International Journal of Entomology Research
www.entomologyjournals.com
E-ISSN: 2455-4758
Received: 05-10-2026, Accepted: 04-11-2026, Published: 19-11-2026
Volume 11, Issue 4, 2026, Page No. 274-285

Insights into the seasonal incidence, biology, behaviour and damage caused by the pine processionary moth, *Thaumetopoea pityocampa*, on Aleppo pine in Southern France

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DOI: https://doi.org/10.66856/ijer.2026.11.4.11402

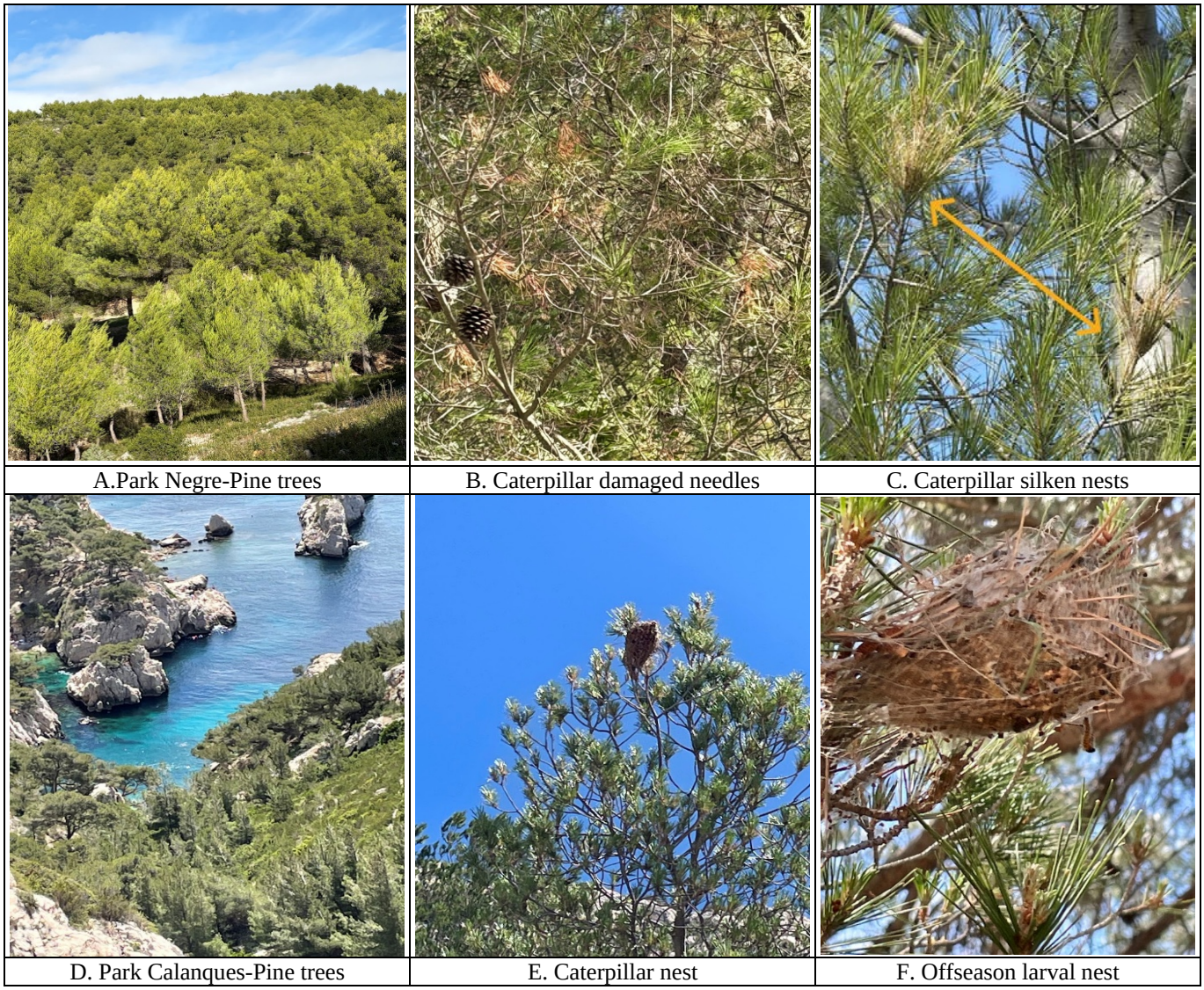
Abstract
The pine processionary moth, *Thaumetopoea pityocampa* (Denis & Schiffermüller) (Notodontidae: Lepidoptera), is an important defoliating pest of coniferous trees, particularly pines, in the Mediterranean region. Its larvae exhibit characteristic gregarious behaviour, communal silk-nest formation and processionary movements during their development. Observations on the seasonal incidence, biology, larval behaviour, nest formation, winter nest orientation and feeding damage were conducted on Aleppo pine, *Pinus halepensis*, in the 10th, 11th and 12th arrondissements of Marseille, Southern France, during 2024–2026. Fifteen trees distributed across three locations were selected for regular observations. The life cycle was completed in one generation annually, with adult emergence and oviposition occurring from the third week of August to the third week of September. Eggs hatched after approximately 28–46 days, and the larvae developed through five instars from September onwards, remaining active during autumn and winter. Larval aggregations progressively constructed communal silken shelters, which developed into permanent winter nests during the fourth and fifth instars. These nests were predominantly situated on southeastern to southern-facing branches (150–175°), apparently favouring solar exposure and larval thermoregulation. Feeding activity intensified during January and early February, resulting in considerable needle consumption and, in some instances, almost complete defoliation of individual branches. Mature fifth-instar larvae descended from host trees in characteristic head-to-tail processions from the first week of February to the first week of March to pupate in the soil. The pupal stage persisted until adult emergence in August. The observations provide insights into the seasonal development, behavioural adaptations, shelter construction and damage potential of *T. pityocampa* under the Mediterranean climatic conditions of Marseille. The findings also highlight the importance of winter nest characteristics and processionary movements in understanding the ecology and seasonal management of this pest.

