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Structure of the natural enemies' community composition to *Thaumetopoea pityocampa* and *Thaumetopoea bonjeani* (Lepidoptera Thaumetopoeidae) in the Algerian cedar forests

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Abstract
Life cycles and composition of the natural enemies' complex of two Lepidoptera species *Thaumetopoea pityocampa* and *Thaumetopoea bonjeani* were studied in Algerian cedar forests at the culmination period between 1987-1988 and 2011-2012 life cycles. Eggs, larvae and pupae were collected from different infested areas and placed in laboratory in ambient temperature for the emergence of adult parasitoids flies and parasitics species. Analysis of results showed that specific parasitoids have over than 15% of incidence for *T. pityocampa* control. While for *T. bonjeani* the egg parasitoid *Ooencyrtus pityocampae* is the main species having a high performance more than 15%. Under this study the natural enemies species moths were listed (16 parasitoids, 12 predators and 5 entomopathogenics species) and described their life cycles to develop IPM for control those insect pests.

Keywords: Natural enemies, parasitoids, predators, life cycle, Lepidoptera

1. Introduction

Natural enemies' complexes have proven to be very efficient and able to reduce over than 50% of the populations of forest pest Lepidoptera which they feed on resinous species [1, 2, 3, 4, 5]. The ecological conditions in particular those related to the geographical position, the structure and the statute of the forest, its specific climate and the climate change assumed to modify structure and community interactions and the importance of generalist and specialist of the entomophagous species of parasitoids and predators of herbivorous insects [6, 7, 8]. In the case of the pine processionary moth (PPM), *Thaumetopoea pityocamapa* Denis & Schiffermüller (1775) (Lep. Thaumetopoeidae) and the cedar processionary moth (CPM), *Thaumetopoea bonjeani* Powell (1922) (Lep. Thaumetopoeidae) there is a sympatric speciation in fact that reproductive isolation is observed while the two species still exist in the same area [9]. Also, the important role related to the control of those insect pests by the entomophagous species was reported by many studies in different natural forests conditions in all its distribution area for PPM. On the contrary, for CPM a few ecobiological observations were reported and in this study, we gathered new data [9].

PPM is distributed in almost all North Africa, Europe and the Eastern countries of Middle East, usually as a pest on various pine and cedar species [10]. This insect pest is generally considered among the most important limiting factors for both growth and survival of pine forest ecosystems in the Mediterranean area, it is present in many pine stands and permanently monitored and controlled in many countries [11]. Control is a necessary measure to prevent tree mortality, which may result in soil degradation, high socio-economic problems for local people and, in some cases in desertification especially in semi-arid North African areas. The cost of the pest control is very high, however control techniques are not well developed and new cost-effective methods are highly desirable [10].

Investigations conducted in different pine and cedar forests in the south of the PPM distribution area have identified the main factors involved in the regulation of its populations. This study's data related to the complex of natural enemies including parasitoids, predators and the main species of pathogenic microorganisms were compared to those obtained through the distribution area of PPM by different authors [1, 2, 3, 11, 12].

CPM specie is specific to *Cedrus atlantica* Manetti which is present in all North African cedar forests. It appears, from a phylogenetic point of view, that CPM is closer to *Thaumetopoea pinivora* Treitschke (1834) observed in Europe on the genus *Pinus* [9, 13, 14]. However, according to the life history traits of the processionary moth of the genus *Thaumetopoea* and the genetic variation to the phylogenetic analysis clearly showed that the *T. pityocampa - wilkinsoni* complex was structured in three strongly supported clades (*pityocampa* clade, Eastern North Africa clade and *wilkinsoni* clade) [15]. Each of the three identified clades showed a strong phylogeographical structure, and composed of 3, 4 or 5 well-differentiated sub-clades. The PPM studied populations' in the Algerian cedar forests belongs to the "South of Morocco" and "South of Algeria and Eastern North African" clades [15].

PPM and CPM species can distinguishe, by some morphological characteristics of larvae, pupae, adults and eggs [9, 16]. The common characteristics of these species are host pests on cedar, the subsocial life and the processions of the larval colonies during trophic activity and in the end of the larval cycle to pupation sites. Althrough PPM and CPM have some similar etho-biological traits during their life cycles; each of them has a special pattern. Since third to fifth instar larvae we can observe urticating setae dorsally generally, acting as a defence against vertebrate predators. These setae pose a serious threat to human health when they get in contact with the skin or other parts of the body [17].

