THE PARASITOID HYMENOPTERA ASSOCIATED WITH DIFFERENT ANIMALS CORPSES IN ALGERIA

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Abstract. This article presents the results of work carried out on three biological models: a laboratory rat *Rattus norvegicus* (Mammalia, Muridae) and the barbary partridge *Alectoris barbara* (Aves, Phasianidae) in 2016 during spring (March) in the Koléa region (Tipaza), and on a wild boar *Sus scrofa* (Mammalia, Suidae) in summer 2016 (July and August) around the Djurdjura National Park (Bouira). Only one trapping technique is used during this study: yellow plates placed around these three corpses. 561 Hymenoptera were captured in the laboratory rat, of which the Pteromalidae family comes second with 24.96% (140 individuals). Likewise, for the barbary partridge, 375 hymenoptera were found, with 22.67% (85 individuals) for the Pteromalidae family. 1595 hymenoptera were found in the wild boar, of which the Pteromalidae family also occupies the second position with 18.93% (302 individuals).

Keywords: parasitoid Hymenoptera, animal corpses, yellow plates, Algeria.

Rezumat. Himenoptere parazitoide asociate cu diferite cadavre de animale în Algeria. Acest articol prezintă rezultatele lucrărilor efectuate pe trei modele biologice, cel al unui șobolan de laborator *Rattus norvegicus* (Mammalia, Muridae) și *Alectoris barbara* (Aves, Phasianidae) în 2016 în primăvară (martie) în Regiunea Koléa (Tipaza), pe un mistreț *Sus scrofa* (Mammalia, Suidae) în vara 2016 (iulie și august) în preajma Parcului Național Djurdjura (Bouira). În timpul acestui studiu a fost utilizată o singură tehnică de capturare: plăci galbene plasate în jurul acestor trei cadavre. Au fost capturate 561 de himenoptere la șobolanul de laborator, din care familia Pteromalidae ocupă locul doi cu 24,96% (140 indivizi). De asemenea, pentru *Alectoris barbara* cu 375 de himenoptere cu 22,67% (85 indivizi) pentru familia Pteromalidae. 1595 himenoptere în porcul mistreț din care familia Pteromalidae ocupă a doua poziție cu 18,93% (302 indivizi).

Cuvinte cheie: Hymenoptera parazitoide, cadavre de animale, plăci galbene, Algeria.

INTRODUCTION

The death of an unsupervised or suspicious person results in the arrival of necrophagous insects (SMITH, 1986; CATTS & GOFF, 1992). These insects are generally the only source of information for the short and long-term determination of post-mortem interval (PMI). The sarcosaprophage fauna is divided into five ecological groups, which are accidental species whose presence is due to chance. In general, necrophages, necrophiles, and omnivores are the most medically important (ARNALDOS et al., 2005). The composition of this fauna varies depending on the nature of the body and the different stages of decomposition (SCHOENLY et al., 1996). Corpse decomposition is influenced by many factors, the most important of which are temperature, humidity, precipitation and insect abundance (TANTAWI et al., 1996). Studies on necrophagous arthropods have been conducted in several regions of the world to determine necrophagous species and succession patterns (TABOR et al., 2005). Certain hymenoptera are also associated with corpses: we occasionally observe the presence of wasps or ants. These species are most often not scavengers, but exploit this ecosystem to hunt the larvae found there (CHARABIDZE & GOSSELIN, 2014). Omnivores also feed on the corpse and associated fauna; we note the presence of Hymenoptera such as wasps and ants but also of Coleoptera (LECLERCQ, 1996; AMENDT et al., 2004; ARNALDOS et al., 2005; WYSS & CHERIX, 2006). Hymenoptera belonging to the Pteromalidae family are parasitoids of Dipterous Calliphoridae (CHARABIDZE, 2008). In Algeria, work on parasitoids is fragmented and limited.

