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# THE ENVIRONMENTAL IMPACT ON EGG FECUNDITY OF *THAUMETOPOEA SOLITARIA* IN THE NORTH OF IRAQ

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**ABSTRACT:**

In this study, egg fecundity of pistachio processionary bud moth *Thaumetopoea solitaria* (Lepidoptera- Notodontidae) on three different types of trees was investigated in Koya, Haybat Sultan forest during 2018 and 2019. The egg masses were collected from branches of *Pistacia vera*, *Pistacia khunjuk* and *Rhus coriaria* after the emergence of larvae. Collecting clusters on *P. vera, P. khunjuk, and R. coriaria* trees during the mentioned period was different (36 and 38, 32 and 30, and 9 and 13 respectively). In 2018, the highest ratio of eggs per mass was 159.44±15.76 on *R. coriaria* tree, and the lowest was 129.50±8.46 on the *P. khunjuk* tree. The highest percentage of the hatched egg was recorded during 2019 on *P. vera* tree, which was 98.41%, while 90.41%.was the lowest rate on *P. khunjuk* tree. Regarding the unhatched eggs, it was 96.34% on *P. khunjuk* tree during 2019, however, it was only 13.34% *on R. coriaria* in 2018. On the other hand, parasites were found to be on 42.00% of the hatched eggs on *R. coriaria* tree and 3.07% on *P. vera* tree in 2019 and 2018 respectively. Although, the ratio of the larval was ascending significantly to 96.93% on *P. vera* during 2018, it was descending to 58.00% on *R. coriaria* tree in 2019. Hence, the success of the eggs was 93.10% on *P. khunjuk* tree, and only 52.53% on *R. coriaria* in 2018. The effect of the rainfall rate during the surveyed period was considered, whilst the variation of air temperature is negligible as its effect is unnoticeable.

**KEYWORDS:** Environmental Impact, Egg Fecundity, *Thaumetopoea solitaria*, Egg Mass, Egg Parasite, pistachio processionary bud moth, Egg parasitoid and Predator

## 1. INTRODUCTION

There are a few studies that have been conducted on the pistachio processionary bud moth *Thaumetopoea solitaria* (Lepidoptera: Notodontidae) (Freyer, 1838). This species has called Solitaria by mistake, because their larvae are in the gregarious or colony (Halperin, 1983), and Processional means the head-to-tail, which relates to the behavior of the larvae at the time of migration (Battisti et al., 2014).

Food preference and environmental conditions are among the most important factors affecting the distribution of organisms (Strong et al., 1984 & Parmesan et al., 1999). The distribution of the insect is related to the spread of its host plant *Pistacia spp.* (Davatchi, 1958), which in most of the countries the host plant exists (Mirchev et al., 2014). In Iraq, three species of Pistachio were found: *Pistacia eurycarpa* Yalt., *Pistacia khinjuk* Stocks, and *Pistacia vera* L. (Townsend & Guest, 1980). These types of trees were also found in Anatolia including Turkey, Cyprus, East of Syria, Lebanon, northern Iraq (Kurdistan Region), Iran, and most of the Mediterranean area (Rougeot & Viette, 1978 & Lamy, 1990). Also, another host plant of *T. solitaria* is a Sumach species (*Rhus coriaria* L.), which is widely distributed in the north of Iraq (Kurdistan Region) (AL-Maa, 2006).

