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Fecundity of The Pine Processionary, *Thaumetopoea Pityocampa* (Denis & Schiffermüller, 1775) In The Case Of Reforestation In Moudjbara (Djelfa - Algeria)

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Abstract

A study of the fecundity of female populations of the pine processionary in the Moudjbara reforestation indicates that there are cyclical variations in the reproduction of this species. Descriptive analysis of pine processionary oviposition lengths showed greater significance for oviposition deposited on needles than for oviposition deposited on twigs. A very highly significant difference was noted between the lengths of the egg-laying supports from the Moudjbara reforestation (p=0.0001). The 195 pine processionary oviposition sites revealed a total of 37,272 eggs, with an average of 191 eggs per oviposition site. Analysis of the variance between the various categories of eggs showed a highly significant probability (p=0.0001). Three parasitoids were identified that emerged from oviposits collected at the Moudjbara reforestation site, with rates varying from year to year. T. embryophagum was encountered only sporadically in 2018, 2019 and 2021, with respective percentages not exceeding 2%. For the four pine processionary caterpillar populations studied, B. servadeii appeared to be more abundant than O. pityocampae. The number of B. servadeii adults observed reached 83.91% in 2020. Parasitoid activity was greater on eggs located at the ends of the clutch. It also appears that O. pityocampae mainly parasitizes the upper part of the egg, whereas B. servadeii shows a preference for the lower part.

Keywords: *Pine processionary, Moudjbara reforestation, Parasitoids, Aleppo pine*

1. Introduction

In Algeria, forests of Aleppo pine (*Pinus halepensis* Mill., 1768) cover more than 850,000 hectares. This forest species is present in all bioclimatic zones, from the coast to the Saharan Atlas, and finds its optimum growth in semi-arid zones. Its great plasticity and robust temperament have made it the species of choice for reforestation projects (Mezali 2003). Among Aleppo pine attackers, the pine processionary caterpillar (*Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775), is the main defoliator of Mediterranean pines. In Algeria, this insect is present in all pine forests. Massive attacks by this defoliator appeared after major reforestation efforts in monoculture as part of the "green dam" program. This led to a demographic explosion in processionary caterpillar populations throughout its range (Bounar 2020). Its cyclical outbreaks cause substantial defoliation even in natural forests, but remain more severe in young reforestation (Battisti et al. 2014). Increases in average temperatures in recent years have led to the colonization of new areas at both altitude and latitude (Tunca et al. 2022). Based on the genetic structure of pine processionary populations, two clades have been identified in Algeria : the ENA clade and the Pityocampa clade. If we consider the map of the geographical distribution of clades drawn up by (Kerdelhué et al. 2009) and by (El Mokhefi et al. 2016), the pine processionary populations considered in the area surveyed in the pine forest of the semi-arid zone of Djelfa, belong to the pityocampa clade.

This defoliator of softwood species of the Pinus and Cedrus genera (Battisti et al. 2005) has become a biological model for many climate change research projects. Climatic differences in latitude or altitude affect the development cycle of the pine processionary (Battisti et al. 2006). Its winter larval development is particularly sensitive to temperature: the further north or the higher the altitude, the lower the average temperature. This increases the duration of pine processionary larval development and shifts the flight period. Despite the studies carried out on the biology and ecology of the species, its ecological behavior remains complex and under the aegis of various environmental variables (Alsanousi & Sheip 2022). Several works have been carried out in Algeria covering several aspects, namely systematics, ecology, damage and means of control against this insect (Alsanousi & Sheip 2022), (Amar et al. 2014), (Sebti & Chakali 2014), (Bouchou 2015), (Boudjahem & Berchi 2020), (El Mokhefi et al. 2016), (Hezil et al. 2018), (Rahim & Chakali 2022) and (Rabhi et al. 2023).

Among the natural factors, the antagonists are the embryonic chalcidian parasitoids, which often play a fundamental role in regulating pine processionary populations throughout their range. In Algeria, two parasitoids have been noted: the specialist *Baryscapus servadeii* (Domenichini 1965) (Chalcidian: Eulophidae) and the generalist *Ooencyrtus pityocampae* (Mercet 1921) (Chalcidian: Encyrtidae).

Little is known about female fecundity in pine reforestation, as in the case of the Green Dam, and this remains the determining factor in infestation status and temporal evolution. Investigation over several successive years provides information on the gradation of the pest and the activity and occupancy strategy of embryonic parasitoids.

In this study, particular attention was paid to the morpho-biometry of the clutches and the quantitative estimation of the total number of eggs present in a clutch, in order to highlight the dynamic potential of the fecundity of the females evolving in the reforestation. On the other hand, we determined the rate of embryonic parasitism and their oviposition frequencies on the surface of the clutches.