MATERIAL AND METHODS

This work presents the results of the study on three biological models: a laboratory rat *Rattus norvegicus* (Mammalia, Muridae), Barbary partridge *Alectoris barbara* (Aves, Phasianidae) in 2016 during spring (March) a forest in Kolea (Tipaza), and on a wild boar *Sus scrofa* (Mammalia, Suidae) in summer 2016 (July and August) around the Djurdjura National Park (Bouira). Only one trapping technique is used in this study: yellow plates placed around these three corpses (Fig.1).

The species captured in the yellow plates are brought back to the Zoology Laboratory of the National Higher Veterinary School for determination purposes. We rely on dichotomous keys, and the relevant works include those of BERLAND (1940); GOULET & HUBER (1993); PINTUREAU (2012) as well as the websites: http://www1.montpellier.inra.fr/CBGP/coleotool/parasitoides.html and http://www7.inra.fr/opie-insectes/ch-01.htm. The photos were taken by digital camera (Samsung J7pro) (Fig. 2).

Analyze data. The results of the yellow plates are used by certain ecological indices as follows: relative abundance (AR %) (DAJOZ, 1971), the Shannon diversity indices and equitability indices (RAMADE, 2003). These data were analysed using Paleontological Statistics software version 2.17 (HAMMER et al., 2001).

RESULTS AND DISCUSSIONS

After a decomposition of the animal corpses which lasted 45 and 50 days for the Barbary partridge and the laboratory rat respectively with a temperature equal to 8.8 °C during spring around Koléa and 53 days for wild boar in summer with a temperature varying from 21.7 and 25.0 °C in the National Park of Djurdjura (Bouira) and using the yellow plates, we were able to collect parasitoids which surrounded the corpses and we obtained the following results. We captured 561 Hymenoptera in the laboratory rat, 375 hymenoptera in the Barbary partridge and 1595 Hymenoptera in the Wild Boar (Table 1). Our results confirm those found by AMENDT et al., 2000; DISNEY & MUNK (2004); GRASSBERGER & FRANK (2003, 2004); TURCHETTO & VANIN (2004) mentioning the presence of families of parasitic wasps of medico-legal importance, such as the Braconidae, Pteromalidae and Ichneumonidae. FREDERICKX et al. (2013) identified the following on pig carcasses: Ichneumonidea (one family), Chalcidoidea (two families), Cynipoidea (two families), and Proctotrupoidea (one family). Six other families were identified: Braconidae, Pteromalidae, Encyrtidae, Figitidae, Eucoilidae, and Diapriidae.

We find that the Shannon diversity value ranges from 1.29 to 1.74 bits for insects found on the two bodies (bird and mammal) of the Koléa region. The population of necrophiliac insects in Koléa seems scarcely diversified. For wild boar, the Shannon index is 1.33 bits in Djurdjura National Park (Bouira). The diversity of necrophiliac insects on these corpses is similar in the two regions. The obtained fairness values tend towards 1, which means that the insects found on the three corpses in the two regions are in equilibrium (Table 2).

