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Full Length Research Paper

The effects of the pine processionary moth on the increment of crimean pine trees in Bartin, Turkey

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The pine processionary moth (PPM), causing significant damage on pine stands in Turkey, affects mainly crimean pine stands within the Ulus vicinity. To determine the damage, 20 sample plots of second site class crimean pine stands were measured; 10 of which were taken as the control sample and 10 of which were damaged by PPM. In all, 289 trees in the damaged areas and 316 trees in the control areas were measured. Consequently, it was ascertained that there was a loss of 22% in diameter increment, 29% at basal area increment, 43% in height, 24.5% at height increment, and 37.5% in volume increment of damaged trees based on their age (70 years) in comparison with the control trees.

Key words: *Pinus nigra* Arn., *Thaumetopoea pityocampa* Den and schiff., increment loss.

INTRODUCTION

Turkey has a great diversity of plant species. Crimean pine (*Pinus nigra* Arnold) is one of the most widespread species, keeping their existence compatibly with the changing environment as a result of natural selection. Crimean pine is one of the first class forest trees that can grow taller than 30 - 35 m. After the calabrian pine, it has the largest distribution (4202298.6 ha) in Turkey (OGM, 2006). With regard to the crimean pine's distribution, it is found on the southern slopes opposite the sea in northern Anatolia and interior districts, on the northern slopes and narrow canyons in the Taurus Mountains, and at high altitudes at the eastern expositions in Western Anatolia. Crimean pine constitutes wide pure forests which account for about 700 - 1400 m in other districts except the Eastern Black Sea region.

The pine processionary moth (PPM), noticable with its cotton-like white caterpillar bags on pine trees, is actually a moth species and the caterpillars of this species are among major pests damaging the forests in our country. The height increments of the trees are damaged by this pest over a few years and eventually the trees deteriorate and volume loss occurs (OGM, 2006). Since the damage occurs during the winter months when growth is dormant, generally no tree deaths occur. But, there were some death reports that PPM could cause some tree deaths especially in young reforested areas (Hodar et al., 2003). Nevertheless, the damage continues intensively and successively for a few years weakening the tree and making it suitable for bark pests and other secondary pests. PPM damage a number of conifer species including *Pinus brutia, P. nigra, Pinus sylvestris, Pinus pinaster, Pinus halepensis, Pinus pinea, Cedrus libani* and *Juniperus excelsa.* This pest has been spreading in the south, west and eastern parts of Anatolia and in southern parts of the western and central Blacksea region. The density of this pest decreases as the altitude increases and as the aspect is close to the North.

PPM (*Thaumetopoea pityocampa* Den and shiff.) is a primary pest causing damage through eating the leaves of crimean pine trees. It has caused damage on 1,500000 hectares of land and is observed primarily in calabrian pine forests as well as in other pine species (DPT, 1995). It is known to cause a decrease of 41 - 50% in sprout height due to moderate damage, and it causes a decrease of 54 - 64% in sprout height when its damage is heavy on *P. pinaster* trees (Markalas, 1998). The height loss between 1 to 4 m. of *P. brutia* trees is 68% (Babur, 2002).

The effects of the PPM on the increment and growth of

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pine forests in Turkey have been studied by several researchers. However, these studies generally focus on calabrian pine and Mediterranean (Carus, 2004; Kanat et al., 2005; Kanat and Sivrikaya, 2005). In addition, there are several studies carried out on chemical and biological control of PPM (Kanat and Alma, 2003; Kanat and Bolat, 2006; Semiz et al., 2005). This study aims to determine the effects of PPM causing damage to the increment of the Ulus Forest Enterprise crimean pine stands.

MATERIALS AND METHODS

The research area Ulus Forest Enterprise has an area of 86678 ha. A total of 56540 ha of the area is forested and the remaining is open land.

For the sample areas with infected stands, the average slope is 43%, altitude is 560 m and the general aspect is southwest in the sample plots in Abdipaşa district. In Stillusçayı district from which control sample plots were taken, the average slope is 36%, altitude is 490 m and the general aspect is southwest. Both areas are second site class pure crimean pine forests.

