Thaumetopoea pityocampa

Scientific Name
Thaumetopoea pityocampa Denis & Schiffermüller, 1775

Synonyms:
Bombyx pityocampa Denis & Schiffermüller, 1774
Traumatocampa pityocampa (Denis & Schiffermüller, 1775)
Cnethocampa pityocampa Denis & Schiffermüller, 1928

Figure 1. Adult male *T. pityocampa* (Photo courtesy of Philippe Mothiron, Lepinet.fr)

Common Name
Pine processionary moth, pine processionary caterpillar, stone-pine processionary caterpillar, winter pine processionary moth

Type of Pest
Moth, defoliator

Taxonomic Position
Class: Insecta, **Order:** Lepidoptera, **Family:** Notodontidae

Reason for Inclusion in Manual
Pests of Economic and Environmental Importance – 2017

Pest Description
Eggs: Eggs are yellowish to white in color, typically laid in cylindrical batches around the needle starting at the base and on the lower branches of the crown (Romanyk and Cadahía, 1992; Schmidt et al., 1999). The number of eggs laid per batch varies, but can range from 37 to 312 eggs per batch (Schmidt et al., 1999). Egg masses can range in size 25 to 40 mm (1 to $1^{9}/_{16}$ in.) wide and about 5 mm (~$^{3}/_{16}$ in.) high (EPPO, 2004) and are covered with scales from the adult females (Schmidt et al., 1999).

Larvae: The larval stages consists of five instars with the first instar being dull green in color with the urticating hairs appearing after the second molt (Romanyk and Cadahía, 1992). The fifth instar larva is 38 to 45 mm ($1^{1}/_{2}$ to $1^{3}/_{4}$ in.) long and is covered in urticating hairs arranged in pairs on each body segment (EPPO, 2004) (Fig. 2). Coloration varies, depending on the locality of the moth, but in general the integument is

a dull bluish-grey to black with the lateral and ventral hairs varying from white to dark yellow and the dorsal hairs yellow to orange (Romanyk and Cadahía, 1992).

Pupae: The pupae is oval in shape, about 20 mm ($^3/_4$ in.) in length and a reddish brown in color (Fig. 3) (Romanyk and Cadahía, 1992). The pupae reside in a brownish-white, oval silk cocoon (Romanyk and Cadahía, 1992).

Adults: The male has a slightly smaller wingspan (30 to 40 mm [$1^3/_{16}$ to $1^9/_{16}$ in.]) (Fig. 1) than the female (35 to 50 mm [$1^3/_8$ to ~2 in.]) and both have a pronounced jagged crest on the chest (EPPO, 2004). The forewings are a dull ashen-grey with three transverse stripes while the hindwings are white, fringed with grey, and a grey-brown spot in the anal region (Romanyk and Cadahía, 1992). The antennae are bipectinate for both sexes, but appear filiform in females and pectinate in males (Romanyk and Cadahía, 1992). Both sexes have a hairy thorax, but the female is stout and covered at its end with golden yellow scales while males are thinner with hairs on its limbs (Romanyk and Cadahía, 1992).

Figure 2. *Thaumetopoea pityocampa* larval procession (Photo courtesy of B. Forster, bugwood.org)

Figure 3. Pupae (Photo courtesy of D.D. Cadahia, Bugwood.org)

Biology and Ecology

Thaumetopoea pityocampa has one generation per year, with a cyclic pattern of outbreaks occurring every 6 to 8 years (Jacquet et al., 2013). Moths emerge in the summer, and males usually preceed the females. After mating, the females typically lay more than 200 eggs in a single mass. Egg masses are usually laid at the base of needles located near the top of trees and are covered with protective scales (Mirchev et al., 2007; Zovi et al., 2008). The larvae, which hatch after 25 to 40 days, are gregarious and feed on pine needles through autumn to early spring (Kanat et al., 2002; Kerdelhué et al., 2009; Zovi et al., 2008). Larval feeding can completely defoliate branches resulting in dieback. Larvae build communal nests that are 12 to 25 cm ($4^3/_4$ to $9^{13}/_{16}$ in.) long, oval, white or light grey. The nests are distinct and visible on branches, or on young trees, in the upper canopy (Arnaldo and Torres, 2006; EPPO, 2004).