From Table 3, we noted a high relative abundance for the family of Formicidae followed by Pteromalidae. Among the parasitoid hymenoptera collected at the level of the three corpses, we obtained for the region of Koléa, 7 families recorded for *Rattus norvegicus* and 5 families for *Alectoris barbara*. In the Djurdjura National Park region (Bouira), we noted 5 families on *Sus scrofa*. We noted the dominance of the Pteromalidae family on the three corpses with percentages ranging from 24.96% for the laboratory rat with 140 specimens, 22.67% for the barbary partridge with 85 specimens and 18.93% for the wild boar with 302 specimens. The most dominant species is *Nasonia vitripennis* (Figs. 3A, B and C). The two corpses from the Koléa region mount the dominance of *Nasonia vitipennis* with percentages ranging from 39.0% for the laboratory rat and 46.0% for the barbary partridge. In the second place comes *Alysia manducator* and *Pachyneuron* sp. with 18.0% each for *Rattus norvegicus*. 19.0% is scored for barbary partridge by *Alysia manducator*. The other parasitoids are poorly represented. Regarding the cadaver of *Sus scrofa* from the Djurdjura National Park (Bouira), we obtained a rate of 42.0% for *Nasonia vitripennis*, followed by *Pachyneuron* sp. with 31.0% and *Torymus* sp. with 12.0%. We identified the species *Alysia manducator* which belongs to the Braconidae family in the two regions on the three corpses. The presence of these parasitoid insects causes the interruption of the Calliphoridae cycle which could lead to the failure of the post-mortem interval (IMP) calculation. The Vespidae represented by the Germanic wasp *Vespula germanica* visited the corpses in both regions at the end of the rotten stage. Our results confirm those found by AMENDT et al., 2000; DISNEY & MUNK (2004); GRASSBERGER & FRANK (2003, 2004); TURCHETTO & VANIN (2004); FREDRICKX et al. (2013) reported the presence of *Nasonia vitripennis* Walker (Pteromalidae) and *Alysia manducator* Panzer (Braconidae) are the most common parasitoids found on corpses. Some authors have noticed that wasps consume dead tissue and at the same time attack the insects found there. These observations therefore confirm the feeding behaviour of these insects (GENNARD, 2012; FREDRICKX et al., 2013). In the British Isles, *A. manducator* is the most common of the parasitic Hymenoptera likely to be seen in carrion (SMITH, 1986). The seasonal activity of *A. manducator* reported in the present study is in agreement with previous observations in the Paris region, where it was active from May to October (BLANCHOT, 1992). In order to estimate IMP using these species, the calculated developmental time of the parasitoid simply has to be added to the time of development of the host, therefore providing an extended IMP timeframe in cases where traditional forensic indicators have completed their development (GRASSBERGER & FRANK 2003; AMENDT et al., 2010). The microhymenopterans are also capable of choosing their hosts by size and developmental stage (DA SILVA MELLO et al., 2010). According to TOMBERLIN et al. (2011), the complex biological processes that are climate-dependent and site-specific, like decomposition and ecological succession, are subject to inherent variability. The *Nasonia vitripennis* is a cosmopolitan species (WHITING, 1967; DARLING & WERREN, 1990; YODER et al., 1994). It is also the most common parasitoid of Diptera found growing on the carcasses (FRAENKEL & BHASKARAN, 1973; VANLAERHOVEN & ANDERSON, 1999; GRASSBERGER & FRANK, 2004; TURCHETTO & VANIN, 2004; KING & ELLISON 2005; FREDERICKX et al., 2013, 2014) and is a common ectoparasitoid that attacks the puparia of fly species of forensic importance, including blow flies, flesh flies, and house flies. The developmental time of *N. vitripennis* can be added to the host development time, providing the potential for an extended minimum IMP timeframe in cases where traditional dipteran larval forensic timeline indicators have completed their development (ZHANG et al., 2018).

After death, a series of physical and chemical changes occur within the body as it decomposes. Decomposition begins within minutes of death, as the cessation of essential metabolic functions triggers cellular changes (CLARK et al., 1996; CARTER et al., 2007; STATHEROPOULOS et al., 2007). The ecological succession of necrophiliac insects follows a predictable sequence, related to their differential attraction to changing odour profiles associated with carrion and colonizing insects. Necrophiliac insect taxa arrive to a decomposing body in a predictable sequence. Several sensory cues contribute to the predictability of insect succession, but primary among these are visual stimuli and volatile organic compounds (VOCs) that are by-products of decomposition (CRUISE et al., 2019).