Keywords: Aleppo pine, biological observations, defoliation, larval instars, Mediterranean climate, Pine Processionary Moth, processionary behaviour, winter nests

Introduction

The pine processionary moth, *Thaumetopoea pityocampa* (Denis & Schiffermüller) (Notodontidae: Lepidoptera), is an important defoliating pest of pine trees in Europe, Asia and North Africa. Its distribution includes several Mediterranean countries, including France, Germany, Italy, Spain, Israel, Lebanon, Syria and Turkey (Stastny *et al*., 2006; Mirchev *et al*., 2007) [30,20]. The larvae feed gregariously on pine needles, causing partial to severe defoliation, particularly during winter and early spring (Hódar *et al*., 2003; Kerdelhué *et al*., 2009) [12,17]. Besides pines, the insect also attacks other conifers, including cedars (Pimentel *et al*., 2006) [23].

Several pine species serve as important hosts, including *Pinus brutia* (Calabrian pine), *P. halepensis* (Aleppo pine), *P. mugo* (mountain pine), *P. nigra* (black pine), *P. pinaster* (maritime pine) and *P. sylvestris* (Scots pine) (Devkota and Schmidt, 1990; Hódar *et al*., 2002; Ferracini *et al*., 2020) [9,13,10]. In France, maritime pine (*P. pinaster*) and stone pine (*P. pinea*) are important hosts, while Aleppo pine (*P. halepensis*) is also widely distributed and frequently attacked by this defoliator (Masutti and Battisti, 1990; Sebti and Chakali, 2014) [19,29]. Apart from its phytophagous activity, *T. pityocampa* is of considerable medical and veterinary importance because its urticating hairs can cause skin irritation and allergic reactions in humans and domestic animals, particularly dogs (Battisti *et al*., 2005; Kaszaki *et al*., 2015) [3,16]. The silken nests constructed by the larvae also provide shelter to numerous other arthropods. Abandoned nests have been reported to harbour more than 60 species of spiders and insects during the off-season (Branco *et al*., 2008) [5]. During visits to two forest parks in Marseille in 2024, considerable larval infestation, characteristic silken nests and feeding damage were observed on Aleppo pine trees (Fig. 1, A–F). The first site, Parc Départemental de la Nègre, is situated on the lower southern slopes of the Massif de l'Étoile, at elevations ranging approximately from 280 to 650 m.



A.Park Negre-Pine trees | B. Caterpillar damaged needles | C. Caterpillar silken nests

D. Park Calanques-Pine trees | E. Caterpillar nest | F. Offseason larval nest

Fig 1: Allepo-pine plantations in two national parks (A and D) infested by processionary caterpillar in Marseille, France

The second site, Parc national des Calanques, extends across the 8th, 9th and 11th arrondissements of southern Marseille, with elevations reaching approximately 366–646 m. Aleppo pine is the predominant pine species in the Aix-Marseille-Provence region and is an important host of the processionary moth. Previous studies have indicated that younger pine trees are particularly susceptible to infestation, especially at lower elevations (Huchon and Démolin, 1970; Martin *et al*., 2021[14,18]. Considering the abundance of Aleppo pine in the 10th, 11th and 12th arrondissements of Marseille, situated at relatively low elevations of approximately 24–89 m above the Marseille Marégraphe reference level, observations were undertaken to investigate different aspects of the insect's biology and ecology.

The study focused particularly on seasonal incidence, oviposition, egg incubation, larval development, processionary behaviour, nest formation and expansion, winter nest orientation, pupation and associated feeding damage. The observations were intended to provide a better understanding of the seasonal biology and behavioural adaptations of *T. pityocampa* on Aleppo pine under the Mediterranean climatic conditions of Marseille.

Materials and Methods

Observations on the pine processionary moth, *Thaumetopoea pityocampa*, were conducted on Aleppo pine (*Pinus halepensis*) during 2024, 2025 and 2026 in three locations situated in the 10th, 11th and 12th arrondissements of Marseille, Southern France. Five trees at each location, comprising a total of 15 selected trees, were earmarked for regular observations. Relatively young and moderately tall trees, approximately 30–50 ft in height, were preferred to facilitate examination of larval development, nest formation and feeding damage.

The selected locations lie in the eastern and southeastern parts of Marseille, where the coastal limestone landscape gradually transitions into inland massifs and valley parks supporting extensive stands of Aleppo pine. Observations included egg-laying patterns, egg-cluster characteristics, incubation and hatching, early larval feeding, larval aggregation, silk production, nest construction and expansion, development of winter shelters, feeding damage and processionary movements towards pupation sites. The orientation and location of permanent winter larval nests on the earmarked trees were ascertained with the help of iPhone-12 Compass.

At least ten egg clusters were considered for observations on egg development and hatching. Larval activities were monitored from the egg-laying period in August through the processionary descent during February and early March. Particular attention was given to the formation and enlargement of communal silken nests, changes in larval colour and size, feeding behaviour and the development of urticating hairs.

Observations were routinely made between 9:00 and 11:30 AM, twice weekly during the egg-laying and hatching periods in August and September. Thereafter, observations were conducted weekly until the end of January and twice weekly during February to monitor the final larval instar and processionary movements. Additional vigilance was maintained from March to July to detect any above-ground activity during the pupal diapause period. The developmental stages and associated biological activities were examined in relation to monthly and weekly minimum and maximum temperatures and daylength recorded for Marseille. Weather observations were obtained from the Marseille meteorological station situated at approximately 6 m elevation. The recorded climatic parameters were compared with the observed seasonal occurrence of eggs, larvae, pupae and adult moths.

