1998; Souliotis, 1999).

The originality of our study also resides in bringing out for the first time in Algeria the auxiliary species *Exallonyx microserus* (Hymenoptera, Proctotrupidae), sampled in the north-south orchard and identified after consulting the standard material. It has been described by Kieffer (1911), as a larval parasitoid by the excellence of Staphylinidae (Hedqvist, 1963; Hoebeke, 1978) which justifies its presence at the level of the sampled orchards. This study shows that the entomic settlement listed in two pear orchards, exposition of north-south and east-west directly derives from the orchards' state of maintenance. The appropriate cultural works and the maintenance monitoring have permitted to preserve the entomocenosis in its biotope, particularly, the auxiliaries. In general, the species seem not to flee any exposition; however, they are only numerous and more active on the east-west orchard, which is better exposed to the sun. Furthermore, it appears that certain points in our research are highly important, consequently, they need to be further investigated or wrapped up using other sampling techniques in order to pinpoint the whole entomofauna which shelters the pears as well as to evaluate the impacts of the pear orchard management practices upon the auxiliaries.

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AUTHORS CONTRIBUTION

Conceptualization, N. Guerrouche, K. Hamadi; Methodology, N. Guerrouche, K. Hamadi; Data collection and insects identification N. Guerrouche and F. Marniche; Data validation, N. Guerrouche, K. Hamadi; Data processing; N. Guerrouche, K. Hamadi; Writing—original draft preparation, N. Guerrouche, K. Hamadi; Writing—review and editing, N. Guerrouche, K. Hamadi and H. Azeri.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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