**Journal of Environmental Biology**
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**March 2008,** 29(2) 223-226 (2008)
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# Defoliation levels of oriental spruce by *Ips typographus* (L.) in relation to elevation and exposure

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(Received: December 22, 2006 ; Revised received: May 20, 2007 ; Accepted: June 22, 2007)

***Abstract:*** *A study concerning the effects of elevation and exposure of the spruce forests on defoliation levels of oriental spruce (Picea orientalis (L.) Link.) by Ips typographus L. was carried out during 2005 and 2006 in Artvin-Hatila National Park, Turkey. Nine spruce stands were selected at 3 zones of elevations (1000-1350 m, 1350-1700 m and 1700-2000 m) and at different aspects to assess the role of elevation and exposure in the crown defoliation level and body length of beetles. Influence of bark thickness and trunk diameter at 1.3 m on the damage caused by the pest was investigated as well. The results of the study were as follows: (1) The mean defoliation level was highest at 1700-2000 m following by 1350-1700 m and 1000-1350 m. (2) The highest defoliation levels occurred on southern slopes following by eastern and northern slopes at 1700-2000 m. (3) No statistical differences were found in the mean bark thickness between tree defoliation levels 1, 2, 3 and 4. (4) Mean trunk diameters of dead trees (level 4) were significantly greater than those with defoliation levels 0, 1 and 2. (5) Mean body length of I. typographus at upper zones was significantly higher than those at middle and lower zones.*

***Key words:*** *Ips typographus (L.), Picea orientalis (L.), Defoliation, Elevation, Exposure*
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## Introduction

The spruce bark beetle, *Ips typographus* (L.) (Col., Scolytidae), is one of the most aggressive and serious pests of spruce in Eurasia (Bakke, 1989). The beetle mostly attacks Norway spruce (*Picea abies* L. Karst.) (Salle *et al.*, 2005) in Europe and oriental spruce (*Picea orientalis* Link.) in Turkey. Oriental spruce is one of the main timber species of northern Turkey (Tufekcioglu *et al.,* 2004).

The spruce bark beetle was first recorded in Artvin Province (Turkey) in 1984 (Alkan, 1985). Since then, it has spread to all over the oriental spruce forests in Eastern Blacksea region of Turkey. Outbreaks of the pest over two decades have caused catastrophic timber loss primarily in Artvin-Hatila National Park (Turkey). In this area, the spruce bark beetle effectively made damage on 1,500 ha. of spruce stands and caused 60,000 $m^3$ wood loss in the year 2003-2004 (Anonymous, 2004; Tilki *et al*., 2005).

Although the spruce bark beetle has been studied in some detail in the Eastern Black Sea Region of Turkey, no study of breeding conditions and defoliation level of spruce trees by the pest in relation to elevation and exposure have been made. This study was initiated to determine the defoliation levels of the spruce tree and some morphological features of the pest in relation to elevation, exposures, and some tree characteristics.

## Materials and Methods

The survey took place in 2005 and 2006. Artvin-Hatila National Park was selected as the study area due to higher density and more intensive damage by the pest than the other spruce stands in the region. The pest has two generation/year in Artvin (Keskinalemdar, 1995). On an average, spruce trees were 80-95 years old and average stand density was 450 stems/ha. The soil type in the study area was mainly a well-drained inceptisol soil with the texture of sandy loam.

Trees were selected randomly from 9 spruce stands at 3 zones of elevations (1000-1350 m, 1350-1700 m, and 1700-2000 m) (Table 1). To estimate the defoliation level of the spruce trees in the study area, the European defoliation categories (0. 0-10%, (1) 11-25%, (2) 26-60%, (3) >60% and (4) dead tree) were used. The defoliation level of 50 trees was estimated on each plot. The mean defoliation index was calculated for each plot as an average value of all individual tree defoliation levels. After that, the average defoliation levels for the 3 zones of elevations and south, east and north exposures were calculated. The diameter and bark thickness of each tree was measured at breast height to compare with defoliation level of each tree.

Effect of elevation on body lengths of the pest was also investigated in this study. In August 2006, about a week after the beginning of the second generation's flight period, 100 adult beetles were collected at each plot from the pheromone traps (Tripheron® produced by Trifolio-M GmbH, Germany) and put into 70% ethanol for the purpose of measuring body length of the beetles. A trinocular stereozoom microscope and a computer image analyser program (ImPA®) were used to measure the body lengths.

All data were subjected to analysis of variance (ANOVA) for determination of differences between the mean values, using the

**Table - 1:** Primary features of the observed plots in Artvin-Hatila National Park, Turkey

| Elevation (m) | Plot number | Exposure | Mean stand age (year) | Mixture |
|---|---|---|---|---|
| 1000-1350 | 1 | S | 85 | Spruce (80%), others (fir, hornbeam, oak) (20%) |
| | 2 | E | 95 | Spruce (80%), others (fir, hornbeam, oak) (20%) |
| | 3 | N | 90 | Spruce (75%), others (fir, hornbeam, oak) (25%) |
| 1350-1700 | 1 | S | 90 | Spruce (90%), others (fir, beach) (10%) |
| | 2 | E | 95 | Spruce (90%), others (fir, beach) (10%) |
| | 3 | N | 85 | Spruce (85%), others (fir, beach) (15%) |
| 1700-2000 | 1 | S | 90 | Spruce (95%), others (fir, beach) (5%) |
| | 2 | E | 80 | Spruce (100%) |
| | 3 | N | 85 | Spruce (95%), others (fir, beach) (5%) |