2. Materials And Methods

Study Site

The biological material considered was collected in the Moudjebara reforestation site, part of the Green Dam project (34° 38' N. ; 3° 19' E.). The total surface area of the site is 13,000 ha. This reforestation is located at an altitude of 1193 m. Planting density is 2,000 plants/ha, with a conventional row layout. Tree heights range from 1.70 to 5.30 m.

Collection and Preparation Of Biological Material

During the summer months, when pine processionary eggs are released, batches of eggs are collected. The eggs are deposited around two needles gathered in a sleeve on the crown of the tree. The biological material considered comes from four generations of pine processionary caterpillars. Eggs were collected during the summer period from 2018 to 2021. As far as possible, the same collection period was maintained throughout the years. Collected eggs were measured and stored separately in numbered glass tubes (1.5 cm in diameter and 7.5 cm long), blocked with cotton to ensure adequate aeration. Once the caterpillars and parasitoids had emerged, the protective scales were manually removed with adhesive tape, and the eggs were counted and analyzed under a binocular magnifying glass. The four-year investigation provides information on the temporal evolution of active parasitoids. Eggs were divided into three parts using a marker : upper, middle and basal, in order to determine the distribution pattern of parasitoids. The upper part of the egg mass considered is the location towards the top of the branch. Egg categories were classified as hatched, unhatched, sterile or parasitized.

Data Analysis

The main aim of descriptive statistics is to present observed data in such a way that it can be easily understood. This analysis involved calculating averages, standard deviations and coefficients of variation. These were carried out using Statgraphic software. The ANOVA test is designed to test for significant differences between means. One-factor analyses were carried out to test the effect of a controlled factor with modalities on the means of a quantitative variable. This analysis was applied to measurements of clutch length and egg count. One-way comparison of means analyses were carried out to test the difference between the fertility of female pine processionaries. The LSD (Least Significant Difference) test was used to compare the means of homogeneous groups. A descriptive model of the relationship using a linear fit was carried out for the number of eggs and the length of clutches, as well as their diameter and the number of rows in which they are deposited.

3. Results and Discussion

Descriptive analysis

The results of oviposition measurements and egg counts for the four generations are shown in Table 1. All the variables considered showed statistically significant differences between the four generations, except for the number of eggs deposited on the twigs, where there was no significant difference between the generations considered.

A total 195 egg batches of processionary moth *Thaumetopoea pityocampa* (Denis & Schiff ermuller, 1775) produced 37,272 eggs in all categories, representing an average of 191/per female.

Table 1. Descriptive statistics related to twigs, batches, and eggs categories, and the corresponding statistical significance between sites.

Years Categories /Average	2018	2019	2020	2021
Sample sizes	50	58	42	45
Batche length Needles (mm)	26,54± 5,46	27,16± 5,46	23,83± 3,40	22,55± 3,59
	(16,27- 42,49)	(16,27- 42,49)	(18,71- 30,01)	(16,57- 30,09)
Batche length Twigs (mm)		21,77± 3,67	17,70± 1,64	18,55± 2,43
	-	(15,92- 29,03)	(14,04- 20,04)	(14,89- 22,62)
Twig diameter (mm)	(2,91± 0,38)	(3,27 ± 0,66)	(3,72± 0,69)	(3,09± 0,89)
	(2,47- 4,16)	(2,18- 4,93)	(2,52- 4,68)	(2,13- 5,89)
Rows/batch	6,68± 0,98	8,93± 1,72	9,66± 2,05	8,8± 2,64
	(6,0- 9,0)	(6,0- 13,0)	(6,0- 13,0)	(6,0- 17,0)
Total eggs Needles ***	189,26 ± 51,72	206,47+ 44,29	210,0+ 20,83	159,88+ 28,88
	(120,0-300,0)	(135- 296)	(169-245)	(105-225)
Total eggs Twigs	-	196,2+ 20,25	191,25+ 22,83	184,75+ 29,70
		(165-230)	(125-234)	(142- 245)
Hatched eggs***	167,04 ± 52,67	166,70 ± 33,24	152,11 ± 42,43	120,8 ± 52,90
	(89,0- 286,0)	(104,0-246,0)	(9,0- 218,0)	(0,0- 199,0)
Non hatched eggs***	11,66± 11,25	22,37± 16,81	40,11± 36,66	37,4± 39,53
	(0,0- 65,0)	(0,0- 88,0)	(1,0- 182,0)	(6,0- 150,0)
Parasitized eggs***	9,08 ± 9,09	8,54± 8,82	2,07 ± 3,17	6,2 ± 6,62
	(0,0- 33,0)	(0,0- 36,0)	(0,0- 13,0)	(0,0- 24,0)
Sterile eggs**	1,48 +2,85	5,15 + 8,08	4,38 + 5,72	6,53 + 9,75
	(0,0- 13,0)	(0,0- 26,0)	(0,0- 22,0)	(0,0- 53,0)
Eggs parasitized by*** *O. pityocampa*	1,62± 2,27	1,94 ± 2,33	0,33 ± 0,87	1,31 ± 1,57
	(0,0- 12,0)	(0,0- 10,0)	(0,0- 5,0)	(0,0- 7,0)
Eggs parasitized by*** *B. servadeii*	7,34 ± 7,93	6,32 ± 7,43	1,73 ± 2,87	4,77 ± 5,33
	(0,0- 27,0)	(0,0- 32,0)	(0,0- 10,0)	(0,0- 20,0)
Eggs parasitized by * *T. embryophagum*	0,12 + 0,38	0,27+ 0,58	0,0+ 0,00	0,11+ 0,43
	(0,0- 2,0)	(0,0- 2,0)	(0,0- 0,0)	(0,0- 2,0)