In February or March, depending on the weather, the larvae form a procession and descend the host tree. Larvae then pupate in the soil, where they remain until emerging as adults the following summer (Arnaldo and Torres, 2006; Pimentel et al., 2006). Pupal cocoons can be found between February and July in the upper layers of the soil or in leaf litter. Pupae are often found in the growing medium in which young plants are grown. Adults usually emerge between June and August; however, pupae can remain in diapause for 1 to 3 years or up to 6 years if there are adverse climatic conditions, lack of food, or elevation (Masutti and Battisti, 1990; Salman et al., 2016). The prolonged diapause that occurred up to six years were results from a semi field condition where pupe were left at different elevations to determine ecosion rates. Pupa exposed to higher elvations demonstrated longer diapause times than pupae reared at lower elevations (Salman et al., 2016). In Turkey, the heaviest defoliation occurs during February and March (Kanat et al., 2002).

Adults remain hidden in trees during the day and fly by night. Females are weaker fliers than males (Kerdelhué et al., 2009), based on flight tunnel studies female moths average dispersal distance was 1.7 km (Robinet et al., 2012). Female emergence is restricted to one month, usually in the middle of the male emergence period (Masutti and Battisti, 1990).

Damage

Damage by *T. pityocampa* is caused by larval feeding on the foliage of host trees. Defoliation by *T. pityocampa* usually results in significant growth reduction through needle consumption and is normally higher in younger trees than mature ones (Jacquet et al., 2013). In France during the winter of 2009 to 2010, some maritime pine stands of all ages were severely defoliated by the insect, some stands were 100% defoliated (Jacquet et al., 2013). Defoliation can result in significant radial growth losses in *P. pinaster*, which can have lasting effects for the next two years (Jacquet et al., 2013).

Pest Importance

In Turkey, insect damage (mostly from *T. pityocampa*) caused a loss of 3% annual wood harvest from 1997-2003 and an estimated reduction in growth for one year valued at $6.9 million (Carus, 2004). In Algeria in 2005, 85,000 hectares of pine were treated for *T. pityocampa* (Sebti and Chakali, 2014).

Defoliation damage is extremely serious in young reforested areas where it may lead to death of trees directly or indirectly from attack by bark beetles or other wood-boring insects. In mature forests, trees are rarely killed but significant losses occur in volume growth. The diameter, height, and volume of trees that were severely defoliated were reduced by an average of 24%, 36%, and 52% respectively (Carus, 2004). On average, defoliated juvenile trees grew less than half when compared to undamaged trees, as well as producing 50% fewer seeds while being 40% lighter than undefoliated trees (Hódar et al., 2003). Hampering of tree survival by altering growth patterns and reproduction can result directly from reduced phytosynthesis or indirectly by being more susceptible to other factors like drought and pathogen attacks (Hódar et al., 2003).

In young reforestations of *Pinus radiata*, wood volume losseswere observed between 14 and 33% for light and high infestations, respectively (Cadahia and Insua, 1970). *Pinus nigra* forests had a 45% reduction in volume in 50 years after being subjected to periodic heavy attacks (Durkaya et al., 2009)..Laurent-Hervouët, 1986 demonstrated that a year after severe attacks by *T. pityocampa* resulted in a 35% reduction in radial growth caused by missing growth rings, along with a 20% radial growth loss in *P. nigra* at the study site in Corsica.. In recreational and residential areas, defoliation may also cause severe deterioration and greater maintenance costs of landscape trees (Cheraghian, 2013).

Thaumetopoea pityocampa can be considered a public health risk due to reactions to the urticating hairs, which may cause allergic reactions such as contact dermatitis, conjunctivitis, respiratory congestion, and asthma (Battisti et al., 2005; Petrakis et al., 2001). Domestic and farm animals may also be affected when coming into contact with the hairs.