Climate data, the dominant climate type in the research area is Black Sea climate type. This type of climate includes four wet seasons, moderately hot summers and mild winters. Due to the research areas being close to the sea and low altitude mountain ranges which are parallel to the shore, the temperature difference along the shore decreases, humidity increases and air mass from the Balkans becomes effective (DMİ, 2004). The data for the last 51 years provided by the meteorological station in Bartın were used to explain the climate conditions of the research area. According to this data, the mean annual temperature in Ulus province is 12.9℃ and the highest temperature was 42.8℃ (in July), the lowest temperature was 4.1℃ (in January). Annual precipitation is 1040.1 mm average and while the highest precipitation amount was 181 mm (in August), the driest month was April with 40 mm. The relative humidity is an average of 55.6% annually. The vegetative period lasts for 6 months. Accordingly, the precipitation type of the area has been found to be rich in humidity and the vegetation cover has been found to be an over-humid forest.

Experimental data, the total amounts of sample plots measured in the research study are 20 sample plots, the size of which is equal to 400 m^2. Ten sample plots from Abdipaşa district and 10 sample plots from Ulusçayı district were included as sample plots. All the trees in the sample plots were dominant and co-dominant. The increment core was taken from a height of 1.30 m (the breast height of each tree) by using a core borer in order to reach the core of the tree to determine the age of trees which were measured in diameter and height. The width of the rings belonging to the last decade in the increment cores was measured at 0.1 mm precision. Using this method, 289 trees in the infested area and 316 trees in the control area were measured. The number of the trees per hectare in the sample plots was between 625 and 925.

Regression analysis, the regression equations modeling the diameter, basal area, volume and height increment as the age function were formed through evaluation of the data. Also, the error variances of regression equations were determined. The compatibility of the equations with the data was examined with an F- test. Differences in infested and control groups were tested by using ANCOVA. The data were classified based on age classes and whether there was a significant difference at 95% confidency level between the areas infested and the control age classes were analyzed using a t-test.

Determining the increments, the diameter and basal areas, belonging to a decade ago, were determined using the increment amounts for the last decade which were obtained from the sample plots. The periodical (10 years) basal area and diameter increments were taken from the differences of the current and the last decade's basal areas and diameters. The single entry tree volume model was used in order to determine the volume increments. The volume increments of ten years were determined using the values of the diameter outside bark of the period's beginning and finishing. The height increments were determined from age-tree height regressions.

RESULTS

Tree age-diameter increment relationship, tree age (A) and diameter increment (Di) values of ten years were determined with the help of the increment cores that had been obtained from the breast-height of the trees were moved to the coordinate system and the regression equations representing the data in the best way. Age-diameter increment values had a wide distribution area on the coordinate system and had a low correlation as in the prior increment and growth research Figure 1 showed a comparison of the age-diameter increment of the trees measured in the infested and control areas. The regression models are given below:

Infested: $Di = 10.30181 - 1.8996 \ln A$ (r: 0.43, F: 49.02, Se: 1.48).
Control: $Di = 9.979962 - 1.67358 \ln A$ (r: 0.26, F: 23.26, Se: 1.41).

Tree age-basal area increment relationship, the age and diameter increment values over a period of ten years were determined through the increment cores obtained from the breast height of the trees in the infested areas and control areas. The basal area increments over a period of ten years were obtained from the diameter increment values. The age (A) and basal area increments Bi) for the 10 years were moved to the coordinate system and the regression equations representing the data in the best way were determined. Figure 2 shows the comparison between the equations of the infested and control groups. The regression models are given below:

Infested: $Bi = - 18.6782 + 0.97423A - 0.0055A^2$ (r: 0.648, F: 68.35, Se: 7.71)
Control: $Bi = - 12.4861 + 0.884367A - 0.00361A^2$ (r: 0.761, F: 212.97, Se: 3.907)