The Chalcidians are medium in size (Chalcididea: 3 to 12 mm), small (Pteromalidae, Eulophidae) or tiny (Trichogrammatidae). The wings have reduced ribs. They are idiobiont ectoparasitoids, that is to say that the host is first killed and the eggs are deposited on the corpse. They are generally polyphagous and not very specific (CHARABIDZE, 2008). CHARABIDZE & GOSSELIN (2014) found that, in his entire career as a forensic entomologist, Dr Leclercq encountered that only one species of hymenoptera belongs to the Braconidae family. Otherwise CHIN et al. (2009) reported that the parasitoid *Exoristobia philippinensis* (Hymenoptera: Encyrtidae) and larvae of *Orphyra spinigera* (Diptera: Muscidae) on pupae of *Chrysomya rufifacies* were collected from carcasses of monkeys in Malaysia. MARCHIORI & MIRANDA (2011) collected dipteral synanthropes in chicken excrements and observed parasitoids of these insects. The parasitism rate was 28.4%. The following species have been identified: *Muscidifurax raptorellus*, *Nasonia vitripennis*, *Pachycrepoideus vindemmiae*, *Spalangia cameroni*, *S. drosophilae*, *S. endius*, *S. nigra*, *S. nigroaenea*, *Spalangia* sp. (Hymenoptera: Pteromalidae) and *Tachinaephagus zealandicus* (Encyrtidae), with the species *P. vindemmiae* having the highest incidence. These data serve as a basis for future evaluations of the biological control of the family Calliphoridae by parasitoids. Despite its potential usefulness in forensic entomology, the presence of parasitoids at the crime scene has been largely due to their small size (about 2 mm in length) and the paucity of available biological information (GRASSBERGER & FRANK, 2004). Successful parasitism by insect parasitoids is usually divided into hierarchical requirements, consisting of habitat location, host acceptance, and evaluation and physiological regulation of the host (BRODEUR & BOIVIN, 2004). The discrimination between a low- and high-quality host is performed by collecting a small sample of the pupae hemolymph through the parasitoid female ovipositor (KING & ELLISON, 2006). The females that neglect the host quality and ovipose in an old or cryoconserved host (KING & SKINNER, 1991; MILWARD-DE-AZEVEDO & CARDOSO, 1996) and already parasitized puparium usually suffer a reduction in the quantity and quality of their progeny.

In Algeria, they are mainly represented by predatory wasps of the genus *Vespula*. Parasitoid wasps are also found in the family Pteromalidae, including *Nasonia vitripenis*, which lay their eggs in the Calliphoridae diphtheria pupae. Some species of ants (Formicidae) are also necrophagous and may leave characteristic lesions on the corpses. In general, very little studies have been performed performed on the cadaveric volatile compounds that influence the behaviour of parasitoids.

Table 1. Hymenoptera collected by the yellow pots around the three corpses.

	Regions:	**Bouira**		**Koléa**			
	Corpses:	**Wild boar**		**Barbary partridge**		**Laboratory rat**	
Families of Hymenoptera	**Species**	Nr	AR (%)	Nr	AR (%)	Nr	AR (%)
Formicidae	*Pheidole pallidula*	39	2.45	25	6.67	45	8.02
	Plagiolepis barbara	5	0.31	16	4.27	6	1.07
	Tetramorium bicarinatum	5	0.31	36	9.60	12	2.14
	Tetramorium semilaeve	25	1.57	0	0.00	25	4.46
	Tetramorium biskrens	40	2.51	0	0.00	16	2.85
	Comporotus barbatus	23	1.44	0	0.00	12	2.14
	Cataglyphis viatica	690	43.26	0	0.00	0	0.00
	Cataglyphis albicans	45	2.82	0	0.00	0	0.00
	Messor barbarus	10	0.63	55	14.67	15	2.67
	Messor capitatus	26	1.63	0	0.00	0	0.00
	Tapinoma magnum	24	1.50	55	14.67	89	15.86
	Aphaenogaster depilis	15	0.94	2	0.53	6	1.07
	Aphaenogaster mauretanicus	11	0.69	0	0.00	0	0.00
Halictidae	*Lasioglossum* sp.	44	2.76	0	0.00	6	1.07
	Halictus sp.	4	0.25	0	0.00	5	0.89
Ichneumonidae	*Ichneumonidae* sp.	36	2.26	0	0.00	12	2.14
Braconidae	*Alysia manducator*	12	0.75	35	9.33	44	7.84
	Aphereta sp.	0	0.00	30	8.00	0	0.00
Encyrtidae	*Leptomastix* sp.	0	0.00	0	0.00	22	3.92
Trichogrammatidae	*Dicoponorpha* sp.	0	0.00	0	0.00	20	3.57
Anthophoridae	*Eucera* sp.	31	1.94	0	0.00	0	0.00
Apidae	*Apis mellifera*	120	7.52	0	0.00	55	9.80
Vespidae	*Vespula* sp.	25	1.57	0	0.00	25	4.46
Bethylidae	*Cephalonomia* sp.	0	0.00	12	3.20	0	0.00
Figitidae	*Granotoma* sp.	0	0.00	22	5.87	0	0.00
Torymidae	*Torymus* sp.	51	3.20	0	0.00	5	0.89
Pteromalidae	*Pachyneuron* sp.	127	7.96	0	0.00	44	7.84
	Nasonia vitripennis	175	10.97	85	22.67	96	17.11
Tiphiidae	*Tiphiidae* sp.	12	0.75	2	0.53	1	0.18
	No.	**1595**	**100.00**	**375**	**100.00**	**561**	**100.00**