The aim of the present study was to (i) list the natural enemies' species of the PPM and CPM witch are activing along its life cycles, (ii) determine the period of activity for each species of the natural enemies, (iii) evaluate their parasitic aptitude to control the insect pests, (iv) discuss the specific richness found in the cedar forests compared to the studies done in another area in the Mediterranean area.

2. Materials and Methods

2.1 Study area

Algerian cedar forests are mixed forests with a combination of several forest tree species distributed in an altitudinal gradient where we can find *Pinus halepensis* and *Quercus suber* in low altitudes (between 1 000 and 1 400 meters (m)) in semi-arid areas. *Quercus ilex* can be found from middle altitude up to 2000 m and *C. atlantica* at high altitude.

The study was based on data from samples units of PPM and CPM egg batches, larval and pupae collected on its host trees *P. halepensis* and *C. atlantica* in different cedar natural forests (Table 1).

Table 1: Main characteristics of study cedar forests from west to east according to geographic position, altitude above sea level of and the species processionary moths studied.

Cedar forests	Region	Lattitude	Longitude	Altitude (m)
Ain Antar[1]	Bordj Bounaama (Ouarsenis)	35°53'N	1°38'E	1136
Theniet El Had[1]	National Parc (Tissemsilt)	35°58'N	1°59'E	1453
Chréa[1]	Ski Club (Blida)	36°25'N	2° 52'E	1497
Tala Guilef[2]	Site touristique (Tizi Ouzou)	36°28'N	3°59'E	1403
Tikjda[12]	Hotel Djurdjura (Bouira)	36°26'N	4°7'E	1450
Belezma[12]	Col Telmet (Batna)	35°35'N	6°2'E	1628
Chélia[12]	Ras Keltoum (Khenchela)	35°19'N	6°38'E	2296

[1] PPM
[2] CPM

2.2 Eggs, larval and pupae collect and rearing

Collection of samples were performed during the outbreak period of PPM at the following life cycles: 1987/1988 (Theniet El Had), 2005/2006 (Ain Antar Chréa and Tikjda), 2006/2007, 2007/2008 and 2008/2009 (Belezma and Chélia). In the case of CPM the outbreak and the collect of egg batches and caterpillars was from 1989/1990 to 1984/1985 for Belezma, in 2005/2006,
2009/2010 and 2011/2012 for Chélia and Tala Guilef). In general, in Belezma, Chelia, Tala Guilef when CPM is in the outbreak period, PPM populations are in increase period.

Different randomly samples was realised to identify and estimate incidence of parasitoids, predators and some of pathogenic micro-organisms such as fungi species. For the natural enemies which play an active role during the aerial phase on trees we collected for each forest and PPM and CPM life cycles studied egg batches (N = 30) after hatching and mature caterpillars at the end of the larval cycle during the nomadic period (N = 300). In case of natural enemies present during the underground phase, we sampled the pupae (N = 300) in pupation sites before the adult emergences. The activity of the various predatory species was observed occasionally in the forests.

All egg batches, larval and pupae collected were kept separately in glass tubes 8 x 1 centimetres (cm), closed with cotton at both ends since the moment of collecting. In this way, it was possible to determine parasitic and parasitoïd species which emerge from each egg batches and larvae. Elsewhere, pupae were placed in plastic boxes of 26.5 x 13.5 x 7.5 cm to observe all the larval and the larval-pupae parasitoïds.

2.3 Statistical analysis

The data related to the efficiency rates of the different natural enemies' species was calculated as a percentage of the number of eggs, larval or pupae affected by each of those species divided respectively by the sum of individuals observed. We estimated that the percentage value obtained for each natural enemy species between 0 and 5% can be considered as low, 5 and 10% as medium and over 15% as high.

3. Results and discussion

3.1 Description of the life cycles

Analysis of the PPM and CPM life cycles observed in Belezma, Chréa, Tikjda, Theniet El Had and Ain Antar showed that after adults' emergence, in case of cedar forests, the PPM moths copulate and the eggs were laid at the same day before the sunrise. In general, incubation of the eggs lasts between 30 to 50 days (Fig. 1). At the middle of August, the young caterpillars appeared and reached the fourth larval stage before winter. At the third larval stage the caterpillars build a tight and silky winter nest on the branches periphery or on the top of the tree to have a good insolation. Inside the nest they overwinter and develop till fifth larval stage then migrate in this nomadic phase in processions into the soil for

pupation during March-April. The pupal diapause lasts till the second week of June to the end of July. Some pupae had a prolonged diapause with a biannual cycle and lasting till 6 years in certain pupal underground sites.