Tree age-height and height increment relationship, the periodical (5 years) height increment values obtained from stem analysis were shown in the coordinate system as the age function. In addition to the age (A)-height increment (Hi) relationship, the age (A)-height (H) relationship was also included. Figure 3 shows the age-height relationship and Figure 4 shows age-height increment relationship of the trees infested and control groups comparatively. The regression models belonging to the age-height relationship are given below:

Infested: $H = - 25.2173 + 9.667486 \ln A$ (r: 0.7, F: 274.34, Se: 4.72)

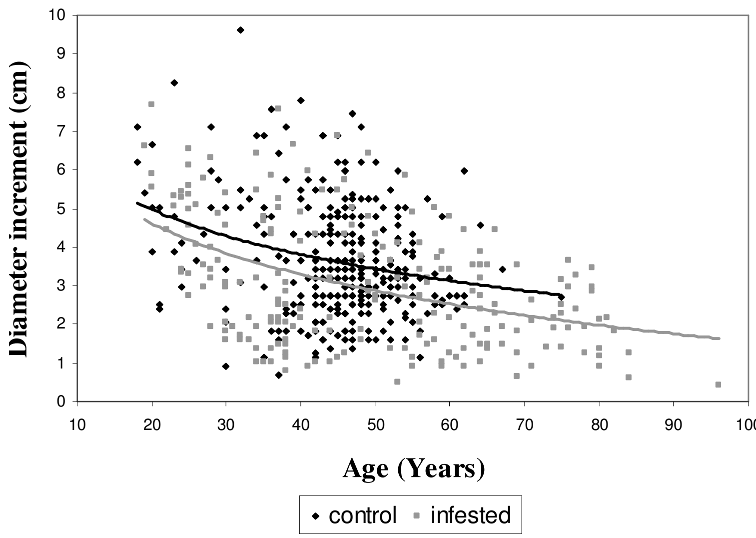

Figure 1. Comparison of the age-diameter increment of trees measured in infested areas and control areas.

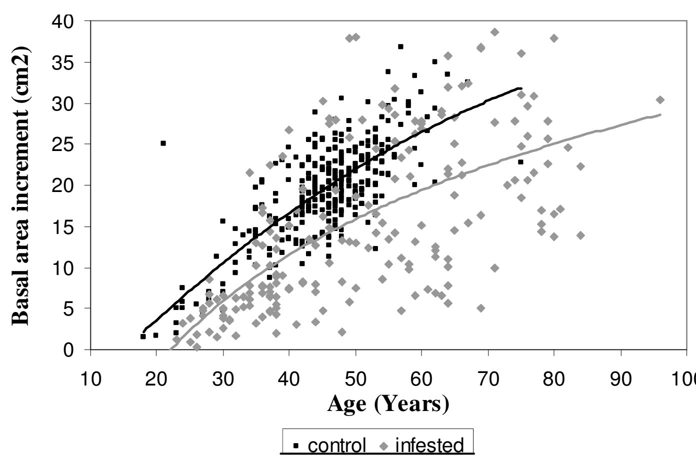

Figure 2. Comparison of age-basal area increment of trees measured in infested areas and control areas.

Figure 3. Comparison of the age-height relationships of trees measured in infested areas and control areas.