Known Hosts

Thaumetopoea pityocampa is a polyphagous defoliator, feeding on *Cedrus* and *Pinus* (Pimentel et al., 2006). *Thaumetopoea pityocampa* is the main insect defoliator of pine and cedar species in Southern Europe (Jacquet et al., 2013). Masutti and Battisti, 1990 reported *Pinus nigra* (black pine) as the preferred host and *Pinus halepensis* (Aleppo pine) as the secondary preferred host of *T. pityocampa.* In Turkey, *Thaumetopoea pityocampa* is reported to be one of the most significant pests on coniferous forests (Mirchev et al., 2007). It attacks 6 *Pinus* species, as well as *Cedrus libani* (cedar of Lebanon) and *Juniperus exelsa* (Grecian juniper) (Mirchev et al., 2007). *Thaumetopoea pityocampa* is the most serious pest of conifer forests in Algeria. It is present in all forests of Aleppo pine and Atlantic cedar (Sebti and Chakali, 2014).

Major hosts

Pinus brutia (Calabrian pine), *Pinus halepensis* (Aleppo pine), *Pinus mugo* (mountain pine), *Pinus nigra* (black pine), *Pinus pinaster* (maritime pine)[1], *Pinus radiata* (Monterey pine), *Pinus sylvestris* (Scots pine) (Avtzis, 1986; Cayuela et al., 2011; Devkota and Schmidt, 1990; Hódar et al., 2003; Hódar et al., 2002; Hódar et al., 2004; Masutti and Battisti, 1990; Pérez-Contreras et al., 2008; Petrakis et al., 2005; Stastny et al., 2006).

Minor hosts

Cedrus atlantica (Atlantic cedar), *Cedrus deodara* (Himalayan cedar), *Cedrus libani* (cedar of Lebanon), *Juniperus excelsa* (Grecian juniper), *Pinus elliottii* (American pitch pine), *Pinus heldreichii* (Bosnian pine), *Pinus pinea* (Italian stone pine), *Pinus strobus* (eastern white pine), *Pinus taeda* (loblolly pine), *Pseudotsuga menziesii* (Douglas-fir) (Avtzis, 1986; Cayuela et al., 2011; Devkota and Schmidt, 1990; Kanat et al., 2002; Masutti and Battisti, 1990; Mirchev et al., 2007; Mol et al., 2002; Petrakis et al., 2005; Sbabdji and Kadik, 2011; Stastny et al., 2006; Zhang and Pavia, 1998).

[1] Masutti and Battisti (1990) list *Pinus pinaster* as a preferred host, but two laboratory experiments have demonstrated that it is less preferred compared to other preferred species (Petrakis et al., 2005) and is an unsuitable host for first instar larvae, resulting in high mortality (Hódar et al., 2002).

Experimental hosts
Pinus contorta (lodgepole pine), *Pinus densiflora* (Japanese pine), and *Pinus ponderosa* (ponderosa pine) (Devkota and Schmidt, 1990).

Pathogens or Associated Organisms Vectored
This species is not known to be associated with pathogens or other organisms.

Known Distribution
Africa: Algeria, Libya, Morocco, Tunisia; **Asia:** Israel, Lebanon, Syria, Turkey; **Europe:** Albania, Austria, Bulgaria, Bosnia, Croatia, Cyprus, France, Germany, Greece, Hungary, Italy, Macedonia, Montenegro, Portugal, Serbia, Slovenia, Spain, Switzerland, United Kingdom, (CABI, 2018; Mirchev et al., 2007; Stastny et al., 2006)

Pathway
The European Forestry Commission states that there is a low risk of egg masses, caterpillars, or adults associated with open pathways. The risk of unintentional movement of *T. pityocampa* during the winter and spring can be considered low due to the high visibility of nests and associated caterpillars during that time, even more so if import and exporters of the plants are aware of the insect (UK Forestry Commission, 2018). Pine plants are not usually imported or exported during the summer months when adult moths are laying eggs, thus lowering the risk of egg mass transport (UK Forestry Commission, 2018). Occasional spread may occur by random remote transfer by cars (Halperin, 1986), but Robinet et al., 2012) state this insect is unlikely to be moved, even indirectly, by this method.