* $p < 0.01$; ** $p < 0.005$; *** $p < 0.0001$

To assess female fecundity, we separated the oviposition samples into two batches, those deposited on needles and those deposited on twigs.

For eggs laid on needles, egg quantification revealed variable fecundities ranging from 189 in 2018 to 210 eggs per clutch in 2020, with this variation pointing in the direction of population growth from one year to the next (F test ; p = 0.0001), except in 2021, when we noted that this growth was slowed (160). This may be due to a number of factors, including the possibility of a decline in pest populations following defoliation in the previous year (2020). On the other hand, this decrease coincides with an increase in the number of eggs laid on twigs in 2021 (184) (Figure 1). The choice of twigs for egg deposition is undoubtedly linked to the intensity of defoliation in previous winters, as females are no longer able to find an ideal needle support and end up opting for twigs. Over time, females tend to seek out young twigs that are suitable for laying their eggs. The morpho-biometric characteristics of the needles in reforested trees do not offer favorable conditions for egg-laying females. A temporal evolutionary strategy is pursued by the population, with females searching for other egg-laying sites, at the same time confirming the dynamic potential of fecundity of females evolving in the reforestation. This also partly explains the reproductive capacities favored by the opportunities for partners to meet (Delorme et al. 2013). Analysis of the data collected on the fertility of females on Aleppo pine at Moudjbara confirmed the correlation mentioned by (Démolin 1969b), who noted that the demands on the support are less and less as the "impulse" to egg emission becomes stronger. This impulse may be due to the filling of the spermatheca. Furthermore, according to this author, needle diameter must be between 1.6 and 2 mm to enable females to lay eggs without constraint. (Tilman 1980) mentioned that the female chooses the egg-laying site that can maximize the survival of her offspring due to a sufficient quantity of available resources. In the same vein, (Ayache et al. 2021) noted that in the Ouled Yagoub cedars and in Chréa, females have the ability to cling to thick twigs to lay their eggs and to maintain themselves easily on thicker branches. (Battisti 1988) found that the evolution of caterpillars in a black pine reforestation by the previous generation was slowed by energy deficits in the latter. According to (Zamoum 1998), the abundance of egg-laying on twigs at Moudjbara could provide an indication of the history of *T. pityocumpa* attacks (variation in the physical quality of needles). For all three (03) years from 2018 to 2020, the average number of eggs per clutch observed at Moudjbara (202) is significantly higher than that already observed by (Bouchou and Chakalı 2014), 129 and 143 eggs per clutch respectively in 2011 and 2012 at the same site, in Meftah (Algiers) (169), in Bou-saada (176) (Zamoum & Dahman 2007). (Zamoum 1998) found that the average number of eggs per clutch at Moudjbara was 126. In France (Géri 1980) observed that this average is around 200 eggs for Corsican populations. (Ayache et al. 2021) noted that the average number of eggs/lot in the Ouled Yagoub site (184 eggs) in Chréa (151). (Demolin 1970) estimated that under favorable conditions for caterpillar development, potentilla fecundity would be 340 eggs. The number of eggs per batch corresponds to the fertility of a female as described by (Mirchev & Tsankov 2005). Studies carried out by (Parker & Begon 1986), (Tiberi et al. 1999) have shown that the quality and quantity of resources available in the host plant are determining ecological factors influencing the egg productivity of *T. pityocampa*. (Démolin 1969a) also noted that population fluctuation is linked to various factors, including climate, altitude, feeding and antagonists. (Tilman 1980) mentioned that the female chooses the egg-laying site that can maximize the survival of her offspring due to a sufficient quantity of available resources.