Table 2. Composition and structure indices applied for the Hymenoptera listed at the level of the three corpses.

Parameters	Wild boar	Barbary partridge	Laboratory rat
Taxa_S	10	6	11
Individuals	1595	375	561
Dominance_D	0.41	0.34	0.25
Simpson_1-D	0.59	0.66	0.75
Shannon_H	1.33	1.29	1.74
Equitability_J	0.58	0.72	0.72

Table 3. Families of parasitoids found in the three corpses.

Regions	**Djurdjura National Park (Bouira)**		**Koléa**			
Corpses	**Wild boar**		**Barbary partridge**		**Laboratory rat**	
Familles	Nr	AR (%)	Nr	AR (%)	Nr	AR (%)
Fourmicidae	958	60.06	189	50.40	226	40.29
Halictidae	48	3.01	-	-	11	1.96
Ichneumonidae	36	2.26	-	-	12	2.14
Braconidae	12	0.75	65	17.33	44	7.84
Encyrtidae	-	-	-	-	22	3.92
Trichogrammatidae	-	-	-	-	20	3.57
Anthaphoridae	31	1.94	-	-	-	-
Aphidae	120	7.52	-	-	55	9.80
Vespidae	25	1.57	-	-	25	4.46
Bethylidae	-	-	12	3.20	-	-
Figitidae	-	-	22	5.87	-	-
Torymidae	51	3.20	-	-	5	0.89
Pteromalidae	302	18.93	85	22.67	140	24.96
Tiphiidae	12	0.75	2	0.53	1	0.18
Total	**1595**	**100.00**	**375**	**100.00**	**561**	**100.00**

- **: no value**

Figure 1. Arrangement of yellow plates on the three corpses (a. Barbary partridge; b. Laboratory rat; c. Wild boar.