The *Pistacia spp*. is one of the most important horticultural trees, which is known as the green-gold tree (Alizadeh et al., 2007). The investigation, however, shows that some different species of this plant has some pharmacological effect, such as anti-inflammatory (Giner et al., 2001), and anti-microbial action (Ali-Shtayeh & Abu Ghdeib, 1999 & Magiatis et al., 1999). *Pistacia khinjuk* stems excrete an exudate whenever it is cut, this exudate is known as bneshta Tal (gum). This could be used as focal therapy to treat burns and stomach ulcers. The hydro distilled essential oils from *Pistacia vera* L. stem exudate was tested against three bacteria (Ghalem & Mohamed, 2009). In addition, Sumach (*Rhus coriaria* Linn.) (Family of Anacardiacea) was used as a condiment, spice, appetizer, and as a souring agent for centuries. In a system of traditional medicine, this plant has been used in the treatment of diarrhea, ophthalmia, sore throat, dysentery, ulcer, hematemesis, animal bites, pain, hemorrhoids, hemoptysis, hemorrhage, antioxidant, antiinflammatory/chondroprotective, wound healing, leucorrhea, conjunctivitis, diuresis, poison, antifungal, antibacterial, and liver disease (Shabbir, 2012, Adwen et al., 2010, Gündüz et al., 2010; Hashem & Alamri, 2010 and Panico et al., 2009).

*Thaumetopoea solitaria* species is an economically important pest, while it causes heavy damages on *Pistacia sp.* The early larval instars are feed and survive only on the swallow bud and very young leaves, which causes a dwarf tree, whereas complete defoliation was caused by consuming mature leaf by older larval instars (Gindin et al., 2008). When defoliation is severe, the summer growth of the fruit stops, and the premature fruit falls (Omer et al., 2004). In addition, the caterpillars have fine hairs on their back containing a protein that causes severe irritation and dermatitis on humans and animals (Ducombs et al., 1981).

Regarding egg fertility, parasitoid is one of the most significant factors, which affects reducing the density of pests (Mirchev & Tsankov, 2012). Three egg parasitoids were recorded for the first time in *T. solitaria* F. eggs *Anastatus bifasciatus* (Hymenoptea: Eupelmidae), *Ooencyrtus pityocampae* and *Ooencyrtus sp*., which is closely related to *O. masii* and *O. ascalaphi* (Hymenoptea: Ooencyrtidae), besides, the impact of egg

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parasitoids on the host was calculated to be 2.9-21.5% (Mirchev et al., 2014). *O. pityocampae* can be found as an egg parasitoid in many species including *T. pityocampa*, *T. wilkinsoni*, *T. solitaria* F., and *T. bonjeani* (Schmidt et al., 1999). *O. pityocampae* is polyphagous and has several generations per year on various hosts. The overall parasitism can locally reach up to 45 % (Tsankov et al., 2006). *Trichogramma embryophagum* frequently emerges from eggs of *Thaumetopoea spp*. in the central and east Mediterranean region (Avci, 2000). Egg predation was found to be about 3%, but supplied no information regarding the species involved (Tsankov et al., 2006). The aim of the study is to understand the environmental, parasite, and predator impacts on the egg fecundity of the insect.

## 2. MATERIALS & METHODS

### 2.1 Sampling Collection

The data were collected from Haybat Sultan Mountains on April 20, 2018, and April 17, 2019, after the larvae emerged. Then the Egg clusters of *T. solitaria* with parts of branches (about 5 cm in length) were put in the test tube, and closed by cotton then stored at a laboratory (Mirchev et al., 2006). After that, the hatched egg masses were collected. The clusters were regarded as a stock field of *P. vera* as a plant stand and *P. khunjuk* and *R. coriaria* were spread as a nature for sampling. This was situated in the main area of *T. solitaria*, which was distributed in the mountains. A total number of 158 masses were collected, which contained 23118 eggs. On *P. vera* trees, 74 masses were collected; 36 of them were in 2018 and 38 in 2019. The number of egg masses which were collected on *P. khunjuk* was 62 masses; 32 egg masses in 2018 and 30 in 2019. 22 clusters were collected on the *R. coriaria* (9 clusters in 2018 and 13 during 2019) and examined.

### 2.2 Determine the egg fecundity affecting factors

To find out the egg fecundity dynamics, some abiotic and biotic factors were considered. Abiotic factors, such as precipitation and temperature of the observed period were contributed. Also, biotic factors including two types of trees of the forest were monitored with the *Thaumetopoea solitaria* natural enemies, such as parasites and predators.

