Potential of Entomopathogens in Biological Control of Pine Processionary Moth (*Thaumetopoea Pityocampa* (Den. & Schiff.): A Brief Literature Review

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Abstract

Pine processionary moth, *Thaumetopoea pityocampa* (Den. & Schiff.) is a serious pest in pine forests. This pest extends its geographical distribution, currently ranging from North Africa to Europe, which includes Turkey. Its larvae cause defoliation by eating leaves mainly on coniferous species, *Pinus brutia, P. nigra, P. pinaster*, and *P. pinea* in Turkey. Today, the fight against *T. pityocampa* is not successful enough. Entomopathogenic microorganisms such as viruses, bacteria, protists, fungi and nematodes are promising agents for pest control. There are some studies on the entomopathogenic organisms that cause diseases in the natural populations of *T. pityocampa*. The *T. pityocampa* populations can be controlled with entomopathogens such as *Bacillus thuringiensis*, cypovirus and fungi. Investigations to find the most effective entomopathogen against *T. pityocampa* should be continued. In this paper, recent developments about entomopathogens, which are either isolated or tested, are discussed as potential agents against *T. pityocampa*.

Keywords: *Thaumetopoea pityocampa, entomopathogen, biological control, pine forest*

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I. INTRODUCTION

The pine processionary moth (PPM) *Thaumetopoea pityocampa* (Den. & Schiff.) (Lepidoptera Thaumetopoeidae) is the most important pine tree pest, which is infecting *Pinus* spp. in many countries, including Turkey other countries [6, 8]. The pest is a serious defoliator of *Pinus* spp., particularly in countries where it occurs in high densities. The *T. pityocampa* extends its geographical distribution over a wide region stretching from North Africa to Central Europe [3, 5]. Chemical insecticides were used to control *T. pityocampa*; however,, these chemicals have potentially undesirable side effects on humans, plants and other animal species, especially predators and parasites of *T. pityocampa* [15]. In forest ecosystems, entomopathogens, such as bacteria, fungi, viruses, protozoa and nematodes, can replace some of the less specific and more dangerous chemical insecticides, enabling naturally occurring beneficial insects to play a greater role in the control and regulation of the pest populations [1]. Entomopathogens provide a resource for selection of novel effective agents in controlling insect pests of forest trees and agricultural crops. Entomopathogenic fungi infect a broader range of insects than do other microorganisms and infection of the Lepidoptera, Homoptera, Hymenoptera, Coleoptera and Diptera are quite common [7]. Baculoviruses have a very important place in biological control because non-target insects do not cause harm to humans and the environment [18]. Symbiotic bacteria in the front of the entomopathogenic nematodes are released into the hemocoel of the host insect during infection, multiplying rapidly in the blood and killing the insect [10]. More than 100 bacterial pathogens have been identified as insect pathogens, but certain *Bacillus* species have been highly successful in biological control [18]). In this context, there are many publications and studies on entomopathogens detected from *T. pityocampa*. Based on available literature, entomopathogens detected from *T. pityocampa* are viruses, bacteria, fungi and nematodes.

II. MATERIALS AND METHODS

A detailed literature review about the pine processionary moth has been carried out. Literature review was conducted using Web of Science, Scopus and Google Academic. The literature is grouped under three headings: damage and distribution of the pine processionary moth, control methods, and entomopathogenic studies for its biological control. As a result of the literature review, an evaluation was made about the place of entomopathogens in the biological control of the pine processionary moth.

III. RESULTS AND DISCUSSION

Viruses

Members of about eleven virus families are known to infect insects. In particular, baculoviridae (especially nuclear polyhedrosis and granulosis viruses) constitute the most important members of the control strategy due to their efficacy, stability and comprehensive safety [1]. According to literatures, a list including entomopathogenic viruses of *T.pityocampa* populations is given in the Table 1. İnce et al. [13] detected cytoplasmic polyhedrosis virus (CPV), which causes infection of midgut cells in the larvae of *T. pityocampa.* Yaman [23] documented the ultrastructure of *T. pityocampa* cypovirus in the intestinal lumen of the predatory insect *Calasoma sycophanta* L. (Coleoptera: Carabidae). They found that the virus would be transmitted to populations of *T. pityocampa* by the predator insect.

Table 1. Entomopathogenic viruses found or tested for *T.pityocampa*.

Entomopathogen Group	Entomopathogen Species	References
Viruses	Cypoviruses (CPV) Cytoplasmic Polyhedrosis Virus (CPV)	Yaman 2021; İkbal Agah 2007; Harpaz et al. 1965

Bacteria

Bacteria cause pathogenicity in insects. According to literatures, entomopathogenic bacteria of *T. pityocampa* populations is listed in Table 2. İnce et al. [14] investigated the bacterial flora of the pest that aims to find a more effective and safe biological control agent against *T. pityocampa*. A large number of bacterial isolates were determined based on morphological, physiological, biochemical and molecular methods. In another study, Cebeci et al. [8] tested the insecticide with *Bacillus thuringiensis* subsp. *kurstaki* in field applications against *T. pityocampa.* Results showed satisfactory results against PPM when insecticide was used under suitable conditions in pine forests in Turkey.

Table 2. Entomopathogenic bacteria found or tested for *T.pityocampa*.