CPM has a biological cycle similar to that of *T. pinivora*. These two species react to the same pheromone synthesis [18]. The observation of sexual calling behavior in Belezma forest cedar during several nights has shown that in general, the females starts calling only at the second night following emergence reaching a maximum after nightfall. We have however recorded sometimes, a call behavior on the very same day as emergence for females that left early (17h-18h Greenwich Universal Times -1). Eggs, as many as 70 up to 280 with a mean of 170, were laid under cedar branches and covered with a small and sharp scales which differentiate them from those of female scales of PPM. Scales covering the eggs confer them a greyish color very similar to the cedar scale. This homochromy makes the eggs hard to detect.

Emergence period for adults' runs the first week of August to that of September. Duration of embryogenesis can last more than 50 days. Starting from second week of October, eggs already contain larvae completely developed. At the stage of neonatal larvae, after a period of winter quiescence, they hatch in spring and coincide with the vegetative growth of host in March/April. Larval development takes place in five stages in a gregarious behaviour but without building nest like PPM.

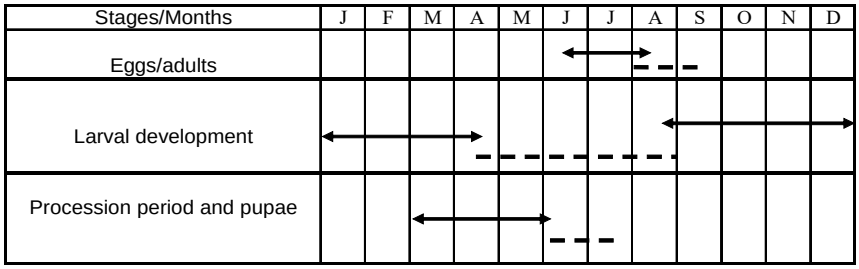

Fig 1: Life cycles diagram of the PPM (arrows line) and CPM (dotted line) in cedar forest conditions.

From June to the middle of July, the caterpillars at the fifth larval stage migrate into the soil for pupation when the temperatures reach 20°C. The adults appear from the beginning of August until the end of September, but some pupae are able to survive in diapauses more than three years [19] (Fig. 1). In life cycles for the two species, there is an intraspecific variation in the duration of different developmental stages, which are linked to different climatic conditions and altitudes [20, 21]. Also, there are some special aspects which are observed with regard, firstly to later flying period of adults for CPM compared to that PPM and mode and time of oviposition. Secondly, rhythm and development of larval instars especially for CPM which depend on young foliage at spring season whereas PPM feeds on the old foliage. Thirdly, incubation of egg with the diapause egg of CPM and its short pupal annual diapause than PPM and, finally, the choice of the sites of pupation preponderantly near the cedar host trees crown in case of CPM.

3.2 Naturals enemies

As in other southern Europe biotopes, in cedar forests experimental stations, presence and abundance of PPM natural enemies depend on host population level [2, 22, 23]. Moreover, in most of these stations, PPM as well as CPM does have the majority of common natural enemy species. This is due to the fact that they share the same ecological niche. The different species of parasitoids and predators identified are reported in Table 2 and 3 with eco-ethological information.

3.2.1 Parasitoid species

- ***Baryscapus servadeii*** **Domenichini (1965) (Hymenoptera Eulophidae) :** This species was been described as monophagous but it has been observed, these past years, in all the cedar forests on PPM. While CPM has been found in the Aures cedar forests [9, 19] and in Morocco [24] with very low incidence. It reproduces generally by thelytoous partenogensis with occasional appearance of male individuals.

  Adult abdomen was metalic green with bluish glare. The abdomen was stretched and it was crossed by two purple strips. Female Antenna had 5 articles while males have 6. They were much more filed with silk and longer than male's. Average body size is between 1.1 ± 0.1 and 2.2 ± 0.05 millimeter (mm).