### 2.3 Sampling Examinations

Directly after collection, the egg clusters were individually separated by cutting into test tubes and closed with cotton stoppers. They were transported to the Entomological Laboratory at Koya University. The cover scales of the egg clusters were removed and all eggs were cut and analyzed in detail under a microscope (40 x magnifications) (see figure 2) to detect the larval emerge the egg, the parasitoids emerging. In order to determine the dead parasitoid specimens in eggs without emergence holes, and disrupted eggs that breakdown by predators.

### 2.4 Study Area

The study area locates at 3.5 km from the northeast of Koysnjaq district, in Erbil Governorate, Kurdistan Region of Iraq (See figure 1) (Aziz et al., 2020). The surveyed forest is a mixture of native and planted trees. The Haybat Sultan mountain height reaches 1110m above sea level and the sampling location elevation was between 740 to 900 m. The climatic condition of the study area is within the Mediterranean climatic system, which is hot, and dry in summer; and cool, and wet in winter (Naqshabandy, 1998 and Salih et al., 2019). The annual precipitation of the last 25 years reaches 646mm (Koya Weather Station, 2018-2019). According to the data in table 1, the average temperature from September 2017 to March 2018 is almost the same as September 2018 to March 2019 which was 17.8C and 17.7C respectively, but among the months, a little variation can be noted. Regarding the total precipitation from September 2017 to March 2018, for 7 months is 467.6 mm, while it increases by 125.1mm for the period between September 2018 to March 2019, which was reached 592.7 mm. In fact, most of the annual precipitation of the study area is occurring in the first three months and the last four months of the year, which is the period that was considered for this study.

Table 1. Meteorological data of the study area for the period of monitoring from 2017 to 2019 (Koya Weather Station, 2018-2019)

| Time period | Precipitation (mm) Total | Temperature (°C) Mean |
|---|---|---|
| September 2017 | 0 | 30 |
| October 2017 | 0.3 | 23 |
| November 2017 | 65.4 | 17 |
| December 2017 | 25.1 | 14 |
| January 2018 | 55.4 | 11 |
| February 2018 | 299.7 | 13 |
| March 2018 | 21.7 | 17 |
| | Total 467.6 | Average 17.8 °C |
| September 2018 | 0 | 31 |
| October 2018 | 69.5 | 27 |
| November 2018 | 58.5 | 18 |
| December 2018 | 75.7 | 14 |
| January 2019 | 137.3 | 9 |
| February 2019 | 86.2 | 9 |
| March 2019 | 165.5 | 16 |
| | Total 592.7 | Average 17.7 |

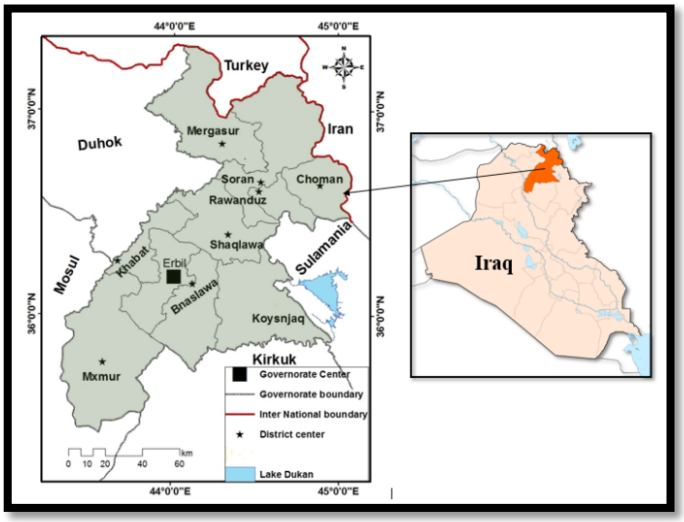


Figure 1. Map of the Studied Area

## 3. RESULTS AND DISCUSSIONS

On the site, where the sample material was collected the egg masses of *T. solitaria* were found on branches of three types of tree (*Pistacia vera*, *Pistacia khunjuk* and *Rhus coriaria*). The *T. solitaria* eggs are white above, grayish-yellow below, an

overturned truncated hexagonal, and they were deposited in a flat, one-layered, symmetrical, hexagonal cluster. The average number of eggs per mass for *Pistacia vera*, *Pistacia khunjuk* and *Rhus coriaria* were 150.69±9.05, 138.65±8.46 and 159.44±15.76 respectively for the first year of the study, and it was 161.21±6.59, 142.30±8.34 and 141.92±10.49 for respectively for the second year as it was shown in table.2. Overall, in both years, the number of eggs laid by the female of *T. solitaria* on *P. vera* was more than the number of eggs which were found on the other trees.