Entomopathogen Group	Entomopathogen Species	References
Bacteria	*Bacillus thuringiensis* subsp. *kurstaki* (Btk) *Arthrobacter* spp. *Staphylococcus* spp. *Bacillus subtilis* *Serratia liquefaciens* *Bacillus thuringiensis* subsp. *morrisoni* *Bacillus thuringiensis* *Staphylococcus cohnii* *Bacillus licheniformis* *Bacillus pumilus* *Brevibacterium* spp. *Bacillus simplex*	İnce 2008; Cebeci et al. 2010; Battisti et al. 1998; Triggiani and Tarasco 2003;

Entomopathogenic fungi in general are less host specific. One strain of *Beauveria bassiana* has been reported as a parasitizing agent of more than 100 different insect species (Cameron 1977). Most entomopathogenic fungi have the advantage compared to others because they infect following contact by penetrating the host integument and need not be ingested, hence, they can be used as contact pesticides [1]. Table 3 shows a list including entomopathogenic fungi of *T.pityocampa* populations. Sevim et al. [17] also investigated fungal pathogens to find a more effective and safer biological agent against *T. pityocampa*. Five different fungi were isolated and identified based on their morphological and molecular features, including ITS and partial EF1-[alpha] sequence.

Alkan Akıncı et al. [2] isolated four fungi, *Isaria farinosa*, *Beauveria bassiana*, *Fusarium sambucinum* and *Aspergillus terreus* from *T. pityocampa* larvae collected from pine forests. The authors performed an experiment against fourth instar larvae under laboratory conditions to determine their activity against *T. pityocampa* larvae. They observed differences between the activities of the fungi and determined *I. farinosa* isolate having the highest activity.

Ozdemir et al. [16] tested the *Metarhizium anisopliae* and *B. bassiana* against fourth instar *T. pityocampa* larvae. This study showed that the entomopathogenic fungal isolates (*M. anisopliae* and *B. bassiana*) are potential biological control agents of *T. pityocampa.* However, further studies are needed to assess the effectiveness of the isolates against *T. pityocampa* and other pests under field condition. Likewise, Barta et al. [3] identified entomopathogenic fungal species in natural populations of *T. pityocampa* in Bulgaria. In this study, *B. pseudobassiana*, *B. varroae* and *Purpureocillium lilacinum* from *T. pityocampa* were reported for the first time. Finally, Georgieva et al. [11] detected the hyperparasitic fungus *Syspastospora parasitica* attacking two *Beauveria* spp., infecting the larvae and pupae of the new tritrophic units *T.pityocampa.*

Table 3. Entomopathogenic fungi found or tested for *T.pityocampa*.

Entomopathogen Group	Entomopathogen Species	References
Fungi	*Beauveria bassiana* *Metarhizium anisopliae* *Beauveria pseudobassiana* *Beauveria varroae* *Purpureocillium lilacinum* *Isaria farinosa* *Fusarium sambucinum* *Fusarium sambucinum* *Paecilomyces* spp. *Tolypocladium* spp. *Beauveria* spp. *Metarhizium* spp. *Lecanicillium* (=*Verticillium*) spp. *Metarhizium brunneum*	Ozdemir et al. 2019; Barta et al. 2019; Alkan Akinci et al. 2017; Sevim et al. 2010; Tarasco et al. 2015; Er et al. 2007; Sönmez et al. 2017; Georgieva et al. 2020

Nematodes

Triggiani and Tarasco [22] tested *Steinernema feltiae, S.*

carpocapsae and *Heterorhabditis bacteriophora* against *T. pityocampa*. Best results were obtained with *S. Feltiae*, which was able to limit the winter populations of the lepidoptera under the threshold of 50 %. In another study of Triggiani and Tarasco [21] tested infective offspring of *Steinernema feliae*, *S. carpocapsae* and *Heteroprhabditis bacteriophora* against to *T. pityocampa* in aqueous and gel suspensions in a *Pinus halepensis* plantation field. As a result of the study, the applicability of the *S. feliae* gel suspension was found to be the most effective in reducing larval populations. Gözel and Gözel [12] investigated the activities of entomopathogenic nematodes (*S. carpocapsae* and *H. bacteriophora*) against *T. pityocampa* larvae under laboratory conditions. Mortality in larvae varied by 60-100% depending on the nematode species and temperature. According to the results obtained from the study, EPNs have an important potential for use in the biological control of *T. pityocampa*.

According to literatures, a list including entomopathogenic nematode of *T.pityocampa* populations and agents for natural control is given in the Table 4.

Table 4. Entomopathogenic nematode found or tested for *T.pityocampa*.

Entomopathogen Group	Entomopathogen Species	References
Nematoda	*Steinernema feltiae* *Steinernema carpocapsae* *Heterorhabditis bacteriophora*	Triggiani and Tarasco 2002; Gözel and Gözel 2019;

IV. CONCLUSION AND RECOMMENDATIONS

Chemical insecticides used to control *T. pityocampa*e have potentially undesirable side effects on humans, plants and other animal species, especially predators and parasites of *T. pityocampa* [15]. In forest ecosystems, entomopathogens such as bacteria, fungi, viruses, protozoa and nematodes can replace some of the less specific and more dangerous chemical insecticides, enabling naturally occurring beneficial insects to play a greater role in the control and regulation of insect pest populations [1]. Investigations to find the most effective entomopathogen against *T. pityocampa* should be continued. *T. pityocampa* populations can be controlled with entomopathogens such as *Bacillus thuringiensis*, cypovirus and fungi.

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