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Original scientific paper

Phenological Form Diversity of *Thaumetopoea pityocampa* in Bulgaria

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Abstract: In Bulgaria, two different phenological forms of pine processionary moth, *Thaumetopoea pityocampa* (Den. & Schiff.) (Lepidoptera: Notodontidae), occur: a typical Mediterranean winter form and an early developing summer form. During the period 2017-2018, the phenological development of *T. pityocampa* was studied in 21 sites of pest' range in Southern Bulgaria. The results of the observations showed that in terms of the phenology, three categories of pine processionary moth development could be distinguished: *i*) six sites with an early developing summer form; *ii*) nine sites with the typical Mediterranean winter form, and *iii*) six sites with larvae that overwinter both into the soil and in the nests. Besides the phenological differences in the development of both forms on the same locality, no other distinguishable morphological features were established.

Keywords: *Thaumetopoea pityocampa*, phenological forms, Bulgaria.

1. Introduction

Bulgaria is the northern range border of pine processionary moth, *Thaumetopoea pityocampa* (Den. & Schiff.) (Lepidoptera: Notodontidae) occurrence in Europe. The species is distributed on the pine plantations growing in the southern regions of West and Central part of the country. Since 1995, a steady expansion of the pest has been observed toward the eastern parts of Southern Bulgaria, with a significant increase after 1999 (Mirchev et al. 2011a). The climatic factors, especially air temperature, have a key importance for pest's survivability and are limiting circumstances for its adaptability. For eggs and larvae in their first instars, the high summer temperatures above 32°C (Huchon and Demolin, 1970), and according Robinet et al. (2013) 40°C, cause huge mortality of pest's population. For overwintering larvae, temperatures below -16°C (Démolin, 1969b) or -24°C according Zankov (1960), are the limiting factors that influence the pine processionary moth's development.

In 1950-60s, it was established for first time in Bulgaria that an early (continental) form of pine processionary moth developed that completed its larval phase and hibernated into the soil before the winter (Zankov, 1960). Such phenologigal form has been established also in Portugal (Santos et al. 2013).

The aim of current study was to present data for some investigated localities in Bulgaria, where different phenological forms of pine processionary moth occur, and to establish their quantitative dimensions by the relative share of assessed overwintering specimens in the nests or hibernated into the soil.

2. Materials and Methods

A study observing the peculiarities of different phenological forms of the pine pracessionary moth in Bulgaria was carried out in the period 2017-2018. In 21 localities of pest's distribution, nests with larvae in them or abandoned nests were taken into account during the coldest months of the year - from December to February (Table 1). The obtained results from the study were summarized with previous data taken by the studies conducted between 2003 and 2016 (Mirchev et al. 2004; Mirchev et al. 2011b; Mirchev et al. 2016).

3. Results

The results of long-term observations showed that in terms of the phenology, three categories of pine processionary moth development could be distinguished: i) an early developing summer form; ii) a typical Mediterranean winter form, and iii) sites with larvae that overwinter both into the soil and in the nests.

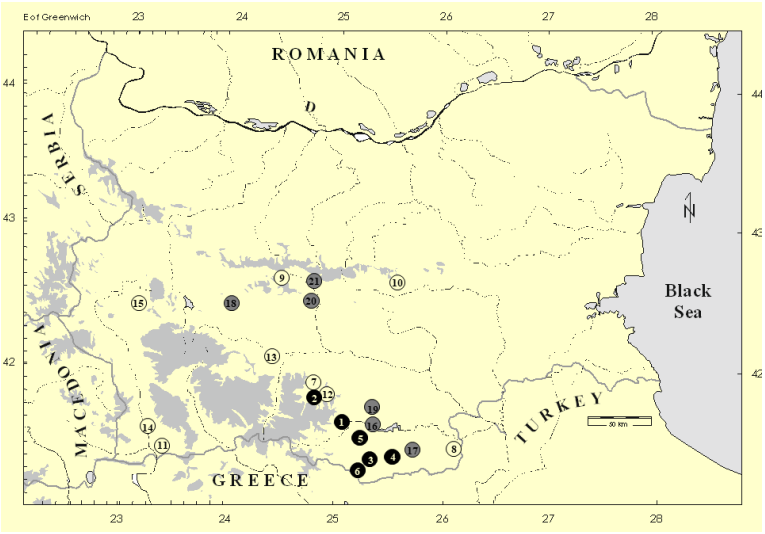

Figure 1. Distribution of *Thaumetopoea pityocampa* phenological forms.

For the third category, besides the phenological differences in the development of both forms, no other distinguishable morphological features were established, so it could be taken into consideration that both forms inhabit these localities. According to the geographic location, the sites from the three categories are characterized by some features (Figure 1).

The rest three sites with summer population occurrence – Svetulka, Davidkovo and Dobrostan, are located at higher altitude in the west part of the Rhodopes. The highest site is Dobrostan – situated on 1,100 m a.s.l. This site is on a distance of 10.5 km to Muldava (located

on the foot of the mountain at 290 m a.s.l.), where only a typical Mediterranean winter form occurs.

The typical Mediterranean winter form, inhabiting biotopes in range between 130 to 830 m a.s.l, occupies the predominant part of the species area in Bulgaria. In nine localities, it was observed that the larvae were staying over the winter into the nests and completed their development inside.

Table 1. Percentage of the hibernation colonies in the soil of *T. pityocampa* in different regions of Bulgaria.