Table 2: Mean±Std. Error number of eggs in masses which were collected on the three types of trees in 2018 and 2019.

| Plant Type | Year | Number of Egg Mass | Total Number of Eggs | Mean±Std. Error |
|---|---|---|---|---|
| *P. vera* | 2018 | 36 | 5425 | 150.69±9.05 |
| | 2019 | 38 | 6000 | 157.89±6.59 |
| *P. khunjuk* | 2018 | 32 | 4144 | 129.50±8.46 |
| | 2019 | 30 | 4269 | 142.30±8.34 |
| *R. coriaria* | 2018 | 9 | 1435 | 159.44±15.76 |
| | 2019 | 13 | 1845 | 141.92±10.49 |
| Total | | 158 | 23118 | 149.05±9.78 |

In both years, *T. solitaria* eggs with high survivability were observed. In 2019, the hatching percentage of the eggs reached up to 98.41%, which was recorded among the eggs deposited on the *P. vera* tree compared to 90.41% for the eggs deposited on the *P. khunjuk* (see table.3). The table below shows the non-hatched egg data, which was 9.59% for *P. khunjuk* tree, and the unhatched eggs were less than 2% for the *P. vera* tree in 2019. The abiotic physical causes were mainly due to the rainfall, which affected the non-hatched egg, therefore, it increased by approximately 10% (see table 1).

Table 3: The percentage of hatched or unhatched eggs of T. solitaria on three types of trees.

| Plant Type | Year | Number of Hatched Eggs | Hatched Eggs Percentage | Number of Unhatched Eggs | Unhatched Eggs Percentage |
|---|---|---|---|---|---|
| *P. vera* | 2018 | 4983 | 91.85 | 442 | 8.15 |
| | 2019 | 5905 | 98.41 | 95 | 1.59 |
| *P. khunjuk* | 2018 | 3987 | 96.21 | 157 | 3.79 |
| | 2019 | 3860 | 90.41 | 409 | 9.59 |
| *R. coriaria* | 2018 | 1405 | 97.90 | 30 | 2.10 |
| | 2019 | 1762 | 95.50 | 83 | 4.50 |

The non-hatched eggs were caused by two factors, which are the natural mortality of the egg and the impact of egg predators, however, the impact of the predators was limited. Hence, the ratio of the non-hatched eggs was 96.34% in 2019 for *P. khunjuk*, but the unutilized eggs were decreased to 13.34% in 2018 for *R. coriaria* tree, as shown in (table 4). Likewise, the number of egg predators was 86.66% for the R. *coriaria* tree in 2018, but this number decreased to 3.66% in the last year for the *P. khunjuk* tree (see table, 3). Lack of rain during 2018 (see table 1) was an important factor for increasing the number of the predators in the studied area to 86.66% of *T. solitaria* over the total number of non-hatched eggs.

Table 4: The percentage of unhatched eggs and egg predators of T. solitaria on three different types of trees.

| Plant Type | Year | Number of Non-hatched Egg | Number of Unhatched Egg | Unhatched Egg % | Number of Predator Egg | Predator Egg % |
|---|---|---|---|---|---|---|
| *P. vera* | 2018 | 442 | 294 | 66.52 | 148 | 33.48 |
| | 2019 | 95 | 48 | 50.53 | 47 | 49.47 |
| *P. khunjuk* | 2018 | 157 | 81 | 51.60 | 76 | 48.40 |
| | 2019 | 409 | 394 | 96.34 | 15 | 3.66 |
| R. *coriaria* | 2018 | 30 | 4 | 13.34 | 26 | 86.66 |
| | 2019 | 83 | 24 | 28.92 | 59 | 71.08 |