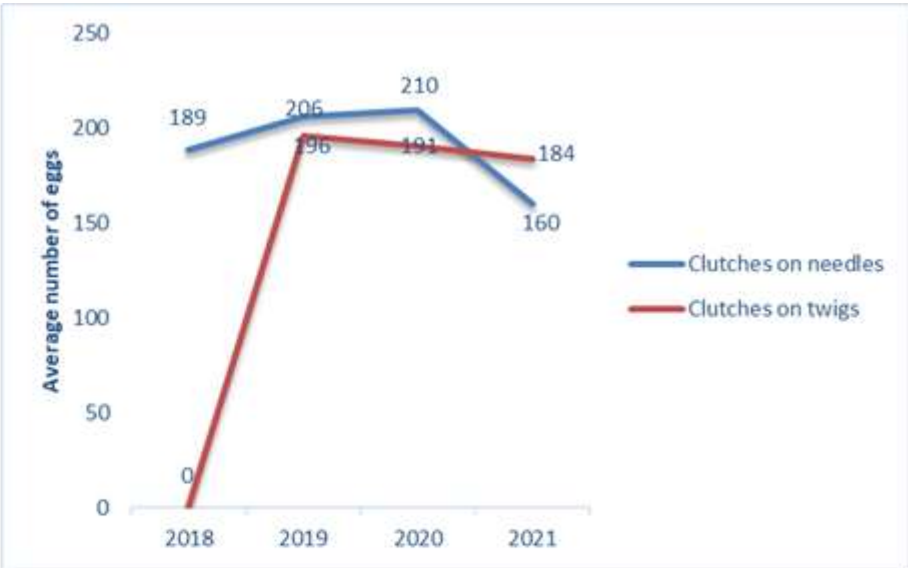

Figure 1 : Change from 2018 to 2021 in the average number of eggs per clutch in the study plot.

Based on egg counts per clutch, we investigated whether there was a relationship between sleeve length and the number of eggs in the sleeve. The number of rows observed is generally between 6 and 9 in the case of layings on needles, and between 10 and 17 for layings on twigs. The average length of eggs laid on needles was 26.54 mm in 2018, 27.16 mm in 2019, 23.83 mm in 2020 and 22.55 mm in 2021. For oviposition on twigs, the average length was 22 mm in 2019 and 18 mm in 2020 and 2021. Using the LSD test, 2 homogeneous groups were specifically identified, with pairs of groups differing from each other in terms of averages. The correlation coefficients between the two parameters are significant. The coefficients of determination (R^2) show that egg-laying length better explains the number of eggs for needle-laying than for twig-laying (respectively 80 - 93% and 62 - 76% of the variation is explained) (Figure 2). Similarly, (Zamoum 1998) noted that there was a relationship between needle and twig lengths and egg numbers, with highly significant correlation coefficients. In this respect, (Ayache et al. 2021) has shown that females have a specific ability to correlate egg-laying and needle lengths, to choose the part to lay on and even to control the number of eggs laid. This insect can be more selective within the same host, and it has been observed that there is a selectivity of needles from the same tree, with long needles being the most sought-after by pine processionary females, particularly as they offer a comfortable length for depositing eggs easily.