Results and Discussion

Seasonal incidence and life cycle: The seasonal occurrence of *Thaumetopoea pityocampa* in Marseille, in relation to monthly and weekly variations in minimum and maximum temperatures and daylength, is presented in Table 1 and Fig. 2. The insect completed its life cycle through four developmental stages: egg, larva, pupa and adult moth. Adult emergence and oviposition occurred from the third week of August to the third week of September. Eggs subsequently hatched from the third week of September onwards, with hatching extending into October. The larvae remained active on pine trees throughout autumn and winter, undergoing five successive instars before descending to the ground for pupation from the first week of February to the first week of March. The pupal stage continued underground until adult emergence during August and September, thereby completing the annual generation.

The developmental stages coincided with marked seasonal variations in temperature and photoperiod. Larval development occurred during autumn and winter, when temperatures and daylength progressively declined, whereas pupal development and adult emergence extended through the warmer months. These observations provide a basis for examining the relationship between seasonal climatic conditions and insect development. However, such relationships represent seasonal associations rather than evidence of direct climatic causation, as other environmental and biological factors may also influence developmental timing (Huchon and Démolin, 1970). The observed pattern in Marseille was characterised by adult emergence and

Table 1: Life cycle of *Thaumetopoea pityocampa* in relation to weather conditions

S No	Month	Week	Min.temp. (°C)	Max.temp (°C)	Daylength (h:min.)	Egg	Larva	Pupa	Moth
1.	January		4.4	13.1	9:20		Larva		
2.	February	I	7.3	14.0	10:05		Larva	Pupa	
		II	8.7	13.7	10:24		Larva	Pupa	
		III	7.7	14.7	10:43		Larva	Pupa	
		IV	9.3	17.8	11:03		Larva	Pupa	
3.	March	I	11.3	18.4	11:24		Larva	Pupa	
		II	10.0	16.6	11:44			Pupa	
		III	7.2	17.9	12:04			Pupa	
		IV	6.5	15.5	12:24			Pupa	
4.	April		10.5	20.0	13:21			Pupa	
5.	May		13.5	23.7	14:39			Pupa	
6.	June		18.9	29.7	15:21			Pupa	
7.	July		20.8	32.0	15:05			Pupa	
8.	August	I	24.8	34.6	14:25			Pupa	
		II	25.0	35.1	14:08			Pupa	
		III	24.3	32.8	13:51	Egg			Moth
		IV	21.9	30.3	13:34	Egg			Moth
9.	September	I	18.8	33.8	13:03	Egg			Moth
		II	15.6	28.5	12:43	Egg			Moth
		III	15.8	29.6	12:23	Egg	Larva		Moth
		IV	16.1	29.0	12:00	Egg	Larva		
10.	October		13.3	22.3	11:06	Egg	Larva		
11.	November		7.8	16.9	09:46		Larva		
12.	December		5.1	13.8	09:02		Larva		

egg laying during late summer, larval feeding from autumn through winter, and processionary descent for pupation during late winter. Although the timing of these events may vary with temperature, altitude, host species and local climatic conditions (Martin *et al*., 2021) [18], the relatively predictable annual development of the population on Aleppo

pine in Marseille facilitated the recording of its major biological events.

Adult emergence and oviposition: The pupal stage terminated during the third week of August, when adult moths emerged from the soil, predominantly at night. The adult lifespan is brief, generally about 24–48 hours, during which mating and oviposition take place (Romanyk and Cadahía, 1992) [24]. Owing to their nocturnal activity and short lifespan, adult moths could not be directly located during the present observations. However, numerous egg clusters were readily detected and collected from the host trees (Fig. 3, G). Following mating, the female moth flies towards a suitable pine tree and deposits her eggs on the needles. In Marseille, oviposition was observed during August and September, with females generally selecting peripheral shoots on the lower branches of Aleppo pine trees (Fig. 3, C). The female deposited her reproductive output in a single compact egg mass, usually arranged around a pair of pine needles. The egg mass was cylindrical and exhibited a characteristic helicoidal or spiral arrangement, comprising approximately 6–12 parallel rows of eggs (Fig. 3, E and F). During oviposition, the female detached greyish-brown to pale buff scales from her abdominal anal tuft and covered the entire egg cluster. This protective covering helped camouflage the egg mass against the surrounding pine shoots (Fig. 3, C) and may provide protection from predators and parasitoids (Mirchev *et al*., 2007) [20].

