DOCTORAL (PhD) DISSERTATION THESES

The development cycle of gypsy moths (*Lymantria dispar L.*) on various host plants and under various abiotic environmental components

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1. Introduction:

Gypsy moths (*Lymantria dispar* L.) are among the most well-known foliage-eater moth pest species. The level of damage they cause and the extension of their mass reproduction gives them a bad reputation in Hungary and in the countries where oaks bear a greater forestry significance among deciduous trees.

In spite of the fact that gypsy moths are polyphagous and have several hundreds of host plants worldwide, there are certain plant species that are not satisfying hosts for them. The plants they consume also facilitate the unfolding of their mass reproduction to a different degree. Beside the host plant, abiotic factors like the temperature or the light also have an influence on the degree of the gradation of the species, cyclically occurring every 8-10 years. As a consequence of that, the elaborate research of the host plants and abiotic factors like the temperature and the light is highly justified.

2. Objectives:

The objective of the author has been the investigation of the influence of various biotic and abiotic factors on the development cycle and reproduction of gypsy moths. In course of the investigation, the author has conducted four breeding experiments in a laboratory environment and sought answers to the following questions:

- How is the development and reproduction of gypsy moths affected when they are forced to develop on a host plant which is not their natural host? (First experiment)
- What are the effects of forcing the gypsy moths to change their host plant in course of their development? (Second experiment)

- What is the influence of temperature on the development cycle of gypsy moths and to what extent does it affect their reproductive performance? (Third experiment)
- How is the development cycle of gypsy moths affected when being exposed to constant light or constant darkness in course of their ontogeny? (Fourth experiment)

3. Materials and methods

The research samples were egg masses collected in the field. The breeding experiment was conducted in a laboratory environment where the required temperature and light conditions could be provided for the gypsy moths.

The first breeding experiment was conducted with a Croatian, a Hungarian and an Austrian gypsy moth population originating from three different host plants, kept on 20°C temperature and on the host plant hybrid poplar (*Populus* x *euamericana Pannonia*). Among the three, the Hungarian population also had hybrid poplar as its original host plant; the Austrian population was originally hosted on sessile oak (*Quercus petraea* (Matt.) Liebl.) and the Croatian population on evergreen oak (*Quercus ilex* L.). The experiment was conducted with 150 specimens per population until L_4 and with 50 specimens per population after that. After the breeding, the moths were crossbred both within their own population and between the populations and the viable eggs were counted to asses reproductive performance. In course of the experiment, the author applied 16 hours of light and 8 hours of darkness per day.

The effects of changing the host plant during the developmental cycle were also investigated. For that purpose, the breeding of two sample groups, consisting of 30 gypsy moths each was performed in a laboratory environment, using Turkey oak (*Quercus cerris* L.) and European hornbeam (*Carpinus betulus* L.) as host plants. With two other sample groups, consisting of 30 gypsy moths each, the host plant was changed from Turkey oak to European hornbeam at different developmental stages – in the third larval stage with the first group, and in the fifth larval stage with the second. The breeding was performed on 20°C temperature and with 16 hours of light and 8 hours of darkness per day.

To investigate the influence of temperature, a breeding experiment was conducted on a Hungarian population of gypsy moths. Three sample groups, each consisting of 30 moths were bred on artificial nutrients and three different temperature levels (20°C, 25°C and 30°C). At the end of the experiment, the moths were crossbred within their own sample group and the viable eggs were counted to asses reproductive performance. In course of the experiment, the author applied 16 hours of light and 8 hours of darkness per day.

In course of the last experiment, the influence of light was investigated on the development cycle and reproduction of gypsy moths bred on artificial nutrients. To achieve that, he breeding of two sample groups, each consisting of 50 gypsy moths, was performed; the first group being exposed to constant light, and the other to constant darkness. The breeding was performed on 25°C temperature and the moths were crossbred within their own sample group.

During the experiments, the following aspects were recorded for the gypsy moths: developmental milestone dates, weight increase of the larvae, the weight of the pupae and the weight of the faeces. In case of the host plants, the wet weight and dry weight of the consumed leaves and remaining leaves as well as the wet weight and dry weight of the etalon leaves was measured.