The hatched eggs were either affected by the parasitoid or emerged as larvae. In 2018, 96.93% of hatched eggs became larvae on the twigs of *P. vera*, while in 2019, it changed to 58.00% for *R. coriaria* (see table 5). The recorded amount of parasitized eggs was varied for different trees; the highest was for the *R. coriaria* tree (42.00), whereas the lowest was for the *P. vera* tree (3.07). Figure 2 shows the unhatched and the hatched eggs which were destroyed by predators. The rainfall could not flash the clusters, as they were firm with the bark, however, and the empty egg clusters are still found to be attached to the twigs 1-2 years after they were deposited. Therefore, the rainfall during 2019 (as in table 1) had a negative effect on the percentage of larval hatched eggs, which reduced them to 58.00% on the *R. coriaria* tree.

Table 5: The ratio of the eggs becoming caterpillars and egg parasitism from hatched eggs of T. solitaria on three different types of trees.

| Plant Type | Year | Number of Hatched Egg | Number of Larval Hatched Egg | Larval Hatched Egg % | Number of Parasitoids Hatched Egg | Parasitoids Hatched Egg % |
|---|---|---|---|---|---|---|
| *P. vera* | 2018 | 4983 | 4830 | 96.93 | 153 | 3.07 |
| | 2019 | 5905 | 5236 | 88.68 | 669 | 11.32 |
| *P. khunjuk* | 2018 | 3987 | 3858 | 96.77 | 129 | 3.23 |
| | 2019 | 3860 | 2820 | 73.06 | 1040 | 26.94 |
| *R. coriaria* | 2018 | 1405 | 1304 | 92.82 | 101 | 7.18 |
| | 2019 | 1762 | 969 | 58.00 | 793 | 42.00 |

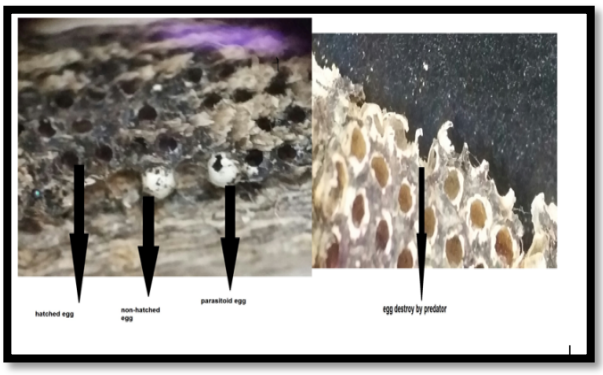


**Figure 2. Types of eggs observed in egg clusters.**

Table 6 illustrates the number and percentage of larval, parasitoid, predator, and unhatched eggs overall egg numbers of *T. solitaria* on three different types of tree during the study. The ratio of the larvae showed that the highest percentage was 93.10

during 2018 on the *P. khunjuk*, but the lowest was recorded on the *R. coriaria* tree in 2019, which was 52.52%. In 2018, the hatched egg was 90.87% on the *R. coriaria* and 89.03 and 87.27% for *P. vera* during 2018 and 2019 respectively. 42.98% was the highest amount for *R. coriaria* in 2019 over the parasite eggs, and the lowest percentage was 2.82 in 2018 on *P. vera*. The impact of predators was 3.20% in 2019 on the *R. coriaria,* which was the highest, and 0.35% on the *P. khunjuk,* which was the lowest in 2019. The data recorded on the unhatched egg was 9.23% for *P. khunjuk* in 2019, which was the highest, and 0.28% in 2018 on *R. coriaria* was the lowest.