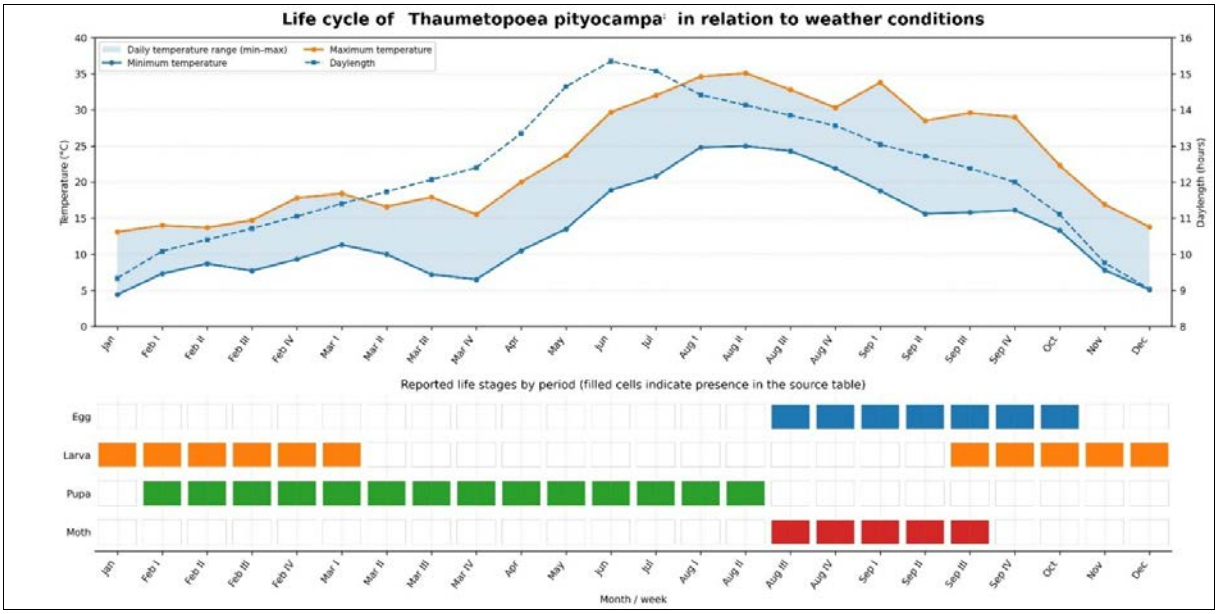


Fig 2: Life cycle of *Thaumetopoea pityocampa* in relation to weather parameters in Marseille, France

The number of eggs per cluster varied considerably, ranging from 52 to 251, with one cluster containing 164 eggs (Fig. 3, D). Earlier studies reported approximately 70 to more than 300 eggs per cluster (Schmidt *et al*., 1999) [28]. Individual eggs were yellowish-white, minute and spherical, measuring approximately 0.9–1.0 mm in diameter. Egg clusters measured 25–50 mm in length, 3.0–5.5 mm in width and approximately 5 mm in height. The eggs remained within the protective covering during incubation for approximately 30 days before hatching during early autumn, principally in September and October. Thus, the egg stage extended from late summer into autumn under the prevailing climatic conditions of Marseille.

Larval development and behaviour: The larval stage represented the most prolonged and destructive phase of the insect's life cycle. Unlike many other defoliating insects, *T. pityocampa* develops actively during autumn and winter, with larvae feeding on pine needles and constructing communal silken shelters from September onwards (Avtzis, 1986; Kerdelhué *et al*., 2009) [2,17]. The caterpillars exhibited pronounced gregarious behaviour, remaining in family groups throughout their larval development. They passed through five distinct larval instars, characterised by progressive changes in body length, coloration, feeding activity and silk production.

First instar: Newly hatched larvae measured approximately 2.5–3.0 mm in length and possessed a dull apple-green body with a distinctly black head capsule (Fig. 3, H). They were relatively delicate and immediately began feeding on the tender pine needles near the egg cluster (Fig. 3, J). Fine, temporary silken threads were produced to maintain contact among individuals and keep the group together. Interestingly, when newly hatched larvae were placed together on paper approximately 7–8 hours after hatching, they attempted to move in a head-to-tail procession (Fig. 3, I). This observation indicated that coordinated processionary movement was evident even at an early developmental stage. First-instar larvae were observed mainly from mid-September until the last week of October on the lower branches of pine trees.

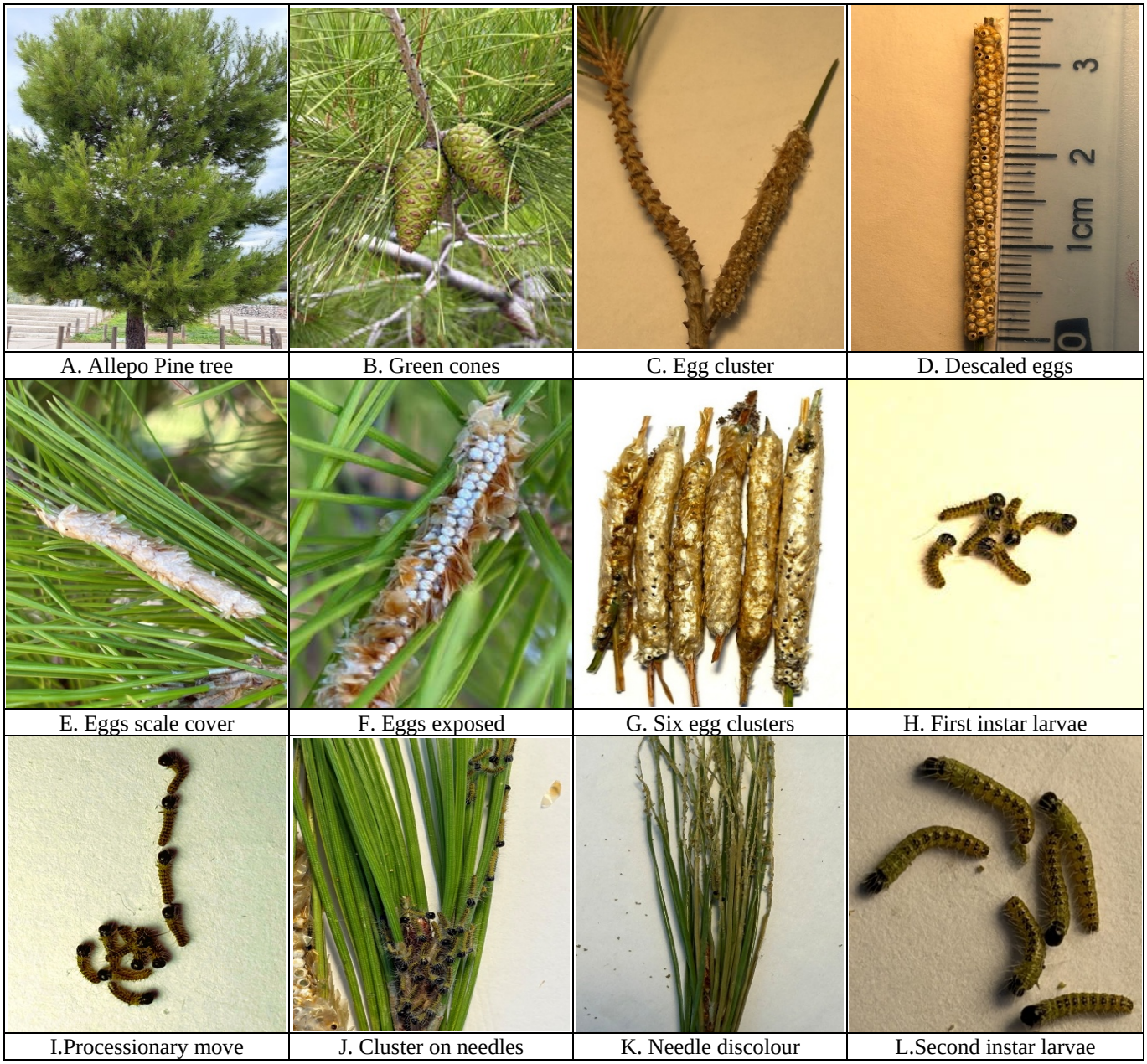
Second instar: The larvae increased in length to approximately 5–8 mm and retained a predominantly greenish-yellow body colour (Fig. 3, L and M). Their