Thaumetopoea pityocampa is a recommended quarantine pest for southern Africa. It poses a risk to any area of Mediterranean climate where *Pinus* species are present or planted (California, USA; Australia, etc.). *Thaumetopoea pityocampa* is regulated by the European Union in order to protect the island of Ibiza, Spain and the Canary Islands. The European Union uses ‘protected zones’ on *Pinus* produced in nurseries, which is easier to implement than the physical inspection of traded plants or the accompanying soil for eggs, larvae, or pupae, because the pest is inconspicuous (CABI, 2018). For the United States, *Pinus* sp. plants for planting from Canada, Japan, and South Korea are allowable if they meet the importing requirements, while plants from other countries are Not Authorized Pending Pest Risk Analysis (NAPPRA) (USDA, 2017). There are no records of interception for *Thaumetopoea pityocampa* or for the genus *Thaumetopoea* for the United States (PestID, 2018).

Potential Distribution within the United States
If introduced into the United States, pine species not present in its native range may be succeptible hosts. In a host map developed by USDA-APHIS-PPQ-CPHST (Fig. 4), parts of the United States with the highest concentration of pine include: the southeastern, northeastern, western, and upper great lakes regions of the United States.

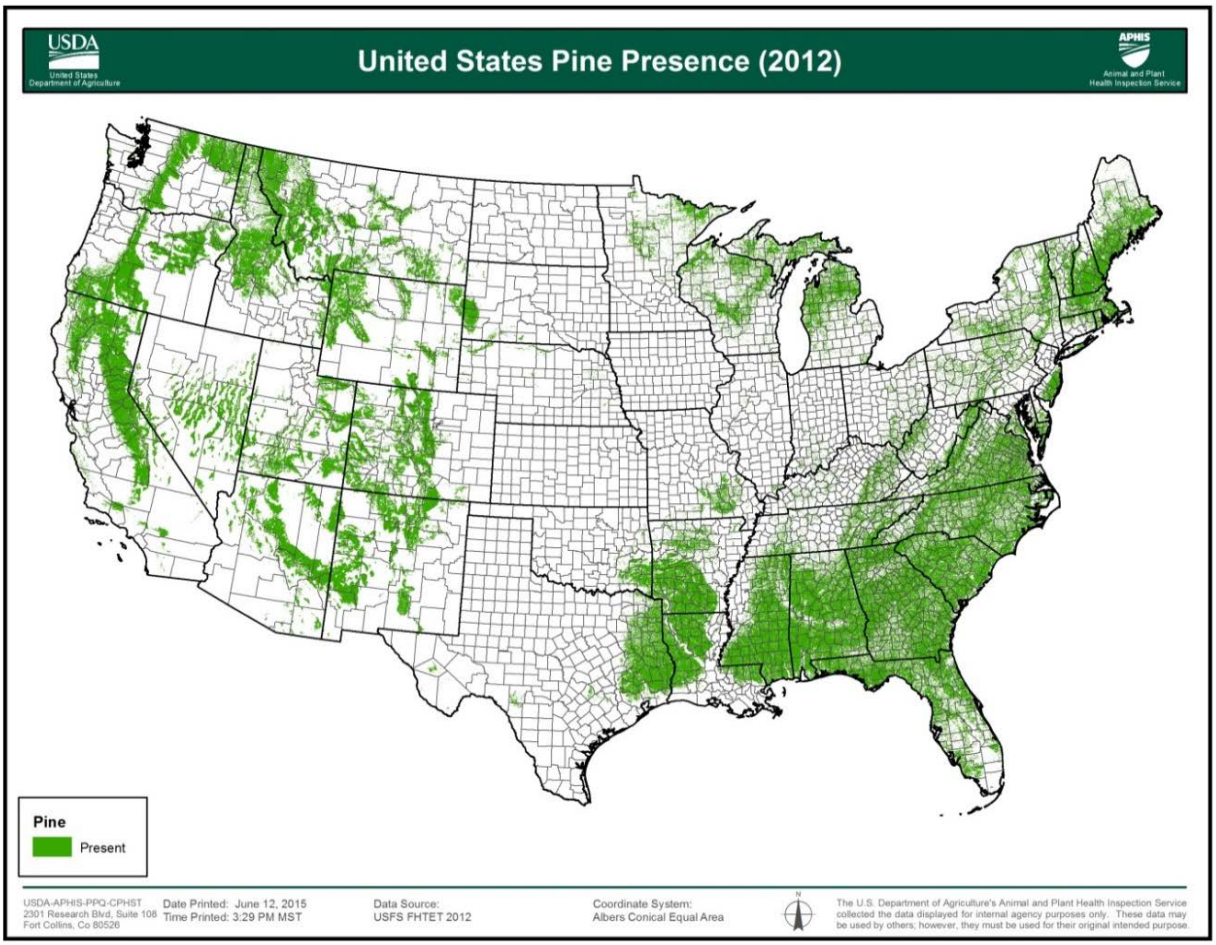

Figure 4. Tree species presence map for Pine (*Pinus* spp.) modeled in 2012 at a 240 meter resolution (USDA Forest Service, Forest Health Technology Enterprise Team). Map courtesy of USDA-APHIS-PPQ-CPHST.

Survey

Approved Methods for Pest Surveillance*:

The Approved Method is a trap and lure combination. The trap is a large plastic delta trap (Fig. 5). The lure is effective for 28 days (4 weeks).

Any of the following Trap Product Names in the IPHIS Survey Supply Ordering System may be used for this target:

Large Plastic Delta Trap, Orange
Large Plastic Delta Trap, Red, or
Large Plastic Delta Trap, White

Figure 5. Large plastic delta trap, orange. (Lee Spaulding, USDA-APHIS-PPQ).

Trap color is up to the State and does not affect trap efficacy for this species.

The Lure Product Name is "*Thaumetopoea pityocampa* Lure."

IMPORTANT: Do not include lures for other target species in the trap when trapping for this target.

Trap spacing: When trapping for more than one species of moth, separate traps for different moth species by at least 20 meters (65 feet).

*For the most up-to-date methods for survey and identification, see Approved Methods for Pest Surveillance on the CAPS Resource and Collaboration Site at http://caps.ceris.purdue.edu/approved-methods.