№	Site	Coordinates		Altitude (m a.s.l.)	Hibernation colonies in the soil (%)
		N	E		
Site with early developing summer form					
1	Davidkovo	41°40'26''	24°58'05''	985	100
2	Dobrostan	41°53'45''	24°55'52''	1100	100
3	Fotinovo	41°22'42''	25°19'22''	450	100
4	Kandilka	41°24'33''	25°35'53''	461	100
5	Svetulka	41°33'52''	25°06'09''	741	100
6	Yakovitsa	41°18'37''	25°15'31''	464	100
Site with typical Mediterranean winter form					
7	Asenovgrad	42°01'03''	24°53'37''	230	0.0
8	Ivaylovgrad	41°31'40''	26°07′07''	250	0.0
9	Klisura	42°42'42''	24°34'10''	526	0.0
10	Maglizh	42°36'08''	25°30'34''	370	0.0
11	Marikostinovo	41°26'24''	23°10'30''	130	0.0
12	Muldava	41°59'16''	24°56'47''	290	0.0
13	Pazardzhik	42°21'00''	24°08'15''	300	0.0
14	Sandansky	41°34'21''	23°17'14''	300	0.0
15	Staro selo	42°28'49''	23°06'53''	830	0.0
Site with both forms					
16	Kardzhali	41°43'01''	25°21'34''	430	50.0
17	Krumovgrad	41°28'20''	25°30'34''	535	18.2
18	Muhovo	42°25'10''	23°59'57''	400	0 - 10.0
19	Pchelarovo	41°46'47''	25°21'27''	480	10.0 - 30.0
20	Pesnopoy	42°20'37''	24°40'15''	300	50.0 - 54.5
21	Sopot	42°39'28''	24°45'21''	550	0.0 - 7.7

In sites Krumovgrad, Kardzhali, Muhovo, Pesnopoy, Pchelarovo and Sopot, both phenological forms occurred. The percentage of wintering populations in the soil varied from 7.7 to 54.5% (Table 1). Of the sites occupied by both phonological forms three of them are situated in the Rhodopes and the rest three in Central Bulgaria in the foothills and the Sredna Gora Mountain.

The differences in the two phenological forms were manifested in the whole life cycle of their ontogenetic development, from the period of young larvae hatching to the last instar development. The hatching of the pine procession moth's larvae in the Kirkovo region was recorded at the beginning of July, unlike the region of Sandanski where the typical Mediterranean winter form is distributed and the hatching began at the end of September.

4. Discussion

The results obtained open the question which factors influence the different phenological forms of pine processionary moth in Bulgaria, and if they are genetically assembled. The monitoring made by pheromone traps to establish the seasonal male activity, showed that there are no significant differences between two forms - the time and duration of imago period in males overlaps largely in all monitored areas (unpublished data).

The most interesting is the fact that males from the region of Dobrostan, where only the early summer form develops, have not reached yet the population in Muldava (with only winter population), situated only on 10 km distance. In Bulgaria, it was established, that males are able to fly to 50 km from the place where they have emerged (Mirchev et al. 2013).

The impact of some climate peculiarities on the phenology of the species has not explain the fact that the two forms occupy sites close to each other and with similar climatic conditions. The usual amplitudes over the years have not leaded to changes in the pine processionary moth's phenology, referring to Dobrostan and especially Kirkovo, where a long-term observations on pest's life cycle have been made in recent years.

The temperature conditions influence the pine processionary moth's survivability (Mirchev et al. 2011b; Mirchev et al. 2016). The emergence of the two phenological forms could not be considered only as an evolutionary adaptation of the species in Bulgaria that is the northern border of its occurrence. The climatic conditions in the country are too different from the Mediterranean regions – the winters are more severe, often with extreme low temperatures. The summer population was not found in sites with severe winter conditions like Staro Selo and Maglizh, but in the southernmost regions of Bulgaria - Kirkovo. It was established that the expansion of the species is to the north and to the east where the typical Mediterranean winter form occurs. Zankov (1960) reports for some differences in the pupal period. For the sites with typical Mediterranean winter form this period is in the spring, while in the areas where two phenological forms occur, it happens late in the autumn or in warm winter days, as in the region of Velingrad, (Central Rhodopes), where 40% of the larvae pupated at the end of October, and the rest part - until February.

Significant differences in the fertility of female moths, egg size, egg coating, and egg parasitism were reported by Santos et al. (2013) for two phenological forms of pine procession moth in Portugal. In Bulgaria, there are no differences in the fertility of females in both forms, comparing samples from Kirkovo and Sandanski (Georgieva et al. 2018).

The summary of the results obtained by the studies on pine processionary moth's phenology, biology and ecology, shows the high degree of species' adaptability to survive in different environment conditions in its various habitats, and to expend its spreading zones. Another biological feature of the pest – to remain in a diapause in the pupal stage up to 6 years (Démolin, 1969a), allows to overcome successfully not only the potential unfavorable climatic conditions but also to avoid the control treatment of attacked forest plantations. After diapause stage, the pest appears again in these forests.

It is supposed that the early developing summer form is adapted to overcome the often-occurring extreme low temperatures in the peripheral zone of its expansion to new territories that is also established in the world distribution of species. Over the last decades, vertical and horizontal expansion has been recorded, the distribution of the borderline of the species to the north as well as the climbing of higher altitudes (Battisti et al. 2005; Battisti et al. 2006).

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