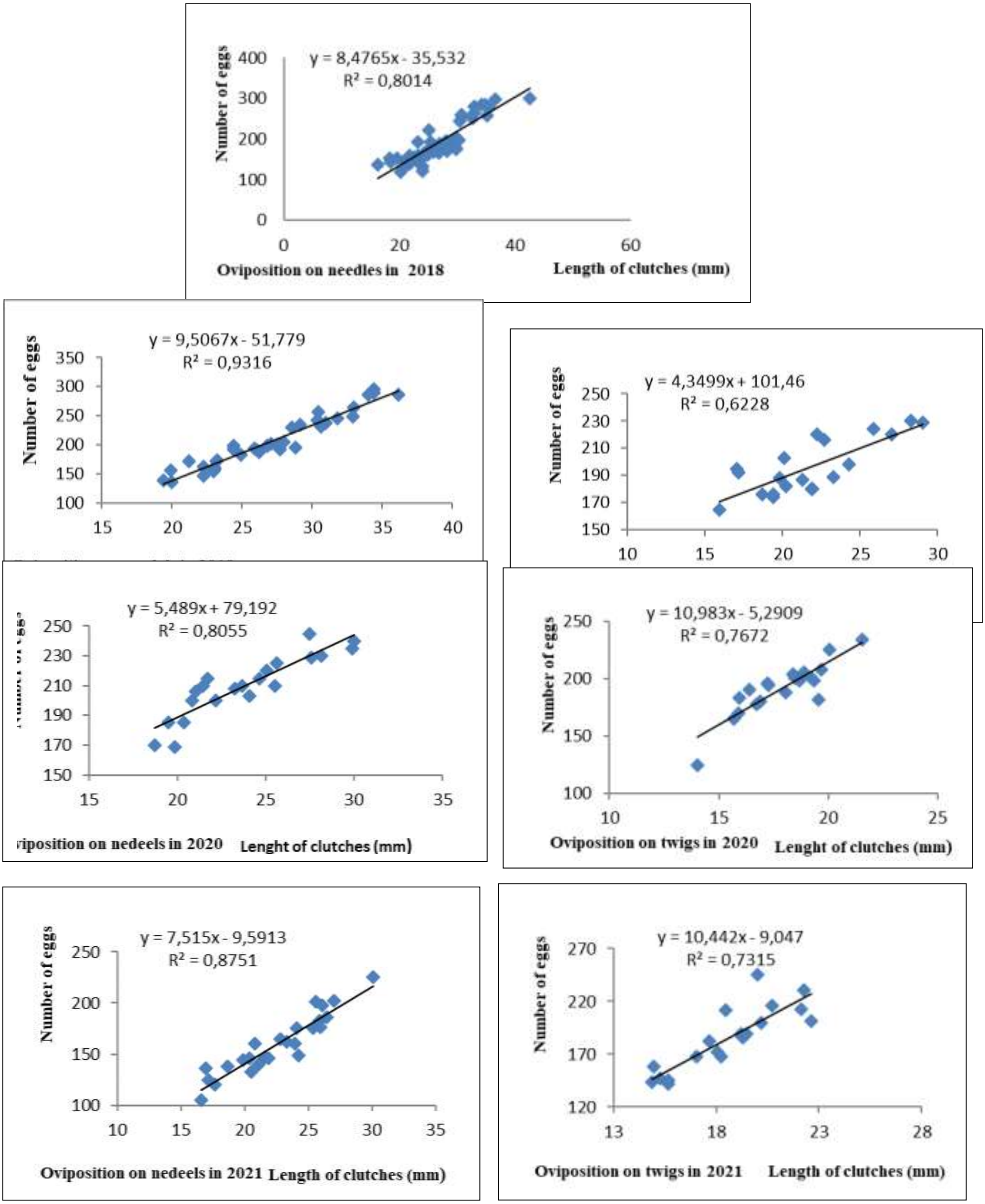

Figure 2 : Relationship between number of eggs per oviposition and oviposition length (in mm), in relation to oviposition medium in 2018, 2019, 2020 and 2021.

The number of eggs hatched in the reforestation is decreasing over the four years of study, with the number of eggs falling from 167 in 2018 to 120 in 2021. This represents a decrease of around 28%. On the same subject (Tsankov et al. 2006) in their study of pine processionary parasitoids shows an egg hatching rate of 76.1%. (Sebti 2011), notes that the number of hatched eggs is very high in Chréa, at 89.64%. Unhatched eggs do not exceed 6.16%. According to the same author, the causes are attributable to failure of embryonic development, emergence or parasites.

At the same time, the increase in egg mortality from 6.16% in 2018 to 21.88% in 2021 is significant. Factors such as temperature can influence this variation, as the hatching rate is mainly affected by natural mortality in the embryonic stage under climatic variations, particularly the temperature factor. A high frequency of temperatures above 28° C during egg development can cause embryo mortality (Roques et al. 2014). Also, according to (Demolin & Millet 1981), clutches that have not hatched are due to the late flight of the population, which takes place after July and does not produce offspring. We also noted a 3.82% egg mortality rate (sterile eggs) in 2021, compared with 0.78% in 2018. For certain categories of eggs, egg mortality and sterile eggs, where no caterpillars emerge, the causes have not been established. These are dead caterpillars, empty eggs and sterile eggs. (Mirchev et al. 2012) have noted that in high populations in outbreak phase, the possibility of mating is limited and may result in sterile egg-laying. Parasitoids are the most important biological factor affecting hatching success (Mills 1995). Collecting batches of eggs at altitude often results in unfertile eggs, according to (Démolin 1969b). The presence of non-emerged dead caterpillars is reported in similar studies carried out in different parts of the pine processionary caterpillar zone, their share being around 2.0 to 3.0% (Mirchev & Tsankov 2005), but there are also cases at sites in Turkey, where they reach up to 10.0% (Mirchev et al. 2004). In samples of *Thaumetopoea pinivora* (Treitschke, 1834) from the Baltic Sea, almost 100% of dead caterpillars have been found (Tsankov et al. 1996). Insignificant numbers of empty eggs were found in samples from Greece (Bellin et al. 1990), Morocco (Schmidt et al. 1997) and Portugal (Pimentel et al. 2006). The proportions of unfertilized sterile eggs are significantly higher. There is a report from the Marikostinovo region, Bulgaria, where in samples from several years they reach up to 30.0%, and in individual batches up to 100% (Tsankov et al. 1998).

The number of parasitized eggs varies on average from 9.08 ± 9.09 in 2018, i.e. a rate of 4.80%, to 2.07 ± 3.17 parasitized eggs in 2020, i.e. a rate of 1.04%. In 2021, the number of parasitized eggs is 6.2 ± 6.62, i.e. a rate of 3.63%. A decrease in the rate of parasitism in 2020, followed by an increase in 2021, could indicate fluctuations in the natural regulation of this insect population. The rate of parasitism noted in the surveyed environment remains relatively low overall, even if there are variations from one year to the next during the four years of study. The same result was found in 2011 and 2012 in the Moudjbara reforestation, the parasitism rate is very low not exceeding 4% (Bouchou & Chakalı 2014). In Bulgaria, the rate of parasitism observed in the pine processionary varies from 19.3% to 38.9% (Tsankov et al. 1998). In Italy, depending on the region, the rate of parasitism has been noted at between 6% and 30% (Tiberi 1990) and in the Iberian Peninsula, between 11.3 and 31.7% parasitism has been observed (Schmidt et al. 1999). Parasitoids are the most important biological factor affecting hatching success (DeBach & Rosen 1991) ; (Wajnberg & Hassan 1994).