4. Results

The results indicate that the changing of the host plant presented no difficulties among the populations, provided that the descendant population was placed on a host plant which is a natural host to the species. The most significant difference in developmental biology was detected between the Croatian and Austrian population, but there were slight changes between the Hungarian and the Austrian population as well.

In the development cycle of the gypsy moth larvae, the last larva stage is the longest, in which they demonstrate the most significant food consumption and the greatest weight gain. In the days before pupation, the weight of the larvae decreases.

In the case of female moths, there is a connection between their growth in the larva stage and the number off eggs they deposit. The female specimens that demonstrated a bigger weight gain in the larva stage were able to deposit more eggs later.

Temperature has an effect on the duration of larva development and the duration of the period. A temperature increase results in a shorter development period. This abiotic factor also affects the reproductive performance – excessive temperature (30°C) had a negative impact in that case as well.

Sample groups which experienced a host plant change demonstrated weaker developmental results in the case of specimens that were hosted solely on Turkey oak. The single group that showed the greatest mortality rate was the one that solely had European hornbeam as its host.

The results also suggest that the presence or the lack of light has no effect on mortality. After crossbreeding the gypsy moths that were exposed to constant light, the females did not deposit viable eggs at all. The duration of development was significantly shorter with both sexes if they were being exposed to constant light. Accordingly, the weight increase of the larvae also had a more limited increase than in the case of absolute darkness. It can be concluded that the condition of absolute darkness provided more favorable conditions for the development of the species than the condition of constant light.

5. Dissertation theses

I. In a mixed forest, there is a greater probability that the developing larvae are going to be forced to change their host plant. In most of the cases, the change occurs when there is no foliage left for the gypsy moths to consume, which, naturally, assumes a certain level of population density. The results of the author's research indicate that the change of the host plant in the larva development phase negatively impacted the development indicators of gypsy moths. Lower values of weight gain for the larvae had a negative impact on the number of viable eggs. Thus, finding the source of nourishment in a mixed forest is not an ideal scenario for the gypsy moth, as it also results in a decrease of the population and, as a consequence, in lesser possible damage inflicted by them in the course of the next year.

II. Considering the development indicators of the gypsy moths, the change of the host plant seems to be a more significant factor than the point at which that change is executed. The change of the host plant at the different developmental stages had lesser significance than the fact whether the new host plant provided a favorable or less favorable environment for the species. Gypsy moths are able to develop and reproduce if they are on a suitable host plant, even if the previous generation originates from a completely different host plant – the difference, however, will be present in the quantitative values.

III. All breeding experiments resulted in a greater number of significant differences with the females than with the males in the different sample groups. Based on that, it can be concluded that temperature, light or the change of the host plan has a more significant effect on the development cycle of the females than on that of the males.

IV.

a. The findings of the author's experiments were not in all cases corroborated by literature evidence. This was true in case of the mortality rate and the presumed optimum temperature as well. A possible reason for that could be the fact that the investigated Hungarian gypsy moth population demonstrated a different sensitivity for temperature than the populations participating in international researches.

b. Contrary to prior expectations, the results indicate that the optimum temperature for Hungarian gypsy moths is not 20, but approximately 25°C instead. This is a greater value than what could have been anticipated based on the monthly average temperature level in Hungary.

c. The gypsy moth samples originating from Hungary demonstrated particularly successful development and reproductive performance on the constant temperature of 25°C. So much so, that their optimum temperature could also be determined around that temperature. Considering the daily fluctuation of temperature and the characteristics of the habitat, this value is considered to be particularly high. That means, that the increase of the annual average temperature level generated by the climate change could positively impact the development and reproduction of gypsy moths, and therefore, further support the damage that gypsy moths inflict in Hungary.

V. The findings of the experiment indicate a difference in the development cycle of the gypsy moths, based on whether they are exposed to constant darkness or constant light. The condition of constant darkness is more favorable for the development of the gypsy moths, while constant light is particularly unfavorable for their reproduction. On the other hand, extreme light conditions have no effect on the on the mortality rate.