mandibles became stronger, enabling them to consume entire pine needles rather than merely scraping their surfaces, as observed in the first instar (Fig. 3, K). Silk production increased, and the temporary webs became denser as the larvae moved collectively across neighbouring branches. They were frequently observed congregating near the bases of pine needles, where silk fibres retained faecal pellets and other debris within the developing shelter (Fig. 3, M). This instar was observed mainly from the latter part of September onwards.

Third instar: The larvae attained a length of approximately 10–12 mm and developed a darker body colour, ranging from dull bluish-grey to black, with conspicuous orange or yellowish dorsal markings (Fig. 3, O). When disturbed, the larvae frequently raised their heads simultaneously, displaying a characteristic defensive posture. An important developmental change at this stage was the appearance of urticating hair patches. Paired reddish-orange patches of microscopic stinging hairs became visible on successive body segments (Fig. 3, O). These hairs are responsible for skin, eye and respiratory irritation in humans and other mammals (Battisti *et al*., 2005; Pimentel *et al*., 2006) [3,23].

Fourth instar: The larvae became considerably larger, thicker and more densely covered with hairs, approaching approximately 30 mm in length (Fig. 4, A). Their feeding activity increased, and they began expanding and reinforcing their silken shelters in preparation for winter. With the onset of lower temperatures during November, the larvae progressively constructed larger and more permanent communal nests (Fig. 4, B). These nests were generally situated on exposed, sun-facing branches in the upper or peripheral crown. The larvae remained aggregated within the shelters during the daytime and generally emerged at night to feed on pine needles.

Fifth instar: The fully developed larvae measured approximately 38–45 mm in length and were characterised by dense white to yellowish lateral hairs and conspicuous urticating hair



A. Allepo Pine tree | B. Green cones | C. Egg cluster | D. Descaled eggs
E. Eggs scale cover | F. Eggs exposed | G. Six egg clusters | H. First instar larvae
I.Processionary move | J. Cluster on needles | K. Needle discolour | L.Second instar larvae



M.Cluster in needles	N. Feeding pattern	O. Third instar larvae	P. Nest expansion

Fig 3: Egg-laying pattern and early instar (L1-L3) larval feeding and nesting behaviour of pine processionary moth.



A.Cluster of 4th instar larvae	B. Winter permanent nest	C. Larva ready for pupation
D. Nest guards (5th instar)	E. Nest on procession day	F. Black and white 5 instar
G. Procession of 4 larvae	H. Damage around nest	I. Long procession of 22 larvae

Fig 4: Feeding, nesting and processionary behaviour of processionary caterpillar.

patches (Fig. 4, C). This was the most voracious feeding stage, and extensive consumption of pine needles occurred during January and February. A few larvae were occasionally observed outside the main nest, apparently occupying positions around its exterior. Their precise function was not established during the present observations. Because of the potential allergic effects of urticating hairs, head-capsule measurements were not undertaken to distinguish the instars.

Processionary behaviour during feeding and pupal transformation: The characteristic processionary behaviour of *T. pityocampa* involves the movement of larvae in a closely connected, head-to-tail formation. During feeding, larvae leave their communal shelters and move collectively towards suitable feeding sites, particularly at night. They subsequently return to their nests, often following established routes. Chemical cues deposited by preceding individuals, together with close-contact stimuli, help maintain the continuity of these processions (Fitzgerald, 2003) [11]. This behaviour was also observed in newly hatched larvae, indicating that coordinated group movement is expressed early in larval development (Fig. 3, I and J). At the completion of the fifth instar, generally between February and March, mature larvae leave the host tree and descend towards the ground in characteristic single-file processions. The movement is commonly led by a dominant female larva, followed by the remaining members of the colony.

During 1–8 February, rainfall occurred on five days, with cumulative precipitation reaching 102 mm and a maximum daily rainfall of 25 mm. Sunshine duration ranged approximately from 7:44 AM to 6:00 PM, while temperatures varied between 7 and 13°C. Relative humidity ranged from 80 to 92%, and wind speeds varied between 7 and 21 km/h, with gusts reaching 26–40 km/h. Under these conditions, several larvae attained lengths of approximately 40–44 mm and developed predominantly dark body coloration, with conspicuous white hairs and occasional orange or reddish tinges (Fig. 4, F).