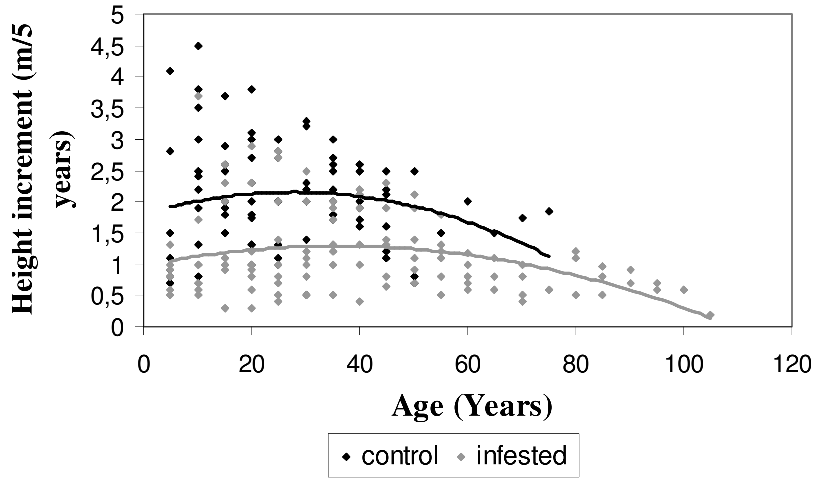

Figure 4. Comparison of the age-height increment of the tree measured in the infested areas and control areas.

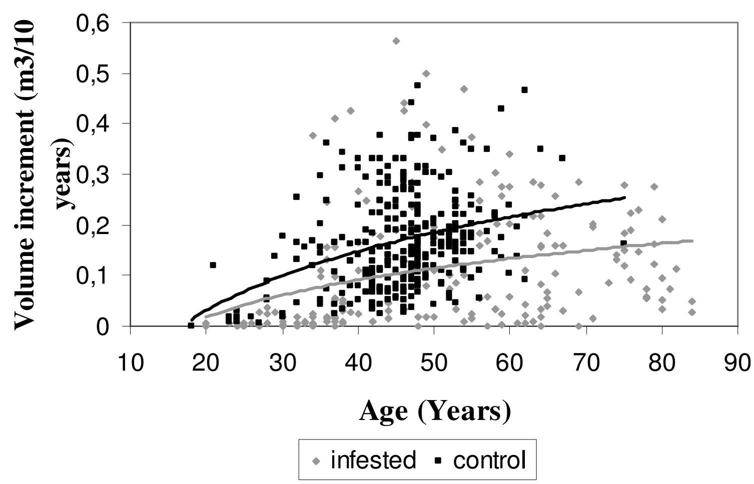

Figure 5. Comparison of the age-volume increment of the trees measured in the infested areas and control areas.

Control: H = - 36.8885 + 15.18555ln$A$ (r: 0.812, F: 615.25, Se: 2.49)

The regression models belonging to age-height increment relationship are given below (Figure 5).

Infested: H_i = 0.973142 + 0.017543A - 0.00024A^2 (r: 0.346, F: 7.89, Se: 0.62)
Control: H_i = 1.797435 + 0.025566A - 0.00046A^2 (r: 0.189, F: 1.76, Se: 0.83)

Tree age-volume increment relationship: The volume increments over a period of ten years were obtained from the volume tables formed by the help of stem analysis and from the measurement of increment cores taken from breast height by us. The volume increment (Vi) and age (A) values were moved to a coordinate system and the regressions representing the data in the best way were determined. The comparative graphic for the tree age-volume increment of the control and infested areas was given below. The regression models belonging to the age-volume increment relationship are given below:

Infested: Vi = - 0.29301 + 0.104218ln$A$ (r: 0.3, F: 17.94, Se: 0.11)
Control: Vi = - 0.47164 + 0.16791ln$A$ (r: 0.346, F: 40.23, Se: 0.08)

The comparisons based on 70th year revealed these results, while the infested group's periodical diameter increment was 2.23 cm, the control group's periodical diameter increment was an average 2.87 cm, which

Table 1. ANCOVA results.

Source	Type III sum of squares	df	Mean Square	F	Significant
Cor. Model	3,806,682[a]	6	634,447	4,103	0.001
Intercept	12,121,432	1	12,121,432	78,399	0.042
Bi	1,252,958	1	1,252,958	8,104	0.004
Vi	457,153	1	457,153	2,957	0.001
H	1,728,677	1	1,728,677	11,181	0.001
Hi	31,500	1	31,500	0.204	0.653
Di	43,142	1	43,142	0.279	0.001
Error	11,286,705	312	154,612		
Total	202,595,000	319			
Cor. Total	15,093,388	318			

means an increment loss of 22%. While the infested group's periodical basal area increment was 22.56 cm^2, the control group's increment was an average 31.72 cm^2. The loss of basal area increment observed here was 29%. While the infested group's average height was 27.62 m the control group's average height was 15.85 m, the height loss observed was 43%. While the infested group's height increment for 5 years was 1.02 m the control group's average height increment was 1.34 m, the height increment loss was 24.5%. While the infested group's periodical volume increment was an average 0.15 m^3 the control group's average increment was 0.24 m^3. The volume increment loss observed here was 37.5%.