VI. Contrary to prior expectations, the extension of the area of gypsy moths is not only influenced by the host plant and temperature, but also by the factor of light. In the northern region, the days during the summer are longer, resulting in longer periods of exposion to the light. The fact that absolute light is not favorable for gypsy moths leads to the assumption that the shift of the photophase and scotophase towards photophase is unfavorable for gypsy moths.

VII.

a. Even though the Croatian population demonstrated a shorter duration of development, it also had a significantly lower mortality rate than the Hungarian population, resulting in the conclusion that the populations originating from different host plant groups also impose a danger to our forest resources. The successful development of the foreign populations can most likely be accredited to the suitable host plant. The factor that primarily determines their spreading in the Hungarian forests is the suitability of the host plant.

b. If the host plant is suitable for the gypsy moths, they can successfully develop on it and inflict damage on it. This is also true for the populations that originate from different host plants. In that aspect, Hungarian gypsy moths would not have a competitive advantage over the specimens of any other populations. Nevertheless, if the thermal conditions in Hungary happened to be lower than in the habitat of the foreign population, their development cycle could reflect a slight slowdown. As the breeding experiments indicate, the specimens of a Hungarian population could be even days ahead in their development compared to the specimens of a foreign population, which could provide a significant advantage in their race for nutrition.

6. Publication list

Journal articles:

Csóka Gy., Hirka A., Csepelényi M., Szőcs L., Molnár M., Tuba K., **Hillebrand R.** és Lakatos F. (2018): Erdei rovarok reakciói a klímaváltozásra (Esettanulmányok). Erdészettudományi Közlemények 8 (1): 149-162.

Hillebrand, R. és Tuba, K. (2013): Különböző tápnövényről származó gyapjaslepke-(*Lymantria dispar*) populációk fejlődésmenete Pannónia nyáron. – Növényvédelem, 49 (3): 101-109.

Conference publications:

Hillebrand, R. és Tuba, K. (2014): A gyapjaslepke (*Lymantria dispar* L.) fejlődésmenete. – p. 320-325. In.: Bidló, A. és mtsai (szerk.): Kari Tudományos Konferencia, 2014 Sopron.

Hillebrand, **R.,** Tuba, K. and Lakatos F. (2014): The development of gypsy moth (*Lymantria dispa*r L.) under different temperatures. – p. 231-234. In.: Marčić, D. et al. (edit): Proceedings of the 7th Congress on Plant Protection, 2015 Belgrade

Hillebrand, R., Tuba K. és Lakatos F. (2015): A gyapjaslepke (*Lymantria dispar* L.) 1758 fejlődésmenete különböző hőmérsékleten. – p. 21. In.: Horváth, J. és mtsai (szerk.): 61. Növényvédelmi Tudományos Napok, 2015 Budapest

Hillebrand, **R.,** Tuba, K. and Lakatos F. (2016): The development of gypsy moth (*Lymantria dispar* L.) on different food plants. – p. 177-185. In.: Ács, K. et al. (edit): V. Interdisciplinary Doctoral Conference, 2016 Pécs

Hillebrand, R., Tuba, K., Hasulyó, P. és Lakatos, F. (2014): A lárvakori táplálkozás és a tojásprodukció összefüggése különböző gyapjaslepke (*Lymantria dispar* L.) populációkban. – p. 114-120. In.: Gór, A. és mtsai (szerk.): A magyar agrár felsőoktatás aktuális kérdései PhD-s szemmel, 2014 Keszthely

Váradi, M. Cs., **Hillebrand, R.** and Tuba, K. (2016): Development and fecundity of gypsy moth (*Lymantria dispar* L.) and poplar leaf beetle (*Chrysomela populi* L.) on *Populus* x *euramericana* cl. Pannonia. V. – p. 72-77. In.: Ács, K. et al. (edit): V. Interdisciplinary Doctoral Conference, 2016 Pécs