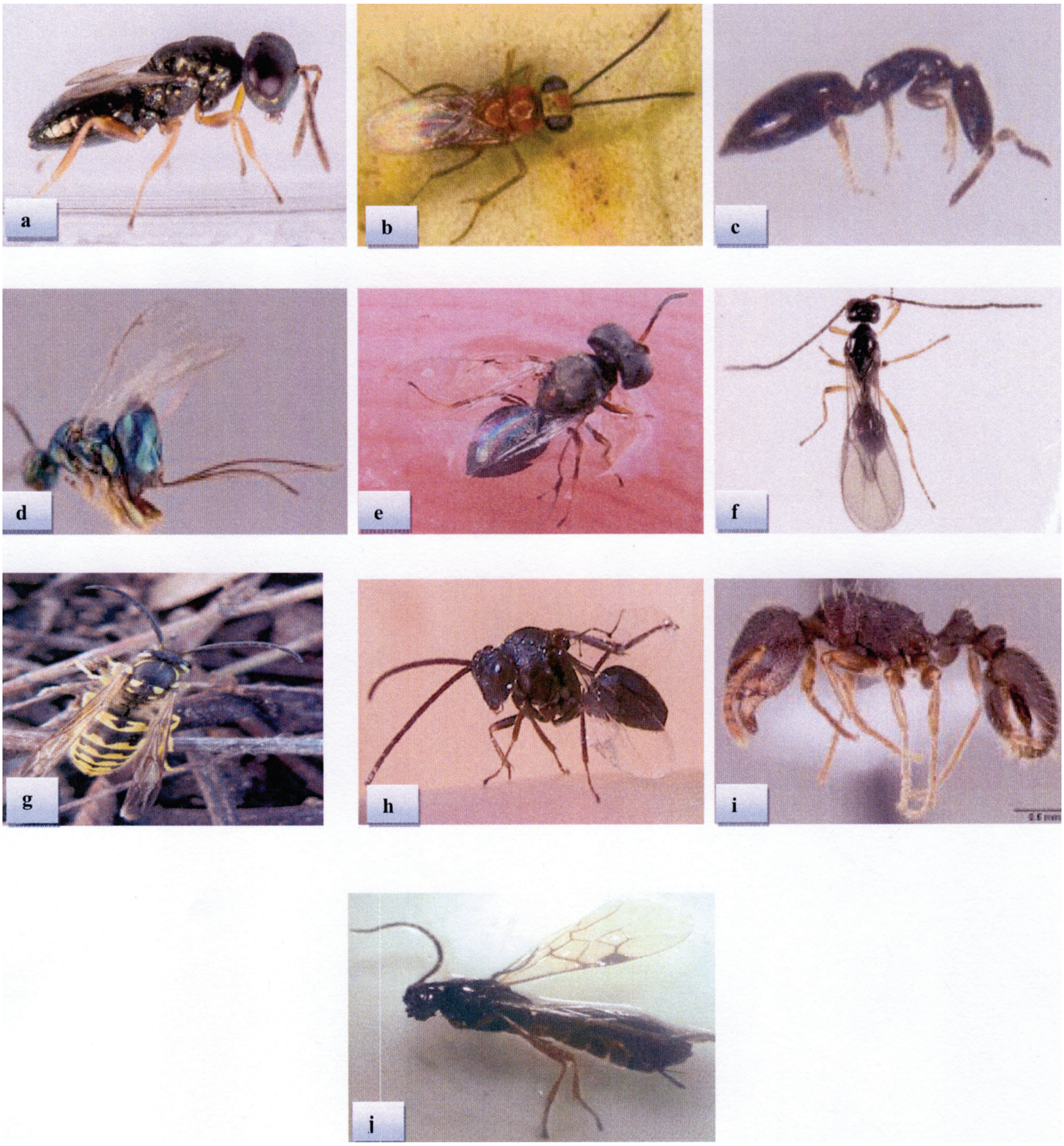

Figure 2. Different parasitoids identified in the yellow pots around the three corpses (Originale) (a: Pteromalidae (*Nasonia vitripenis*), b: Encyrtidae (*Leptomastix* sp.), c: Bethylidae (*Cephalonomia* sp.), d: Torymidae (*Torymus* sp.), e: Pteromalidae (*Pachyneuron* sp.), f: Braconidae (*Aphereta* sp.), g: Vespidae (*Vespula germanica*), h: Figitidae (*Granotoma* sp.), i: Formicidae (*Tetramorium semilaeve*), j: Braconidae (*Alysia manducator*).