Impact of pine processionary parasitoids

The biological material observed revealed the embryonic entomological diversity of three chalcidian Hymenoptera. *Baryscapus servadeii* (Domenichini, 1966) *Ooencyrtus pityocampae* (Mercet, 1921) and *Trichogramma embryophagum* (Hartig, 1838).

The three parasitoids identified emerged from oviposits collected in the reforested Moudjbara site at varying rates from year to year. *T. embryophagum* was encountered only sporadically in 2018, 2019 and 2021, with respective percentages not exceeding 2%. These active parasitoids are found on practically all egg-laying sites, but at very low percentages, not exceeding 3%. For the four (04) pine processionary caterpillar populations studied, *B. servadeii* appears to be more abundant than *O. pityocampae*. The number of *B. servadeii* adults observed reached 83.91% in 2020. Existing studies on the parasitoids of the studies have always highlighted the predominance of two parasitoid species, the specialist *Baryscapus servadeii* and the generalist *Ooencyrtus pityocampae*, with proportions varying from region to region. Studies carried out in Bulgaria and Italy revealed a higher percentage of *O. pityocampae* than of *B. servadeii* (Tiberi 1990); (Tsankov et al. 1996). In Algeria and Marcoc, *B. servadeii* is more abundant than *O. pityocampae* (Schmidt et al. 1997) ; (Tsankov et al. 1995). In Greece, *B. servadeii* is most abundant in the north, while *B. servadeii* and *O. pityocampae* are equally abundant in the south (Bellin et al. 1990). It is important to note that *Baryscapus servadeii* is the specific host of the processionary moth, *T.pityocampa* (Gachi et al. 1994). *O. pityocampae* is characterized by polyphagy of lepidopteran species (Tiberi et al. 1999).

A comparable specific diversity of embryonic parasitoids has been noted in various species of the Thaumetopoea genus such as *T. bonjeani* (Powell, 1922) in Algeria (Rahim et al. 2016) and T. pinivora (Treitschke, 1834) in Spain (Battisti et al. 2014). (Mirchev & Tsankov 2005) in the pine forests of Greece, (Penpoul & Laplace 2017) in the pine forests of Tuscany in Italy have identified the species *Baryscapus transversalis*, *Anastatus bifasciatus* (Geoffroy, 1785) and *Pediobius bruchicida* (Rondani,

1872) In addition, the species *Ooencyrtus telenomicida* (Vassiliev, 1904) has been observed on batches of eggs collected in the pine forests of southern Italy (Tiberi 1990). (Arnaldo & Torres 2006) in the pine forests of northern Portugal reported that the two parasitoids mentioned above emerge in two periods, the first in autumn of the same year during the oviposition period, and the second in spring of the year following a winter diapause.

According to (Tiberi 1990), in Italy, *B. servadeii* is higher in the warmer central and southern regions of the country, but has not been found in Sicily and in the low-altitude pine forests of Abruzzo. (Mirchev et al. 2012) noted that *B. servadeii*, the specific parasitoid of the egg pine processionary, is best adapted and *O. pityocampae* is sensitive to increases in air temperature above certain limits. (Masutti 1964) stresses that temperature is the limiting factor, with temperatures above 30 °C making it more difficult for *O. pityocampae* to develop. The aforementioned author notes that *Baryscapus servadeii* had the ability to slip between the protective scales to reach the eggs. Similarly, (Biliotti 1958) considers that the presence of scales is an obstacle for *O. pityocampae*, and that most scales are absent at the ends of the clutches. (Mirchev & Tsankov 2005) note that if, for some reason, the covering scales are absent, this occurs mainly in the upper part, this probably being due to some disturbance of the female butterfly or insufficient conglutination. An absence of *B. servadeii* in the eggs of *Traumatocampa. ispartaensis* has been noted in Turkey (Avcı 2003). Under laboratory conditions, the appearance of *B. servadeii* begins well before the egg-laying period of *T. pityocampa* late phrenological ("winter") form (Tsankov et al. 1996).

Our investigations have shown that parasitoid activity is highest on eggs at the ends of the clutch (Figure 3). The highest percentage of oviposition observed for both ends (1/3 and 3/3) represent 89.87% in 2018. For the middle parts of the clutch (2/3), the maximum was observed in 2020 with a rate of 26.31%. The results obtained by (Mirchev et al. 2012) showed that the upper parts were the most sought-after by parasitoids.