Table 6: Number and percentage of larvae, parasitoid, predator, and unhatched eggs overall egg numbers of T. solitaria on three different types of trees during 2018 and 2019.

| Plant Type | Years | Number of Total Egg | Larval | | Parasitoid | | Predator | | Unhatched | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. | % | No. | % | No. | % | No. | % |
| *P. vera* | 2018 | 5425 | 4830 | 89.03 | 153 | 2.82 | 148 | 2.73 | 294 | 5.42 |
| | 2019 | 6000 | 5236 | 87.27 | 669 | 11.15 | 47 | 0.78 | 48 | 0.80 |
| *P. khunjuk* | 2018 | 4144 | 3858 | 93.10 | 129 | 3.11 | 76 | 1.83 | 81 | 1.95 |
| | 2019 | 4269 | 2820 | 66.06 | 1040 | 24.36 | 15 | 0.35 | 394 | 9.23 |
| *R. coriaria* | 2018 | 1435 | 1304 | 90.87 | 101 | 7.04 | 26 | 1.81 | 4 | 0.28 |
| | 2019 | 1845 | 969 | 52.52 | 793 | 42.98 | 59 | 3.20 | 24 | 1.30 |

## 4. DISCUSSION

The egg cluster of *Thaumetopoea solitaria* was found on one planted tree (*Pistacia vera*) and two native trees (*Pistacia khunjhuk* and *Rhus cariaria*), although a greater number of collected masses was on the *P. vera*. The egg masses of the moth were found only on the *Pistacia terebinthus* L. However, Schmidt in 1990 declared that the egg cluster of the *T. solitaria* was discovered on all the *Pistacia* genus trees. In addition, Serafimousky in 1975 mentioned that, all caterpillars died on the leaves of *Juglans regia* L., *Pinus spp*., *Cupersus sempervirens* L., *Quercus spp*. *Ailanthus altissima* (Mill) Swingle, and *Fraxinus americana* L. while some others illustrated that the Pistachio Processionary Bud Moth larvae were mono-delicious, they were fed on three different species of trees, as well as when the host plant was changed to another host plant of the study, when there was no food left for the larvae, and they were hungry then it fed on the new host, consequently, most of the larvae died.

In Bulgaria, the moth egg fecundity was established (Mirchev et al., 2006) and the successful hatching eggs was ranged between 75 to 81 %, while in Israel it was more than 95 %. Georgiev et al. in 2018 presented that there was no significant difference between the egg fecundity and aborted eggs results for Pine Processionary Moth (*Thaumetopoea pityocampa*) in both studied areas (Sandanski and Kirkovo). Mirchev et al., in 2003 recorded no parasitoid on the eggs of Oak Processionary Moth (*Thaumetopoea procesiona*). Besides, the activity of egg parasitoids (9.5 %) was reported by Mirchev et al. in 2006.

The previous data showed that the role of the predator on the egg of the *Thaumetopoea* genus was insignificant and the range was no more than 2-3% on the other species, such as *T. wilkinsoni* (Halperin, 1990), *T. pityocampa* (Tsankov et al., 1996) and *T. processionea* (Mirchev *et al*., 2003). In this study, the effect of predators on the *T. solitaria* was range 0.35-3.20%. The egg predation on *T. solitaria* was about 3%, which was recorded by Mirchev et al. in 2006.

Karadag˘ et al. in 2007 recorded that the high relative humidity adversely affected the survival of egg clusters of the moth. This study presented the effect of abiotic factors like temperature and rainfall that affect the egg fecundity; in 2018 the rainfall was less, but the egg fecundity percentage was higher than in 2019.

## 5. CONCLUSION

The egg masses of *Thaumetopoea solitaria* was found on *Pistacia vera*, *Pistacia khunjuk* and *Rhus coriaria*. Caterpillars of *T. solitaria* feed on both buds and leaves. Differences in fecundity in two successive years were observed during the 2018 outbreak. This study has presented the high fecundity of the *T. solitaria* in North Iraq, which can be very harmful to the growth and production of the mountain host plant. The difference in egg hatching percentage between 2018 and 2019 for *P. vera*, *P. khunjuk*, and *R. coriaria* is most likely due to an increase in precipitation in 2019, as it could cause a reduction in the percentage of larval hatching eggs and an increase in the percentage of the parasitized egg.

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