Literature-Based Methods:

The chemical structure of the sex pheromone of *T. pityocampa* produced by virgin females was identified as (Z)-13-hexadecen-11-ynyl acetate (Zhang, & Pavia, 1998). Two different syntheses of this compound have been published.

Trapping:

A variety of traps, sticky (delta-traps or Pherocon II traps) or non-sticky (funnel traps) baited with synthetic pheromone ((Z)-13-hexadecen-11-ynyl-acetate) have been used and placed at a height between 2.0 – 3.0 m from the ground (Athanassiou et al., 2007; Pimentel et al., 2006; Zhang and Pavia, 1998). Comparisons of the different traps available demonstrated that delta traps or Pherocon II traps caught significantly more male moths than funnel traps (Athanassiou et al., 2007). Lights traps have been used as well, however, they were found to capture fewer moths when compared to delta or Pherocon traps (Cuevas et al., 1983).

Visual inspection:

Throughout the Mediterranean region, populations have been monitored for many years by means of winter-nest censuses (Battisti et al., 2005). During the winter, defoliation increases and the white *T. pityocampa* nests stand out plainly, allowing for easy detection of the nests. Counting the nests provides accurate data on the distribution and abundance even at low population densities (Cheraghian, 2013).

Not recommended:

For CAPS surveys, light traps are not an approved method for this species as they are not species-specific.

Key Diagnostics/Identification

Approved Methods for Pest Surveillance*:

Morphological:

Morphological identification of adult moths to *Thaumetopoea* genus can be done by the following characteristics. Adults are approximately 10 – 17 mm long, feathery antennae at apex, hairy body, vestigial proboscis, gray to brownish gray forewings with three dark

lines with a dark spot, and a sclerotized projection on the head (Gilligan et al., 2014). Moth specimens identified to genus level can be identified to *pityocampa* species with the following characteristics: canthus with protuberance, underside of forewings gray, males have a black without yellow scales transvers line on the underside of forewings, females have anal scales longer than 2mm or the proximal part is not pointed, the the discoidal vein (bent-elbowed line) on the underside of the forewing forms a 35° angle with costal margin (EPPO, 2004; OEPP/EPPO, 2004)

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at https://caps.ceris.purdue.edu/approved-methods.