Differences in infested and control groups were tested by using ANCOVA. Results are given at Table 1.

ANCOVA analysis were done according to full factorial model at 99.9% (P = 0.001) reliability level. Analyses results showed that there were significant differences between infested and control trees at Di, Bi, H and Vi. But there was no significant difference at Hi. The data were classified based on age groups and whether there was a significant difference at 95% reliability level between the areas infested and the control age groups were analyzed with a t-test. The results are given in Table 2.

Table 2. T-test results.

Age groups (years)	Di	Bi	H	Vi
I-21-30		*	*	*
II-31-40	*	*	*	*
III-41-50		*	*	
IV-51-60	*	*	*	
V-61-70	*	*	*	*

DISCUSSION

The effect of PPM defoliation on the increment of crimean pine trees in Ulus Forest Enterprise was investigated. The differences were ascertained through exposing the increment courses of the infested and control areas on the same graphic. The data was grouped according to age groups and whether there was a difference at 95% reliability level which was tested with a t-test. The aimed was to determine especially which age categories had a difference.

Kanat et al. (2005) have determined that the pest causes approximately 21% decrease in Calabrian pine diameter increment. Kanat and Sivrikaya (2005) have compared the Calabrian pine trees damaged by PPM according to damaged and damageless period and they found that the pest caused 28.5% decrease in diameter increment. Laurent-Hervouet (1986) stated that *T. pityocampa* causes radial growth reductions of 35% in *P. nigra* subs p. *nigricans* forests after a severe attack. According to Carus (1998), PPM causes about 26% decrease in diameter increment. We found increment losses 22% at diameter increment and 29% at basal area increment.

Calas (1897) estimated a 60% reduction in height growth of *P. nigra* trees. The results of Carus's study (1998) aiming to determine the effect of PPM on the increment of Calabrian pine shows that the pest causes 33% decrease in height increment. We found 43% loss in height growth.

In young *Pinus radiata* reforestations, Cadahía and Insua (1970) demonstrated losses at volume increment between 14 and 33% for light and high infestations. Bouchon and Toth (1971) determined that forests of *P. nigra* periodically subject to heavy attacks lost about 45% of their volume in 50 years by using dendrochronological techniques. We found 37.5% loss in volume increment. The results obtained in our study are similar to the results other studies.

According to ANCOVA test results, there were significant differences between infested and control trees at Di, Bi, H and Vi at 99.9% reliability level. t-test results showed that PPM has negative effects on growth and increment of *P. nigra* trees. Basal area increment and height growth losses occur at all age groups. There were significant difference between infested and control trees at II, IV and V age groups in diameter increment and at I, II and V age groups losses in volume increment at 95% reliability level.

Conclusion

In conclusion, the study shows that PPM has a negative effect on the increment in the Crimean pine in the Ulus Forest Management District. Since the density of the damaged stands is relatively lower than the density of the control areas, it is likely that the amount of the difference between the groups may have become less. Moreover, it can be seen that the damage is not fatal and that a limited loss of increment due to PPM feeding occurs during out of vegetation period. The most significant effect of the pest damage has been on the tree height. When the results of this study are compared with studies carried out in the Mediterranean region, it can be seen that the loss of increment caused by the PPM in over-wet and semi-arid climate types is close to each other in percentage and there has not been an important change in the level of damage in respect to climate types.

The next step should include the evaluation of the relationships between economic outcomes of the studies related to increment loss, expenses to counter the pest, and the income losses resulting from the pest damage.

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