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Effect of defoliation by *Thaumetopoea pityocampa* (Den. & Schiff.) (Lepidoptera: Thaumetopoeidae) on annual diameter increment of *Pinus brutia* Ten. in Turkey

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Abstract – In this study, the influence of defoliation by pine processionary moth, *Thaumetopoea pityocampa* (Den. & Schiff.) (Lepidoptera: Thaumetopoeidae) on the annual diameter increment of Turkish Calabrian pine, *Pinus brutia* Ten. in Kahramanmaraş province, Turkey, was investigated. The study was carried out between 1995 and 1998. During the four years, the defoliation of pine processionary moth caused a significant decrease (average 21% for four years, $P < 0.05$) in the annual diameter increment with respect to control, undefoliated trees.

Thaumetopoea pityocampa / diameter increment / Kahramanmaraş / Turkey / *Pinus brutia*

Résumé – Effet des défeuillaisons par *Thaumetopoea pityocampa* (Den. & Schiff.) sur l'accroissement annuel de *Pinus brutia* Ten. en Turquie. L'influence de défeuillaisons par la processionnaire du Pin *Thaumetopoea pityocampa*, sur l'accroissement annuel en diamètre de *Pinus brutia*, a été testée dans la province de Kahramanmaraş, en Turquie. L'étude fut conduite de 1995 à 1998. Durant ces 4 années, les défeuillaisons ont causé une diminution significative (en moyenne 21 % pour les 4 ans, $P < 0,05$) de l'accroissement annuel en diamètre, en comparaison avec des témoins non défeuillés.

Thaumetopoea pityocampa / accroissement en diamètre / Kahramanmaraş / Turquie / *Pinus brutia*

1. INTRODUCTION

The pine processionary moth (PPM) live on the genera *Pinus* and *Cedrus* grown in Cyprus, Turkey and Middle East and has been known as *Thaumetopoea pityocampa* (Den. & Schiff.) until now, except for the population found in the province of Aydn, Aegean region of Turkey [27]. However, there is the possibility that the species studied in this paper may refer to *Th. wilkinsoni* Tams known from Cyprus, Eastern Turkey, and Israel [27]. Further studies are needed to clarify the taxonomic position of the studied populations.

Th. pityocampa Schiff is known to feed on leaves and build large silk nests on the top of the trees. In addition, PPM has urticating hairs, which cause allergies resulting in conjunctivitis, respiratory congestions and asthma [29]. The PPM is one of the most harmful insect that defoliates *Pinus* and *Cedrus* and has serious economic importance [2, 4, 5, 8, 16, 20–24, 26, 28]. In mature forests, trees are barely killed, but significant losses bring about in volume and radial growths [18].

It is well known that defoliation may increase tree stress and their susceptibility to secondary pests such as bark beetles and pine weevils, particularly in young trees [11, 15, 16]. Outbreaks of PPM are quite periodic, occurring every 5–7 years. It was also reported that losses in total shoots of *P. pinaster* were between 41–50% in moderately defoliated trees and between 54–64% in completely defoliated trees [25]. Due to PPM attack on *Pinus brutia* (with 1–4 m height) in Turkey, a great loss of 68% was determined by Babur [5].

PPM has been damaging pine species (i.e., *Pinus brutia*, *P. nigra*, *P. sylvestris*, *P. pinea*, and *P. halepensis*) as well as species *Cedrus libani* growing in Turkey. The PPM occurs at the regions from sea level to an altitude of 1 800 meters [3, 12] at different levels of intensity. In Turkey, the PPM is available in a forest area of 1 500 000 hectares [1].

The damage of PPM has been mostly observed on *P. brutia* in Turkey, which consists of the majority of forests (with more than 3 million hectares) and are distributed particularly in the coastal regions of Turkey, namely, the Mediterranean (47%),

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Marmara regions (40%) and Aegean (10%) [1, 12]. It has a volume of more than 161 million m³ and an annual volume increment of more than 5 million m³, 4 million m³ of which is allowed to be cut [6]. The PPM created severe damage in an area of about 1.5 million hectares in Turkey [1]. It was reported that the damage resulted from larvae being nourished with the needles of *P. brutia* and *P. nigra* continued for about 7 or 8 months to a great extent. Especially, the larvae at the 4th and 5th instars consume all the leaves of the Calabrian pine trees remarkably. Thereby, the damaged trees look like as if they were burned [17].