The first daytime processionary movement from an earmarked nest was recorded on 3 February, when caterpillars were observed descending towards the ground (Fig. 4, E). Four distinct groups, each comprising at least 4–5 caterpillars, were recorded moving in search of suitable pupation sites (Fig. 4, G). Although feeding activity was predominantly nocturnal, this downward procession occurred during daylight at approximately 11:30 AM. A further mass procession involving 22 caterpillars was recorded on 1 March from another infested tree (Fig. 4, H and I). These observations established that the main period of larval descent in Marseille extended from the first week of February to the first week of March.

After reaching the ground, the larvae searched for suitable loose soil, generally in relatively sunny locations, where they burrowed to a depth of approximately 5–20 cm and constructed protective cocoons before pupation. The pupae remained underground until adult emergence during August and September (Arnaldo and Torres, 2006; Pimentel *et al*., 2006; Bonsignore *et al*., 2019) [1, 23, 4]. The observed processionary period and subsequent underground pupation were consistent with the univoltine developmental pattern reported for Mediterranean populations (Masutti and Battisti, 1990; Salman *et al*., 2016) [16, 27]. Nevertheless, prolonged pupal diapause may occur under unfavourable environmental conditions, resulting in emergence after more than one year (Martin *et al*., 2021) [18].

Communal nest formation, expansion and ecological significance: Following egg hatching, the young larvae initially remained aggregated near the oviposition site and began feeding on adjacent pine needles. They produced fine silken threads and constructed small, temporary web-like shelters. As feeding progressed and the occupied needles deteriorated, the larvae moved towards fresh foliage and gradually enlarged their shelters.

Eggs laid around the last week of September hatched on 26 October, after an incubation period of approximately 30 days. Egg clusters detached from the tree on 13 October also hatched on 26 October when maintained at room temperature. Maximum hatching activity was observed during the second week of October, as indicated by drying and browning of pine needle clusters on the lowermost branches, particularly on the outer or peripheral portions of the trees. Newly hatched larvae emerging from individual egg clusters appeared to disperse into two or three smaller groups and began feeding on nearby needles. As the initially occupied needles dried, the larvae shifted to fresh branches and progressively enlarged their silken shelters. The temporary nests increased from approximately 2 cm to 4 cm in size during the transition to the second instar. During this early period, larval movement was largely restricted to adjacent branches. However, upon entering the third instar, the larvae developed more conspicuous orange markings and moved upwards by approximately 2–4 ft, constructing larger shelters measuring about 5 cm. Groups of approximately 10–15 larvae were observed within these nests. The larvae displayed characteristic defensive behaviour when disturbed. Their aggregation and increasing silk production appeared to contribute to the maintenance of group cohesion and the structural reinforcement of the developing shelters. The observations also suggested that smaller larval subgroups progressively formed larger aggregations during the transition to the third instar. The construction of protective shelters by the earliest larval instars is of considerable biological significance, as these structures provide protection against adverse weather conditions as well as natural enemies, particularly in the relatively sparse canopy of pine needles. The importance of such shelters was clearly highlighted by the severe weather experienced at the experimental sites in Marseille on 20–21 October 2026, when 131 mm of rainfall was recorded within just two days, accompanied by two thunderstorms with wind gusts reaching 37 km h^{-1}. Such intense weather conditions

illustrate the potential vulnerability of newly hatched and early-instar larvae to heavy rainfall and strong winds, emphasizing the adaptive importance of constructing protective silken shelters at an early stage of larval development.

During the third instar, the shelters were generally thin and loosely woven, providing resting sites between feeding periods. Such temporary nests were abandoned when colonies moved to fresh feeding sites, with new shelters being constructed along their movement routes. Similar observations of larval development throughout winter and the occasional merging of different larval batches have been reported earlier (Pérez-Contreras *et al*., 2003) [22]. A major transition in nest construction occurred during the fourth instar, when the larvae began developing permanent winter shelters. These nests were considerably larger and more compact than the temporary webs constructed during the earlier instars. Winter nests generally measured approximately 12–25 cm in length and were oval-shaped, with a white to greyish appearance (Dajoz, 2000; Arnaldo and Torres, 2006) [8, 1].

The development of permanent shelters coincided with declining temperatures during November and December 2025, when temperatures in Marseille generally ranged from 5 to 16°C. During the first week of January 2026, temperatures declined considerably, ranging from approximately −2 to 8°C. On 7 January, temperatures fell to −5°C at night and approximately −1°C during the day, accompanied by snowfall, an unusual event in Marseille after approximately ten years. Relative humidity during this period generally ranged from 60 to 80%. The occurrence of low temperatures and occasional adverse weather conditions highlighted the importance of communal winter shelters for the survival and continued development of the larvae. The definitive winter nests consisted of several layers of silk interwoven with pine needles and other debris (Fig. 5, C). Mature larvae actively added silk to the external surface, progressively strengthening the structure. The resulting shelters were sufficiently compact to provide a protected resting environment during adverse weather.

The larvae generally aggregated inside the nests during the daytime and emerged, particularly at night, to feed on pine needles. After feeding, they returned to their shelters, frequently following established silk-marked routes. Such nests are considered important for protection against predators, parasitoids and unfavourable environmental conditions, besides facilitating larval thermoregulation (Breuer and Devkota, 1990; Roversi *et al*., 2023) [6,25]. Additional adverse weather conditions were recorded during January 2026. A rainfall event from 15 to 17 January resulted in approximately 35 mm precipitation, followed by strong winds on 18 January, reaching approximately 35 km/h with gusts of up to 57 km/h. Further rainfall occurred during 19–26 January, with daily precipitation generally ranging from 5 to 10 mm. Another prolonged rainy period during 24–31 January resulted in approximately 100 mm rainfall, with a maximum of about 30 mm in 24 hours. Temperatures during these periods generally ranged from 7 to 12°C, relative humidity from 70 to 90%, and wind speeds from 7 to 25 km/h, with gusts reaching approximately 58 km/h. These observations indicate that the construction and progressive reinforcement of communal winter nests provide an important sheltering mechanism for larvae developing under fluctuating Mediterranean winter conditions.