  B. servadeii produces two generations per year. It implies that individuals that develop from PPM first egg laying are capable to lay themselves in the later laying of PPM [25] and probably on those of CPM. In some case in the South of France [26] and in semi-arid area in Algeria [27], a high level of individuals present a diapause of 2 years after PPM egg laying.
- ***Ooencyrtus pityocampae*** **Mercet (1921) (Hymenoptera Encyrtidae) :** This species was polyphagous and reproduces through thelytokous parthenogensis [25]. In laboratory, it develops in the ovarian eggs of PPM while CPM accepts eggs of different Lepidoptera species. It has also been encountered on PPM and CPM in all Algerian and Moroccan cedar forests.

  Adult have a short and a rather stocky abdomen with a body size between 0.48±0.01 and 0.74± 0.05 (mm). Antennas present 8 articles; the last one being more developed and divided into three lobes. Male individuals have their antennas hair twice as long as that of females.

  It was observed that *O. pityocampae* develops within two generations that follow one another in nature [1]. Adults of the first generation, or "prompt" individuals, complete their development before the period of PPM hatching eggs in September. While mature larvae of the second generation enter into a diapause at this stage until the next spring. As for *B. servadeii*, this species is capable of entering a two years diapause in the high altitude biotopes of South as well as the North of the Mediterranean area.
- ***Anastatus bifasciatus*** **Geoffroy (1785) (Hymenoptera Eupelmidae) :** This species is well known in low altitude *Pinus* forests in South European countries [1, 25]. In the Algerian cedar forests, it is of low incidence and has been observed only on PPM. it can grow at the expense of

embryos at different stages of development of host whether it be young or old.

- ***Trichogramma embryophagum* Hartig (1838) (Hymenoptera Trichogrammatidae):** *T. embryophagum* has been encountered only in the egg batches originating from all PPM cedar forests, in Djurdjura and Aures for CPM. Its weak incidence and adult emergence have been observed at June up. This species is endoparasitoid in eggs, polyphagous and characterized by a polyembryony. More than 10 individuals can develop in the same one egg.
- ***Phryxe caudata* Rondani (1859) (Diptera Tachinidae) :** This endoparasitoid specific to PPM is present in all cedar forests and has two generations per year for the same generation of PPM; first adult flight is in autumn while the second is in spring.

  Females of the *first* generation of the *P. caudata* lay their eggs ready to hatch on tegument of young larvae of PPM at the second and third larval stage. The young larval of *P. caudate*, after hatching, enter in the main opening and will stay close to tracheal stems of first and mainly last abdominal segments in order to induce a secondary trachea cover [28]. They make a pause in their development that last until the transition of the molt from the fourth to fifth larval stage of host. The worm then resumes its evolution, always within the main opening of larvae. As it reaches maturity, it leaves the place and becomes pupae either within the excrement of larvae located in the base of the winter nest or in nest weaves mesh. *P. caudata* stops until passage at slough of PPM. Then the Diptera worm starts its development in the general cavity of the PPM larval.

  Pupae become adults of spring second generation. After mating and egg maturation in the ovaries, they go lay on the PPM larval in the winter nest or during their nomadic moving to pupation in the soil. Worm at the first stage stops developing in the adipose lobules of the PPM pupae and resumes development at the end of the host diapause. It means that if host follows a multiannual diapause cycle, *P. caudata* will respect it. When it reaches maturity, worm mutes in pupae outside its host.
- ***Compsilura concinnata* Meigen (1824) (Diptera Tachinidae):** It has been noted at the CPM in cedar forests of Djurdjura and Aures. It should also be observed that unlike *P. caudate*, presence of this generalist polyphagous endoparasitoid in PPM larvae causes a disturbance of the sub social behavior. At the autumn, infested larvae are frequently less active and individualized outside nests and nest weaves.

  When the worm resumes its development in spring, infested larvae leave the colony in solitary, most often before the nomadic period to pupate in the soil or in the case of a late or slow larval development, they follow the colony only for a little while during their migration.

Table 2: Parasitoid species observed from the main development stages of PPM and CPM in Algerian cedar forests.