There are several studies on the effects of the attacks of *Th. pityocampa* (Den. & Schiff.) on the radial [5, 18, 19], volume [7, 9] and the height growths [10] of various pine species. To our knowledge, little information [5, 16] on the effects of the PPM attack on annual diameter increment of *P. brutia* has been known in the literature so far.

Therefore, the aim of this study was to investigate the influence of damage by the PPM on annual diameter increment of *P. brutia* growing in Kahramanmaras, the Eastern Mediterranean region of Turkey.

2. MATERIALS AND METHODS

2.1. Selection of material and study area

The study area of both control and defoliated trees was around Ferhus village (with plantation forest), within the boundaries of the Directorate of Kahramanmaras Forest District, Turkey (322 500 E; 41 55 000 N (UTM grid zone 37 S); altitude 560 m).

Specifically, *P. brutia* forests in the region of Kahramanmaras cover an area of 192 521 hectares, which corresponds to 6% of the total area of *P. brutia* forests in Turkey. About 87 600 hectares (45%) of the total area of *P. brutia* in Kahramanmaras region are unproductive while the remaining 104 926 hectares (55%) is productive [6, 14].

The diameter at the breast height of both control and defoliated pine trees (25–35 years old) studied herein varied between 13 and 19 cm. Unfoliated trees and trees whose about two-thirds of needles of *P. brutia* (i.e., especially from the top to middle of tree) were estimated to have been defoliated by PPM were selected for control and defoliated trees, respectively. The control trees were managed to keep free of attack throughout by removing the egg batches on trees in September and October. Furthermore, the average height of both control and defoliated trees in this study ranged between 11–12 m. The exposure of the study area for both control and defoliated trees were north-east.

2.2. Observation on the PPM defoliation

The feeding of larvae was found to take place much more in April and May rather than other months in the study area. And then, trees foliated themselves, starting from May to July. In the study area, the first natural outbreak was observed in 1994, followed by 1995 (7–8 nests on each defoliated tree), 1996 (5–6 nests), 1997 (6–7 nests) and 1998 (3–4 nests). It was also observed that PPM laid about 273 eggs in one egg batch on the needles of *P. brutia* trees in September, 1995. Generally speaking, two-thirds of needles of *P. brutia* (i.e., especially from the top to middle of tree) were estimated to have been defoliated by the larvae in these infestation years. About 24% of these eggs were destroyed due to pressure of some parasitoids and environmental factors. And then, the number of larvae hatched in September–October is 208 in each egg batch.

In the study area, the larvae generally entered the soil for pupae in May, and pupae could live for 4 years in the soil. Between the years 1995 and 1998, the population of PPM remained at a certain level. In addition, it was observed that in the years at which infestation decreased, the population of *Calosoma sycophanta* and *Phryxe caudata* considerably increased.

2.3. Determination of annual diameter increment

The measurements of the diameter at the breast height of *P. brutia* trees were obtained using a Pressler increment bore (Djos 400, diameter: 6 mm, height: 33 cm, made in Sweden) and a Zeiss Winkel apparatus (Dendromotor 2000, made in Finland). Annual diameter increment (*ADI*) and percent decrease in annual diameter increment (*PDADI*) were determined as follows:

$$ADI = (D_2 - D_1) \text{ (mm)} \quad (1)$$

where, D_2 is the diameter of the pine tree measured at the end of the vegetation period of each year and D_1 is the diameter of the tree measured at the beginning of vegetation period of each year.

$$PDADI = (ADI_c - ADI_i) / ADI_c \times 100 \text{ (%) } \quad (2)$$

where, ADI_i is annual diameter increment for the pine trees defoliated by PPM and ADI_c is annual diameter increment for the control pine trees.

Annual diameter (at the breast height) increments of the pine trees were measured for four different growing years, namely, 1995, 1996, 1997 and 1998. This study was conducted on the same trees throughout the studied years. For both the control and defoliated trees, the average of 30 measurements was reported.

The repeated measurement analysis of variance (rmANOVA) and Tukey's mean separation test were applied to determine whether or not there were significant differences in annual diameter increment of defoliated and control trees [13].