The following screening aids are available on the CAPS Resource and Collaboration website:

- Processionary Moths *Thaumetopoea* spp. http://download.ceris.purdue.edu/file/2545

Easily Confused Species

The related species *Thaumetopoea pinivora* has a more northerly range than *T. pityocampa*. Morphologically, the two species can be differentiated by noting the posterior indentations of the canthus (a crest which allow the emerging adults to dig towards the soil surface); the indentations are higher in *T. pityocampa* than in *T. pinivora*. On *T. pityocampa*, the fringes of the hindwings are white and and the thorax of the female is covered in light-grey scales (EPPO, 2004). Whereas,on *T. pinivora,* the fringes of the hindwings are grey and the thorax of the female is covered in dark grey scales.

Behaviorally, the caterpillars of *T. pityocampa* aggregate in colonies and spin silken nests for shelter, which enlarge as they develop and overwinter,while, *T. pinivora* caterpillars aggregate freely in pine needles (EPPO, 2004). *Thaumetopoea pityocampa* feeds on *Abies, Castanea, Cedrus, Larix, Malus, Pinus,* and *Quercs* spp., whereas *T. pinivora* feeds only on *Pinus* spp. (EPPO, 2004).

Commonly Encountered Non-targets

Although not known to be attracted to *T. pityocampa* pheromone traps, the following moths may have the potential to be non-target captures in baited traps; *Ceolodasys unicornis*, *Heterocampa blundata*, *Heterocampa guttivitta*, *Heterocampa lunata*, *Ianassa lignicolor*, *Lochmaeus bilineata*, *Misogada unicolor*, *Schizura ipomoeae* (Gilligan et al., 2014)

References

Arnaldo, P. S., and L. M. Torres. 2006. Effect of different hosts on Thaumetopoea pityocampa populations in northeast Portugal. Phytoparasitica 34(5):523-530.

Athanassiou, C. G., N. G. Kavallieratos, S. F. Gakis, L. A. Kyrtsa, B. E. Mazomenos, and F. T. Gravanis. 2007. Influence of trap type, trap colour, and trapping location on the capture of the pine moth, *Thaumetopoea pityocampa*. Entomologia experimentalis et applicata 122(2):117-123.