Hymenoptera	Host		Distribution	Host stages		Activity period	Efficiency[b]	
	PPM	CPM		Attacked	Killed		PPM	CPM
*Baryscapus servadeii (*Eulophidae)[a]	x[1]	x[7,8]	wide	Egg	Egg	VI-IX	+++	+
Ooencyrtus pityocampae (Encyrtidae)[a]	x[1]	x[5,6,8]	wide	Egg	Egg	IV-VI & VII-X	++	+++
Anastatus bifasciatus (Eupelmidae)	x[1]		wide	Egg	Egg	VI & IX	+	
Trichogramma embryophagum (Trichogrammatidae)[a]	x[1]	x[5,6,8]	wide	Egg	Egg	V-VI & VII	+	+
Pediobius sp. (Eulophidae)	x[4]		limited	Egg	Egg	III & IV	+	
Eupelmus (Macroneura) seculata (Eulophidae)	x[4,7]		limited	Egg	Egg	V-VI-VII	+	
Erigorgus femorator (Ichneumonidae)	x[2,3,4,7,8]		limited	L4-L5	P	I-II-III	+++	
Apanteles vestalis (Braconidae)	x[2,3,4,5,6]		limited	L1-L2	L4-L5	IX-X-XI	+	
Habrocytus chrysos (Chalcidoidae)	x[2,3,4,6,8]		limited	L4-L5	L4-L5	IV	-	
Dibrachys lignicola (Chalcidoidae)	x[2,3,4,6,8]		limited	L4-L5	L4-L5	IV	-	
Coelichneumon rudis (Ichneumonidae)	x[4,6]		limited	P	P	V-VI	+	
Conomorium pityocampae (Pteromalidae)	x[4,6]		limited	P	P	VI-VI	+	
Diptera (Tachinid):								
Phryxe caudata (Tachinidae)[a]	x[1]		wide	L4-L5	L5 – P	IX-X et II-III-IV	+++	
Compsilura concinnata (Tachinidae)	x[1]	x[5,6,8]	limited	L3-L4	P	IV-V	++	+
Exorista segregata (Tachinidae)	x[1]	x[5,6,8]	wide	L5	P	IV	+	+
Diptera (Bombyliidae):								
Villa brunnea (Bombyliidae)	x[1]		wide	L5	P	VIII-IX	+++	

[a] Mutivoline species
[b] Effeciency: +++ (High), ++ (Medium), + (Low), - (Unknown)
Specie observed in: [1]all cedar forests, [2] Antar, [3] Theniet El Had, [4] Chréa, [5] Tala Guilef, [6] Tikjda, [7] Belezma, [8] Chélia

- ***Exorista segregata* Rondani (1859) (Diptera Tachinidae):** This specie is an endoparasitoid of CPM laval, polyphagous and polyembyonic [29]. In North Africa, it develops in the Djurdjura, in the Aures [9, 16, 19] and in the Moroccan cedar forests [24]. It is also encountered in PPM and in those of *Lymantria dispar* (Lepidoptera Lymantriidae) in all cedar forests. After a maturation period, eggs are now ready to hatch; the female lays them down by using its membranous ovipositor on the hair or tegument of the caterpillar; particularly when these are moving in the soil during the nomadic period to pupate.

  Young larvae rapidly hatch and penetrate in the main opening of their host where they develop through three stages. Worm exits the caterpillar to nature, pupae can be found underground near dead larvae.

  In laboratory, after the adult's emergence, the rest of the shell eggs is frequently found on the larval tegument. Hence, for the same parasited larval, it has been counted up to 5 eggs hatched recognizable for their white coloring, ovoid form and size of about 1mm.

  This super parasitism has already been noted on CPM [9] and on the last larval stages of *L. dispar* [30].
- ***Erigorgus femorator* Aubert (1960) (Hymenoptera Ichneumonidae):** This endoparasitoid and specialist of PPM [29] has been detected in the majority of cedar forests. A very clear sexual dimorphism easily allows

identification of male. The latest presents yellow front and clypeus while they are totally black for the female.

Females lay on caterpillar at the fourth and fifth larval stages while they are still on trees. Often by attacking them inside their nests. Larval development takes place in the pupae. Adult emergence at the end of summer but stays in quiescence in its pupae shell until the beginning of next spring. Pupae infected by this specie can be identified by a light expansion of their abdomen and by the black coloring of spaces between abdominal segments.