Winter nest orientation and microhabitat selection: Observations from November 2025 to February 2026 revealed a distinct preference for southeastern to southern-facing positions for winter nest construction on Aleppo pine trees in the 10th, 11th and 12th arrondissements of Marseille. Most nests were located on branches facing approximately 150–175°, corresponding to southeastern (150–158°) and southern (160–175°) orientations (Fig. 5, A and B).

On 5 November, numerous small nests containing second- and third-instar larvae were recorded on branches receiving prolonged sunlight. As larval development progressed, these shelters increased in size through the incorporation of pine needles held together by silken threads produced by the caterpillars. Larval exuviae and faecal pellets accumulated within the lower portions of the nests and remained trapped in the silken mesh (Fig. 5, F). The larvae generally fed during the night and remained concealed inside the nests during daytime. Younger larvae, particularly those belonging to the second and third instars, were frequently observed in groups of 4–12 individuals around the nest structures. In contrast, fourth- and fifth-instar larvae were generally represented by only 1–3 individuals on the outer surface of the nests.

The preference for southeastern and southern orientations appeared to provide greater exposure to solar radiation during winter. Such positioning may contribute to maintaining favourable nest temperatures and facilitating larval thermoregulation. The thicker silken covering on the southern side of the nest may further enhance its capacity to absorb solar radiation, although this requires experimental confirmation (Kaszaki *et al*., 2015) [16].

The observed nest orientations coincided with the period of active pine needle and cone development from December to mid-February. Prolonged solar exposure may influence the microclimatic conditions around the nests and the nutritional characteristics of host foliage. However, the present observations do not establish a direct causal relationship between nest orientation, foliage quality and larval performance. Maximum feeding damage was recorded from the second week of January to the first week of February. Intermittent rainfall during this period resulted in damp conditions within some nests and coincided with increased activity of mature larvae preceding their processionary descent. A distinct change in the colour of faecal pellets was also observed during larval development. Pellets were predominantly green during the first and second instars (Fig. 3, M and N), became greenish-brown during the third and

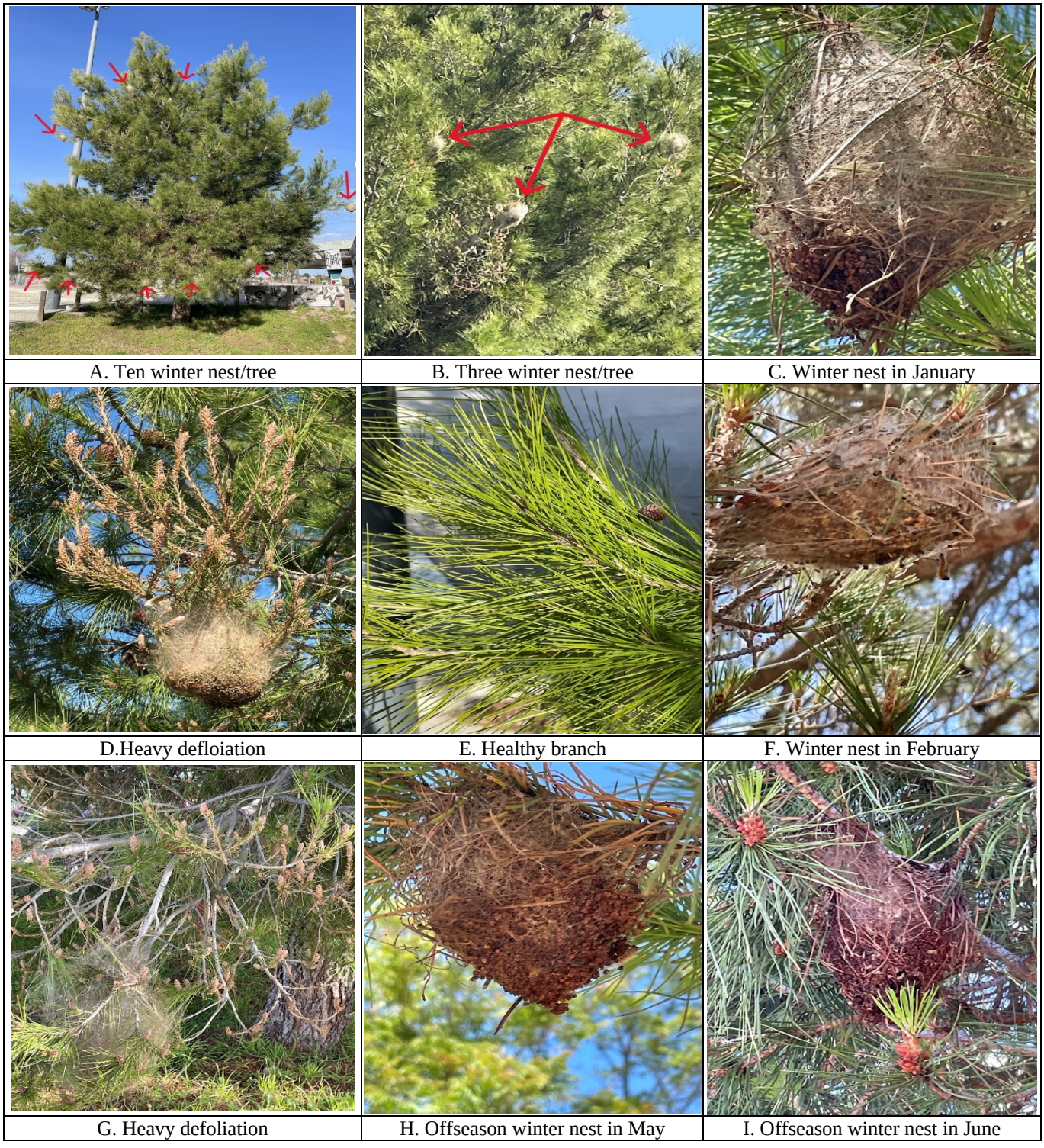


Fig 5: Winter communal nest intensity, foliar damage, offseason persistence of nests of pine processionary moth in Marseille, France.