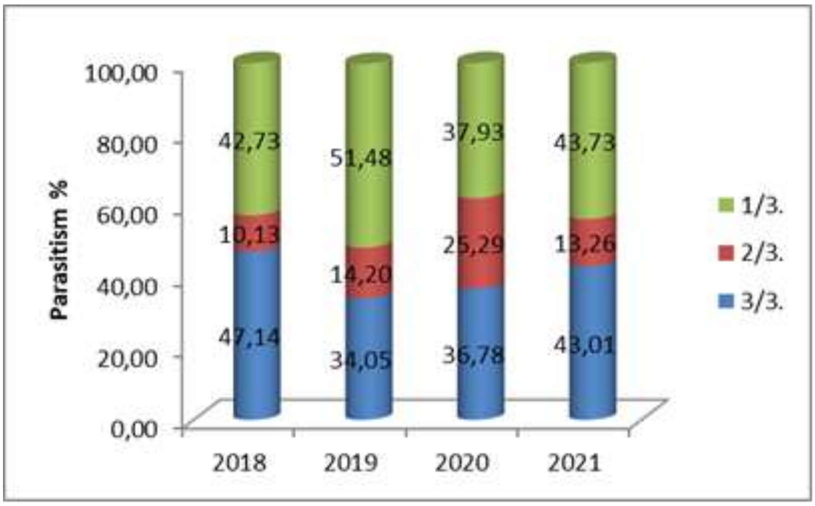

Figure 3 : Parasitoid oviposition frequencies on egg-laying surfaces

It also appears that *O. pityocampae* mainly parasitizes the upper part of the clutch, while *B. servadeii* shows a preference for the lower part (Figure 4 and 5).

In the literature, there are conflicting reports on the location of eggs parasitized by the various parasites Tiberi (1978) found that *O. pityocampae* is more often found in the basal part of batches, while *B. servadeii* prefers the upper parts, but the results obtained by (Kitt & Schmidt 1993) show that *O. pityocampae* mainly parasitizes the apical part of the clutch, while B. servadeii shows a preference for the basal part.

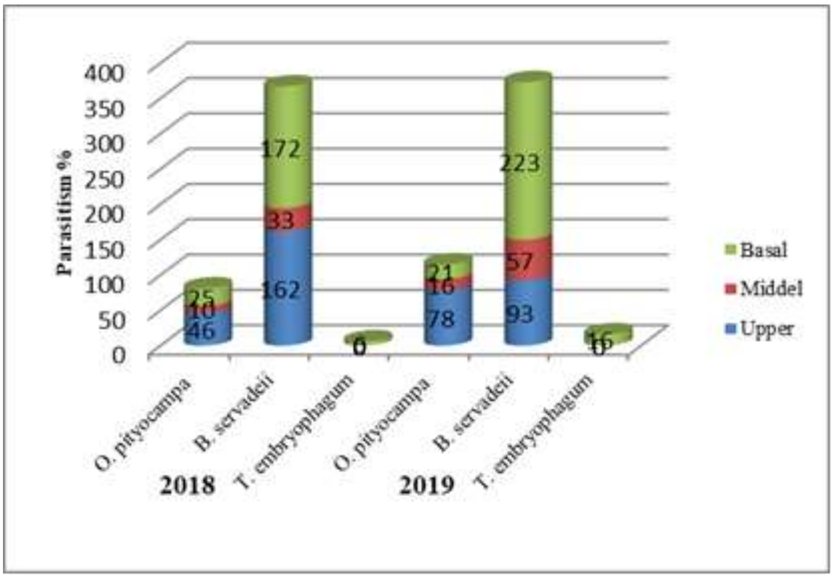

Figure 4 : Distribution of parasitoids on the egg-batch surface 2018- 2019.

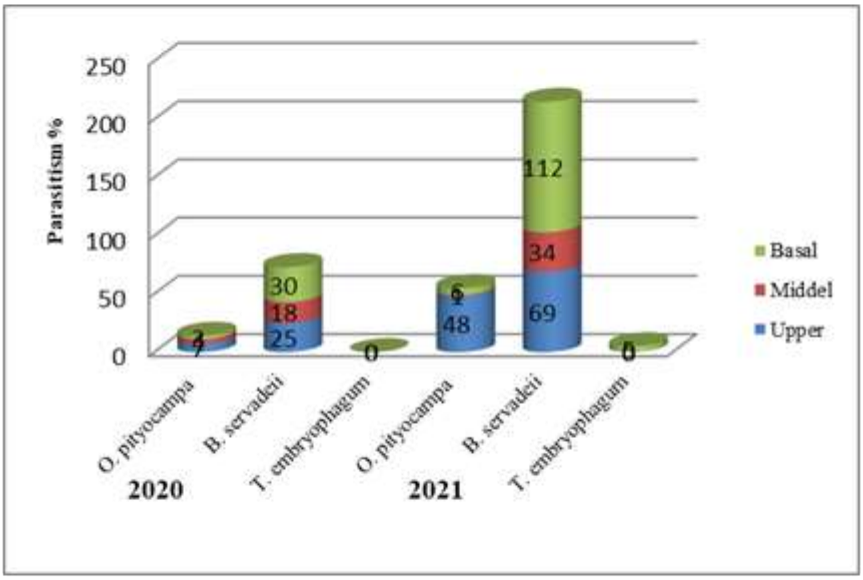

Figure 5 : Distribution of parasitoids on the egg-batch surface 2020 - 2021.