- ***Villa brunnea* Becker (1916) (Diptera Bombyliidae) :** This specie is a solitary and specialist endoparasitoid of pupae, it can be observed in all cedar forests in PPM only. Eco-ethology of *V. brunnea* was detailed by Du Merle in Mont-Ventoux (South of France). Among behavioral sequences studied by this author, the most important is the remarquable existence of nuptial parades of males whether it can lead or not to mating (sexual selection). Eggs hach in spring, the young larvae go for a search of a host. The later can be found either underground or at the stage of prepupal or pupal or in certain cases during the nomadic period of pupation or underground. Planidiums infest pupae by piercing their teguments. After their penetrating in the general cavity of the pupae, we observe sometimes a defense reaction of the latter by an enkystement of planitium. Before pupation, larvae of the third stage of *V. brunnea* that has now reached maturity, goes through a quiescence period of 15 to 45 days and in some cases an extended diapause of one year or even two.
- ***Coelichneumon rudis* Boyer de Fonscolombe (1847) (Hymenoptera Ichneumonidae):** A very clear sexual dismorphism can easily distinguish the male by his white color of its front and all around black antennas. While female presents a totally black front and a white median ring on antennas. The emergence of adults can be noted during May in the cedar of Chrea. This period coincides with the formation of pupae of PPM This species was encountered for the first time in Chrea cedar forest in a low incidence (5%) with respect to the one observed in Mount Ventoux [29] (more than 20%) and in South of Italy (more than 38%) [31].
- ***Conomorium pityocampae* Graham (1992) (Hymenoptera Pteromalidae):** This specie is characterized by a low incidence and a polyembryony. It was encountered in the pupae of PPM in landfill sites at Chrea, Theniet El Had and Bordj Bounaama forest cedars.

Compared complex of the natural enemies shows that the one observed for CPM is weak with five species of parasitoids. On the other hand, PPM shows 16 species of parasitoids, it comprises in general key species but is relatively poor in its specific composition with regard to the one observed in Southern Europe [11]. This concerns at least, *Meteorus versicolor* (Hymenoptera Braconidae) observed in numerous Spanish regions and in Mont-Ventoux (South of France); also the pupal parasitoid *Psychophagus omnivorus* (Hymenoptera Pteromalidae) and at least 7 Diptera species mentioned as hyperparasitoid or having an uncertain status [29].

3.2.2 Predators species

- ***Xanthandrus comtus* Harris (1780) (Diptera Syrphide):** at the end of November, Syrphide larvae were encountered in PPM nests in all cedar forests except those of the Aures. This predator normally aphidiphagous presents a certain tendency to polyphagy and even to saprophagy [32].
- ***Sphodromantis viridis* Forskal (1775):** attacks caterpillars of the first two larval stages. It was observed in low altitude biotopes in Chrea and in Tikjda near the autumnal pre-nests of PPM.
- ***Coccinella septempunctata* Linnaeus (1758):** is frequently on trees on border and often located near farm fields; consume the first larval stages of the two species in all the cedar forests.
- ***Vespa germanica* Fabricius (1793)** (Hymenoptera vespidae) consume adults occasionnally.
- ***Ephippiger ephippiger* Fiebig (1784) and *Tettigonia viridissima* Linnaeus (1758):** occasional predator of eggs.
- ***Crematogaster scutellaris* Olivier (1792) (Hymenoptera Formicidae):** larval are sometimes attacked on trees or on the soil while living adults can be eaten by colonies of *Leptothorax recedens* Nylander (1956) (Hymenoptera Formicidae) just after emergence near the pupal sites.
- ***Upupa epops* Linnaeus (1758):** predator activity of hoopoe has been observed only in the pupal sites located in open places or on borders areas of open places at the end of April and at beginning of May in Belezma and Theniet El Had. This species has been recorded as a predator of pupae in Venetian Alps (Italy), where its incidence can reach 56.5% [33].
- ***Parus major* Linnaeus (1758):** starting in January, caterpillars can be consumed by this specie in the pine and cedar forests located at North region.
- ***Cyanistes caeruleus* Linnaeus (1758):** eats young caterpillars at the end of summer, particulary those of PPM.
- The impact of predators, with 12 species for PPM and 5 for CPM seems, in general, weak with regard to the one of Southern Europe and remains to be confirmed. Larval predator species observed in resinous forests of Europe have not been encountered as were the bird *Cuculus canorus* and *Corvus pyrrhocorax* [1] and the two coleopteran Carabidae *Carabus graecus* and *Pristonychus* spp. [34]. Indirect predation was detected namely by the soil tillage by wild boars (*Sus scrofa).* As a consequence, pupaes appear on the surface and perish by desiccation under the effect of pre-summer high temperatures.