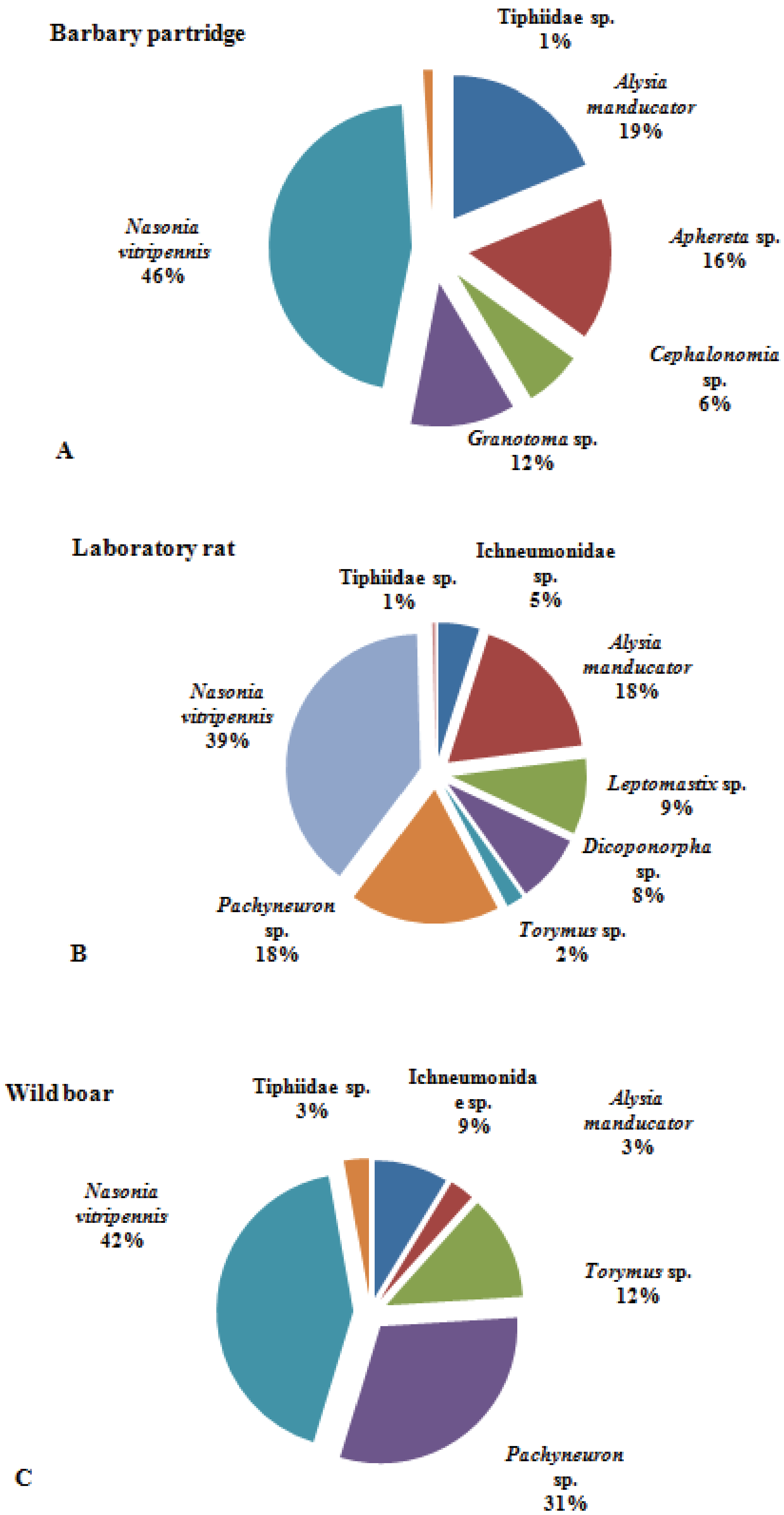

Figure 3. Different species encountered of parasitoids on the three corpses in two different localities (A, B: Koléa; C: Djurdjura National Park (Bouira).

CONCLUSION

Some species of beetles, hymenoptera and lepidoptera are also associated with decaying bodies, but they occur later and are therefore less common. In addition, although the diptera larvae of Calliphoridae are necrophages *sensu stricto*, that is to say that they feed on decaying animal tissue, the majority of beetles and hymenoptera are necrophiles. They are predators attracted to bodies by the presence of many potential preys. The presence of the Hymenoptera parasitoid, which lays their eggs inside the larvae or pupae of Diptera (genus *Nasonia*), is also observed. Forensic entomology and the study of the succession of scavenging insects are new and require more attention from researchers and scientists. It has been shown that species and succession levels can vary between geographic areas, type of habitats, or between seasons and years. These data highlight the importance of repeated local studies and the risk of errors associated with the use of standard succession.

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