Avtzis, N. 1986. Development of *Thaumetopoea pityocampa* Schiff.(Lepidoptera: Thaumetopoeidae) in relation to food consumption. Forest ecology and management 15(1):65-68.
Battisti, A., M. Stastny, S. Netherer, C. Robinet, A. Schopf, A. Roques, and S. Larsson. 2005. Expansion of geographic range in the pine processionary moth caused by increased winter temperatures. Ecological applications 15(6):2084-2096.
CABI. 2018. Crop Protection Compendium. Commonwealth Agricultural Bureau International (CABI). htpp://www.cabi.org. (Archived at PERAL).
Cadahia, D., and A. Insua. 1970. Estimación de los daños producidos por *Thaumetopoea pityocampa* Schiff. en repoblaciones de Pinus radiata D. Don. Boletín del Servicio de Plagas Forestales 28:1959-1970.
Carus, S. 2004. Impact of defoliation by the pine processionary moth (*Thaumetopoea pityocampa*) on radial, height and volume growth of Calabrian pine (*Pinus brutia*) trees in Turkey. Phytoparasitica 32(5):459-469.
Cayuela, L., J. A. Hódar, and R. Zamora. 2011. Is insecticide spraying a viable and cost-efficient management practice to control pine processionary moth in Mediterranean woodlands? Forest ecology and management 261(11):1732-1737.
Cheraghian, A. 2013. Pine Processionary Caterpillar *Thaumetopoea pityocampa* (De. & Schi). Ministry of Jihad-e-Agriculture, Plant Protection Organization, Islamic Republic of Iran. 11 pp.
Cuevas, P., R. Montoya, X. Belles, F. Camps, J. Coll, A. Guerrero, and M. Riba. 1983. Initial field trials with the synthetic sex pheromone of the processionary moth *Thaumetopoea pityocampa* (Denis and Schiff.). Journal of chemical ecology 9(1):85-93.
Devkota, B., and G. H. Schmidt. 1990. Larval development of Thaumetopoea pityocampa (Den. & Schiff.) (Lep., Thaumetopoeidae) from Greece as influenced by different host plants under laboratory conditions. Journal of Applied Entomology 109(1-5):321-330.
Durkaya, A., B. Durkaya, and İ. Dal. 2009. The effects of the pine processionary moth on the increment of crimean pine trees in Bartin, Turkey. African Journal of Biotechnology 8(10).
EPPO. 2004. Diagnostic Protocols for Regulated Pests Protocoles de Diagnostic Pourles Organismes Reglementes. OEPP/EPPO Bulletin 34(2):271-279.
Gilligan, T. M., S. C. Passoa, and F. Groenen. 2014. Screening aid: Processionary moths, *Thaumetopoea* spp. USDA-APHIS-PPQ-S&T, Fort Collins, CO. 6 pp.
Halperin, J. 1986. Application of pityolure for detection and control of *Thaumetopoea pityocampa* in Israel EPPO Bulletin 16(4):627-632.
Hódar, J. A., J. Castro, and R. Zamora. 2003. Pine processionary caterpillar *Thaumetopoea pityocampa* as a new threat for relict Mediterranean Scots pine forests under climatic warming. Biological conservation 110(1):123-129.
Hódar, J. A., R. Zamora, and J. Castro. 2002. Host utilisation by moth and larval survival of pine processionary caterpillar *Thaumetopoea pityocampa* in relation to food quality in three Pinus species. Ecological Entomology 27(3):292-301.
Hódar, J. A., R. Zamora, J. Castro, and E. Baraza. 2004. Feast and famine: previous defoliation limiting survival of pine processionary caterpillar Thaumetopoea pityocampa in Scots pine Pinus sylvestris. Acta Oecologica 26(3):203-210.
Jacquet, J.-S., A. Bosc, A. P. O'Grady, and H. Jactel. 2013. Pine growth response to processionary moth defoliation across a 40-year chronosequence. Forest ecology and management 293:29-38.
Kanat, M., F. Sivrikaya, and M. Serez. 2002. A research on damage of pine processionary moth (Thaumetopoea pityocampa Schiff.) on Pinus brutia Ten. trees, and the effect of tending activities on the diameter increment of Calabrian pine in Kahramanmaraş. Pages 44-51 *in* Pine Processionary Moth Symposium,(Ed. M. Kanat),(Kahramanmaraş, Turkey).
Kerdelhué, C., L. Zane, M. Simonato, P. Salvato, J. Rousselet, A. Roques, and A. Battisti. 2009. Quaternary history and contemporary patterns in a currently expanding species. BMC Evolutionary Biology 9(1):220.
Laurent-Hervouët, N. 1986. Mesure des pertes de croissance radiale sur quelques espèces de *Pinus* dues à deux défoliateurs forestiers. I-Cas de la processionnaire du pin en région méditerranéenne. Pages 239-262 *in* Annales des sciences forestières. EDP Sciences.
Masutti, L., and A. Battisti. 1990. *Thaumetopoea pityocampa* (Den. & Schiff.) in Italy bionomics and Hódar

Mirchev, P., G. Tsankov, Avci, and M. Matova. 2007. Study of some aspects of ecology of pine processionary moth, Thaumetopoea pityocampa (Den. & Schiffe.) (Lep., Thaumetopoeidae) and its egg parasitoids in Turkey. Silva Balcanica 8(1):66-78.

Mol, T., S. Inac, and M. Kanat. 2002. Pheromon trials against pine processionary moth (*Thaumetopoea pityocampa* (Schiff.)) for Calabrian pine stands at the Ferhus field of Kahramanmaras-Turkey. In T. Naydenova, I. Raev, A. Alexandrov, B. Rossnev, I. Marinov, V. Vassilev, et al. (Eds.) Study, conservation and utilisation of forest resources. Proceedings of the Third Balkan Scientific Conferece, 2001, October 2-6, Sofia, Bulgaria. 2002.

OEPP/EPPO. 2004. Diagnostic protocols for regulated pests Thaumetopoea pityocampa. Bulletin OEPP/EPPO 34:155-157.