3.2.3 Main pathogenic microorganisms

- **Virus (*Smithiavirus pityocampae* and *Borrelina pityocampa),* of bacteria (genus *Clostridium*):** During the larval cycle, caterpillars can be contamined by these species especially in winter at the third and fourth larval stage. PPM caterpillar's mortality due to diseases can exceed 80% in certain ecological conditions.

Table 3: Eco-ethological data's related some predator species of PPM and CPM observed in cedar forests.

Species	Host			Host stages	Activity	
	PPM	CPM	Distribution	Attacked	period	Efficiency
Xanthandrus comtus Harr. (Dipt. Syrphide)	$x^{2,3,4,5,6}$		wide	L1, L2 & L3	IX-X-XI	medium
Scolopendra sp. (Myriapode)	$x^{2,3,4,5,6,8}$		limited	L5	IV-VII	low
Sphodromantis viridis (Mantidae)	$x^{4,6}$	$x^{5,6}$	limited	L1-L2	VIII-IX	low
Ephippiger ephippiger (Orth. Tettigoniidae)	x^{1}	$x^{2,3,4,5,6}$	wide	eggs	VI-XI	low
Tettigonia viridissima (Orth. Tettigoniidae)	x^{1}	$x^{2,3,4,5,6}$	limited	eggs	IV-XI	low
Coccinella septempunctata (L.) (Col., Coccinellidae)	x^{1}	x^{1}	wide	L1-L2	VIII-X	low
Vespa germanica (Hym., vespidae)	x^{1}	x^{1}	wide	Adult	VI-IX	low
Crematogaster scutellaris Ol. (Hym., Formicidae)	x^{1}		wide	Adult	VII-IX	low
Leptothorax recedens Nyl. (Hym., Formicidae)	x^{1}		wide	Adult	VII-IX	low
Upupa epops (L.) (Upupidae)	x^{1}		limited	Pupae	V-VI	low
Parus major terrasanctae Hart. (Paridae)	x^{1}		limited	L4 & L5	III-IV	low
Cyanistes caeruleus (L.) (Paridae)	$x^{2,3,4}$		wide	L1 to L5	VIII	medium

Specie observed in: [1]all cedar forests, [2] Antar, [3] Theniet El Had, [4] Chréa, [5] Tala Guilef, [6] Tikjda, [7] Belezma, [8] Chélia

- ***Beauveria bassiana* ([Bals-Criv.] Vuillemin, 1912):** this mycosis specie is more frequent in PPM and CPM; it is observed mainly on caterpillars during the last larval cycle and underground at the pupal stages and at an incidence that can exceed 13%.
- ***Poecilomyces fumoso-roseus (*Wize) A.H.S. Br. & G. Sm. (1957)*:** *Metarrhizium* sp. and *Verticillium* sp.: these entomomycosis have also been identified in the cedar forest of Chrea with a low incidence (between 4 and 5% in the case of PPM).
- ***Aspergillus* sp.** was found at the pupal stage and identified by the center of Laurentides Forestery (Canada) with an incidence rate of over 10% of pupae CPM affected in Belezma.

  The parasitic incidence seems for the whole guild of encountered parasitoid species and, according to many studies done in the Mediterranean Basin area that is in the optimal with regards to the one observed in southern Europe.

4. Conclusion

This knowledge permits the definition of the specific composition of the natural enemy's complex of PPM and CPM in the ecological conditions of the cedar forests of Central North Africa. Nonetheless, the weak composition of this complex results from selective pressures acting on the environment and the natural enemies' communities. Indeed, several authors reported changes and disappearance of forest landscape particularly following wildfires, the irrational exploitation of forest products, climate changes and pollution. These can have impacts on the adaptation ability and survival of certain species of the entomophagous cortege.

It is without any doubt that this study must be continued to complete list of entomophagous species of PPM/CPM complex in numerous others biotopes that are still poorly known. On a practical point of view, it seems helpful as well to coordinate these studies on a regional scale on the Mediterranean countries as to bring about the appropriate solutions in matters of natural cedar forests protection in North Africa and the Middle East and to those artificial ones newly introduced in southern Europe.

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