3. RESULTS AND DISCUSSION

The results of rmANOVA test for the annual diameter increment of both control and defoliated pine trees are presented in Table I. As shown in this table, the interaction of defoliation and growing years studied and year itself are not statistically significant. However, a strong significant difference is determined for defoliation, thus revealing that annual diameter increments in the pine trees are considerably affected by the defoliation of the larvae, $P < 0.05$.

The results of Tukey's mean separation test for the diameter increment of the both control and defoliated trees as well as percent decrease in annual diameter increment are given in Table II. As indicated in this table, the annual diameter increments of the defoliated trees significantly differ from those of control trees for all the growing years at a significant level of 5%. As one can see from the same table, there are no significant differences in the annual diameter increments of the defoliated trees between 1995 and 1998. However, the annual diameter increments determined in 1996 and 1997 are found to significantly differ from those in the other two years, 1995 and 1998, $P < 0.05$.

Average decrease in annual diameter increment for four growing years is about 21%. The greatest percent decrease (about 30%) in the annual diameter increment of the pine trees

Table I. The results of rmANOVA for annual diameter increment of control and defoliated Calabrian pine trees on the basis of times.

Source	Sum of squares	DF	Mean square	F	Significance*
Intercept	1343.79	1	1343.79	555.40	*** ^a
Time	78.55	1	78.55	32.47	***
Defoliation	14.60	3	4.86	15.17	***
Error (within)	55.76	174	0.32		
Defoliation × time	4.04	3	1.35	4.20	** ^b
Error (between)	140.33	58	2.40		

^a Strong significant at the level of 5% ($P < 0.05$). ^b Weak significance at the level of 5% ($P < 0.05$).

Table II. The results of Tukey's mean separation test for the annual diameter increment of Calabrian pine trees (control and defoliated by PPM) on the basis of years.

Years	Mean annual diameter increment (mm)		Percent decrease in annual diameter increment
	Control	Defoliation	
1995	2.36 ± 0.30 ^{a*}	1.64 ± 0.10 ^d	30
1996	2.46 ± 0.24 ^b	2.02 ± 0.16 ^e	18
1997	2.33 ± 0.21 ^a	1.85 ± 0.13 ^f	20
1998	1.93 ± 0.19 ^c	1.66 ± 0.09 ^d	14

* Means followed by the same letter are not significantly different using Tukey's mean separation test (significance level is 0.05).

defoliated by the larvae is for the year of 1995, followed by 20% in 1997, 18% in 1996 and 14% in 1998, respectively (Tab. II).

This fact can be attributed to the number of nests on defoliated trees in relevant year based upon our observation described in material and method section. That is to say, the percent decrease in the annual diameter increment is found to be directly proportional to the nest number.

It was also reported that due to damage of PPM, an about 23%-loss in annual diameter increment was measured in the tending felling area of *P. brutia* in Kapicam village, Kahramanmaras-Turkey, which is closed to the present study region [16].

Moreover, Laurent-Hervouet [18] found that the PPM caused a 35%-loss in the diameter increment (radial growth) of *P. nigra* subsp. *nigricans* growing on Mont Ventoux after a severe attack of *Th. pityocampa*, which is slightly higher than the maximum loss (30%) determined in this study. This may be attributed to both pine species and population of the PPM depending upon regions [1].

Cadahja and Insua [9] found out the losses in wood volume increment between 14 and 33% in young reforested area of *P. radiata* because of *Th. pityocampa*. Also, Bouchon and Toth [7] reported that forests of *P. nigra* periodically subjected to heavy attacks of *Th. pityocampa* showed an about 45%-volume decrease within 50 years. This difference is due, most probably, to the age of tree and species [10, 16].

Lemoine [19] also determined a reduction of 30% in radial growth of *P. pinaster* in Les Landes (France) after an attack of *Th. pityocampa* and 20% loss in radial growth of *P. nigra* subsp. *laricis* in Corsica for the 28 years after the attack of the same moth. Decrease in the radial growth (about 21%) determined for *P. brutia*, studied herein, attacked by the PPM was

evidently smaller than that found for *P. pinaster* just mentioned above, and almost the same as that for *P. nigra* subsp. *laricis* grown in Corcica.

Furthermore, Calas [10] found a 60%-reduction in height growth of *P. nigra* trees due to *Th. pityocampa*.

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