Pérez-Contreras, T., J. J. Soler, and M. Soler. 2008. Needle asymmetry, pine vigour and pine selection by the processionary moth *Thaumetopoea pityocampa*. Acta Oecologica 33(2):213-221.

PestID. 2018. Pest Identification Database (PestID). United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine. https://mokcs14.aphis.usda.gov/aqas/login.jsp. (Archived at PERAL).

Petrakis, P. V., V. Roussis, D. Papadimitriou, C. Vagias, and C. Tsitsimpikou. 2005. The effect of terpenoid extracts from 15 pine species on the feeding behavioural sequence of the late instars of the pine processionary caterpillar Thaumetopoea pityocampa. Behavioural Processes 69(3):303-322.

Petrakis, P. V., C. Tsitsimpikou, O. Tzakou, M. Couladis, C. Vagias, and V. Roussis. 2001. Needle volatiles from five Pinus species growing in Greece. Flavour and Fragrance Journal 16(4):249-252.

Pimentel, C., T. Calvao, M. Santos, C. Ferreira, M. Neves, and J.-Å. Nilsson. 2006. Establishment and expansion of a *Thaumetopoea pityocampa* (Den. & Schiff.)(Lep. Notodontidae) population with a shifted life cycle in a production pine forest, Central-Coastal Portugal. Forest ecology and management 233(1):108-115.

Robinet, C., C.-E. Imbert, J. Rousselet, D. Sauvard, J. Garcia, F. Goussard, and A. Roques. 2012. Human-mediated long-distance jumps of the pine processionary moth in Europe. Biological invasions 14(8):1557-1569.

Romanyk, N., and D. Cadahía. 1992. Plagas de pinos y otras coníferas. Plagas de insectos en las masas forestales espanolas. 2a ed. Madrid: Ministerio de Medio Ambiente.

Salman, M. H. R., K. Hellrigl, S. Minerbi, and A. Battisti. 2016. Prolonged pupal diapause drives population dynamics of the pine processionary moth (*Thaumetopoea pityocampa*) in an outbreak expansion area. Forest ecology and management 361:375-381.

Sbabdji, M., and B. Kadik. 2011. Effects of Atlas cedar (Cedrus atlantica) defoliation on performance of the pine processionary moth (*Thaumetopoea pityocampa*). Journal of Pest Science 84(2):213-217.

Schmidt, G., E. Tanzen, and S. Bellin. 1999. Structure of egg-batches of *Thaumetopoea pityocampa* (Den. and Schiff.)(Lep., Thaumetopoeidae), egg parasitoids and rate of egg parasitism on the Iberian Peninsula. Journal of Applied Entomology 123(8):449-458.

Sebti, S., and G. Chakali. 2014. Distribution and importance of the pine processionary moth winter nests *Thaumetopoea pityocampa* (Denis & Schiffermüller)(Lepidoptera: Notodontidae) in the forests cedar of the national park of Chréa (Algeria). International Journal of Agricultural Science and Research (IJASR) 4(5):77-84.

Stastny, M., A. Battisti, E. Petrucco-Toffolo, F. Schlyter, and S. Larsson. 2006. Host-plant use in the range expansion of the pine processionary moth, *Thaumetopoea pityocampa*. Ecological Entomology 31(5):481-490.

UK Forestry Commission. 2018. Pine processionary moth - (Thaumetopoea pityocampa). UK Forestry Commission. Last accessed 9/19/2018, https://www.forestry.gov.uk/pineprocessionarymoth#publications.

USDA. 2017. Plants for Planting Manual. United States Department of Agriculture, Washington, DC. 1102 pp.

Zhang, Q. H., and M. R. Pavia. 1998. Female calling behaviour and male response to the sex pheromone in *Thaumetopoea pityocampa* (Den. & Schiff.) (Lep., Thaumetopoeidae). Journal of Applied Entomology 122(1-5):353-360.

Zovi, D., M. Stastny, A. Battisti, and S. Larsson. 2008. Ecological costs on local adaptation of an insect herbivore imposed by host plants and enemies. Ecology 89(5):1388-1398.

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