4. Conclusion

The pine processionary, *Thaumetopoea pityocampa* (Lep., Thaumetopoeidae), a defoliator of softwood species throughout the Mediterranean basin, has been in a permanent state of culmination for over a decade in the *Pinus halepensis* Mill. Reforestation of the "green dam" in Algeria. Analysis of pine processionary eggs from the semi- arid zone has revealed the dynamic fecundity potential of females in the Moudjbara reforestation.

In all, 195 pines processionary clutches produced a total of 37,272 eggs in all categories, representing an average of 191/per female. The pine processionary generally deposits its eggs in two main locations, on pine needles and on twigs. This difference in egg-laying sites may have implications for the development of the larvae and their impact on the trees. Analysis of egg-laying material shows an increase in fecundity on needles for three consecutive years, followed by a decrease the following year (2021), suggesting cyclical variations in pine processionary reproduction. These results may be linked to environmental factors, resource cycles or long-term population adaptations. The decline in fecundity on needles in 2021 coincides with an increase in the number of eggs laid on twigs in 2021. Females' choice of twigs for egg deposition may be influenced by the intensity of defoliation in previous winters, since if they can't find a needle, they opt for twigs. This illustrates how female pine processionaries can adapt to changing environmental conditions to ensure the survival of their offspring. Further studies on the structure and chemical/biochemical composition of egg-laying materials may provide more information on the choice of sites sought by females.

In this study, descriptive analysis of pine processionary egg-laying lengths showed greater significance for needle-laying than for twig-laying. To obtain more reliable results, we compared the means using ANOVA. A highly significant difference was noted between the lengths of egg-laying supports from the Moudjbara reforestation (p=0.0001). Regression analysis indicates that sleeve length has a better explanatory capacity for the number of eggs in the case of oviposition on needles than on twigs. This suggests that the length of layings on needles is more strongly correlated with the number of eggs.

in relation to egg-laying on twigs. This information could be useful for processionary research and management.

The decrease in the number of eggs hatched by the pine processionary from 2018 to 2021 is important information for the preservation of the forest ecosystem. It is likely that control or management measures have been put in place to reduce this insect pest population. Preserving the growth of young trees in reforestation areas is crucial, and this reduction is positive from a forest management point of view.

The increase in egg mortality from 6.16% in 2018 to 21.88% in 2021 is cause for concern. Factors such as temperature may influence this variation. It would be important to continue monitoring and examining the consequences of this mortality to understand the impact on the ecosystem and the pine processionary population.

For some egg categories, egg mortality and sterile eggs, where no caterpillars emerge, the causes have not been established. This indicates that there are still unknown aspects or unidentified factors affecting these egg categories. This underlines the need for further research to understand the reasons for these problems and to put in place appropriate management measures.

The decrease in hatched pine processionary eggs and increase in egg mortality observed over the four years of study, with a very low percentage of parasitism not exceeding 3%, implies that pine processionary infestation is low over this period.

An embryonic entomological diversity of three chalcidian Hymenoptera has been identified. *Baryscapus servadeii*, *Ooencyrtus pityocampae* and *Trichogramma embryophagum*.

The three parasitoids identified emerged from oviposits collected in the reforested Moudjbara site at varying rates from year to year. *T. embryophagum* was encountered only sporadically in 2018, 2019 and 2021, with respective percentages not exceeding 2%. These active parasitoids are found on practically all egg-laying sites, but at very low percentages, not exceeding 3%. For the four (04) pine processionary caterpillar populations studied, *B. servadeii* appears to be more abundant than *O. pityocampae*. The number of *B. servadeii* adults observed reached 83.91% in 2020. The investigation revealed that parasitoid activity is most pronounced on eggs located at the ends of the clutch. It also appears that *O. pityocampae* mainly parasitizes the upper part of the egg, while *B. servadeii* shows a preference for the lower part. These observations demonstrate the complexity of interactions between species and their role in regulating insect populations.

Finally, the results of this study lead us to give some recommendations to forest managers in Djelfa to ensure that the infestation remains under control and to take preventive measures if necessary to avoid a future increase, particularly in Moudjbara. First of all, it should be pointed out that protection against this pest can only be effective through the use of an integrated control strategy which, depending on the situation, requires different forms of intervention. Biological control techniques involving the use of beneficials can have a profound but not radical effect on populations. In the case of Moudjbara, we think it would be very useful to reinforce the action of the ooparasitoids with an inoculative release.

Abbreviations

ENA clade: Eastern North Africa clade.

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