fourth instars (Fig. 4, D), and developed a reddish appearance during the fifth instar in late January and February (Fig. 4, E). On 30 January, additional infested trees bearing several nests were recorded at southeastern orientations of approximately 150–156° and 154–158°. In one instance, fifth-instar larvae were unusually positioned outside the nest, displaying conspicuous white setae and a darkened body integument. Although birds were observed near or on infested trees, no direct predation of the processionary caterpillars was recorded during the observations. Overall, the findings suggest that nest orientation, communal shelter construction and nocturnal feeding are important behavioural characteristics associated with larval development during winter.

Pupal transformation: The pupal stage represents the underground phase of the life cycle of *T. pityocampa*. Following the completion of larval development, mature caterpillars leave the host tree and enter the soil, where they undergo metamorphosis within protective cocoons. After burrowing to a depth of approximately 5–20 cm, each mature larva constructs a tough, oval-shaped, ochreous-white silken cocoon. The enclosed chrysalis is approximately 20 mm long and oval in shape (Dajoz, 2000)

[8]. Pupal development is also associated with a period of diapause during which the insect remains underground until favourable conditions permit adult emergence. Previous studies have indicated that pupae originating from higher elevations may exhibit longer diapause periods than those from lower elevations (Salman *et al*., 2016) [27].

In the present observations, processionary descent and soil entry occurred from the first week of February to the first week of March. The pupae subsequently remained underground until August, when adult emergence initiated the next annual generation. Although the population observed in Marseille exhibited a predominantly univoltine life cycle, prolonged diapause lasting several years has been reported under extreme or unfavourable environmental conditions (Salman *et al*., 2019) [26]. Such extended diapause is less likely to occur under the relatively moderate climatic conditions prevailing at the lower elevations of the study locations.

Feeding damage and its consequences: The feeding activity of *T. pityocampa* resulted in considerable damage to Aleppo pine foliage. The larvae consumed pine needles progressively throughout their development, with feeding intensity increasing substantially during the fourth and fifth instars.

During the first and second instars, feeding damage was relatively minor and generally appeared as superficial feeding marks or partial consumption of individual needles. Damage became increasingly conspicuous during the third instar as the larvae developed stronger mandibles and consumed larger quantities of foliage. The fourth- and fifth-instar larvae caused extensive defoliation, particularly when several colonies occurred on the same tree. Trees bearing multiple nests, in some cases up to ten per tree, exhibited substantial foliage loss (Fig. 5, A). The combined feeding activity of several colonies results in extensive consumption of needles from individual branches.

By 28 January 2026, almost complete removal of needles was observed on certain infested branches (Fig. 5, D and G), whereas adjacent branches on the same tree retained their foliage and provided a useful comparison of the extent of feeding damage (Fig. 5, E). The loss of foliage reduces the photosynthetic capacity of host trees and may consequently impair growth, vigour and reproductive performance. Repeated or severe defoliation can weaken trees and increase their susceptibility to secondary insect pests and environmental stresses. Younger trees and plantations are particularly vulnerable to substantial foliage loss.

Previous investigations have also documented severe defoliation associated with *T. pityocampa*, including complete defoliation of some stands (Cadahia and Insua, 1970; Pérez-Contreras *et al*., 2008; Jacquet *et al*., 2013) [7,21,15]. Defoliated trees have also been reported to produce approximately 50% fewer seeds, with seed weight reductions of 40–45% compared with undefoliated trees (Hódar *et al*., 2003) [12]. The present observations confirm that the feeding activity of mature larvae, particularly during January and early February, can result in considerable localised defoliation of Aleppo pine. The presence of characteristic silken nests, aggregations of larvae and partially or completely consumed needles provides useful field indicators for identifying infested trees and assessing the extent of damage. The presence of previous season nests of processionary caterpillar during May-June (Fig 5, H and I) were the potential indicators of the severe infestation of the pest in the region which could be helpful to decide appropriate pest management strategies. Though such off-season nests have been used as shelters by many species of spiders and insects (Branco *et al*., 2008) [5].

Conclusion

The present observations provide an account of the seasonal incidence, biology and behavioural characteristics of the pine processionary moth, *Thaumetopoea pityocampa*, on Aleppo pine (*Pinus halepensis*) in Marseille, Southern France. The insect exhibited a predominantly univoltine life cycle, with adult emergence and oviposition occurring during August–September, larval development extending from September through winter, and processionary descent for pupation taking place from early February to early March. The pupal stage persisted underground until adult emergence during the following August. Larval development was characterised by pronounced gregarious behaviour, progressive changes in body coloration and size, and the construction of temporary and permanent silken shelters. The transition from small temporary webs to large, compact winter nests during the fourth and fifth instars represented an important behavioural adaptation to winter conditions. The predominant southeastern to southern orientation of winter nests suggested a preference for sun-exposed microhabitats, potentially facilitating nest warming and larval thermoregulation. The characteristic head-to-tail processionary movement was observed even among newly hatched larvae and became particularly conspicuous during the mature larval stage preceding pupation. Feeding activity intensified during January and early February, resulting in extensive needle consumption and, in some cases, almost complete defoliation of individual branches. These observations emphasise the importance of the mature larval stages in determining the extent of damage to Aleppo pine. Overall, the study highlights the close association between seasonal development, larval aggregation, communal nest construction, microhabitat selection and feeding damage in *T. pityocampa* under the Mediterranean climatic conditions of Marseille.

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