S = South, E = East, N = North

**Table - 2:** Mean defoliation levels for *I. typographus* as related to elevation

| Elevation (m) | Number of trees | European defoliation level $\pm$ SE |
|---|---|---|
| 1000-1350 | 150 | $0.41 \pm 0.07^{c}$ |
| 1350-1700 | 150 | $0.79 \pm 0.12^{b}$ |
| 1700-2000 | 150 | $2.33 \pm 0.13^{a}$ |

Different letters after the means indicate a significant difference between the means (LSD test, $p \leq 0.05$)

**Table - 3:** Mean defoliation levels for *I. typographus* as related to exposures

| Elevation (m) | Exposure | Number of trees | European defoliation level $\pm$ SE |
|---|---|---|---|
| 1000-1350 | S | 50 | $0.56 \pm 0.14^{c}$ |
| | E | 50 | $0.36 \pm 0.10^{c}$ |
| | N | 50 | $0.32 \pm 0.10^{c}$ |
| 1350-1700 | S | 50 | $0.88 \pm 0.21^{c}$ |
| | E | 50 | $0.80 \pm 0.17^{c}$ |
| | N | 50 | $0.70 \pm 0.18^{c}$ |
| 1700-2000 | S | 50 | $2.60 \pm 0.20^{a}$ |
| | E | 50 | $2.36 \pm 0.24^{ab}$ |
| | N | 50 | $2.02 \pm 0.21^{b}$ |

S = South, E = East, N = North
Different letters after the means indicate a significant difference between the means (LSD test, $p \leq 0.05$)

**Table - 4:** Mean bark thickness at 1.3 m as related to defoliation levels

| Defoliation level | Number of trees | Mean bark thickness (mm) $\pm$ SE |
|---|---|---|
| 0 | 235 | $10.31 \pm 0.25^{a}$ |
| 1 | 73 | $10.74 \pm 0.47^{a}$ |
| 2 | 42 | $10.17 \pm 0.73^{a}$ |
| 3 | 27 | $10.45 \pm 0.69^{a}$ |
| 4 | 73 | $11.36 \pm 0.57^{a}$ |
| Total | 450 | $10.71 \pm 0.20$ |

Different letters after the means indicate a significant difference between the means (LSD test, $p \leq 0.05$)

SPSS® 10.0 for Windows® software. When significant differences occurred, LSD test with $p \leq 0.05$ was used for mean separation.

## Results and Discussion

The mean defoliation levels at the 3 zones of elevations and south, east and north exposures of the zones were analyzed with one-way analysis of variance (ANOVA). Differences between means were tested by LSD test (Tables 2, 3). The defoliation levels were varied significantly ($p \leq 0.05$) among the 3 zones. It can be seen that the mean defoliation level was highest at 1700-2000 m following by 1350-1700 m and 1000-1350 m (Table 2). In the study area, the forests at 1000-1350 m and 1350-1700 m consist of more diversified stands than those at 1700-2000 m. There is overwhelming evidence that plant mixtures (intercrops) support lower numbers of pests than pure stands (Altieri and Liebman, 1994). In the same way, higher natural enemy populations persist in diverse mixtures because they provide more continuous food sources (nectar, pollen, and prey) and habitat (Sullivan, 2003). Grodzki (2004) also found the mean defoliation index higher at altitude above 800 m than at altitude below 800 m in the Sudeten Mountains, Poland.

The highest defoliation levels occurred on southern slopes following by eastern and northern slopes at 1700-2000 m. At 1000-1350 m and 1350-1700 m, mean defoliation level values did not vary significantly among southern, eastern and northern slopes (Table 3). South-exposed and sunlit trees were preferably attacked, especially after abrupt increases in solar radiation levels (Lobinger and Skatulla, 1996; Jakus, 1998; Wermelinger, 2004). Grodzki (2004) reported that mean defoliation index was the highest on western slopes at altitude below 800 m and on southern slopes at altitude above 800 m.

The bark thickness at breast height increases in a logarithmic relationship as the trunk diameter increases ($y = 0.024x + 0.3198$, $R^2 = 0.6413$, $p<0.001$) (Fig. 1). The highest bark thickness was measured from the dead tree trunks. Nevertheless, no statistical differences were found in the mean bark thickness between tree defoliation levels 1, 2, 3 and 4 (Table 4). Spruces with thick bark and dense resin ducts seem to be more efficient in

**Table - 5:** Mean diameter at 1.3 m as related to defoliation level

| Defoliation level | Number of trees | Mean diameters of tree trunks (cm) $\pm$ SE |
|---|---|---|
| 0 | 235 | $29.72 \pm 0.87^b$ |
| 1 | 73 | $31.16 \pm 1.27^b$ |
| 2 | 42 | $29.74 \pm 2.23^b$ |
| 3 | 27 | $32.52 \pm 1.63^{ab}$ |
| 4 | 73 | $37.18 \pm 2.00^a$ |
| Total | 450 | $31.34 \pm 0.66$ |

Different letters after the means indicate a significant difference between the means (LSD test, $p \leq 0.05$)

**Table - 6:** Mean body lengths of *I. typographus* captured from 3 zones of elevations

| Elevation (m) | Number of insects | Mean body length (mm)$\pm$SE |
|---|---|---|
| 1000-1350 | 300 | $4.76 \pm 0.02^b$ |
| 1350-1700 | 300 | $4.78 \pm 0.02^b$ |
| 1700-2000 | 300 | $4.86 \pm 0.02^a$ |
| Total | 900 | $4.80 \pm 0.01$ |

Different letters after the means indicate a significant difference between the means (LSD test, $p \leq 0.05$)

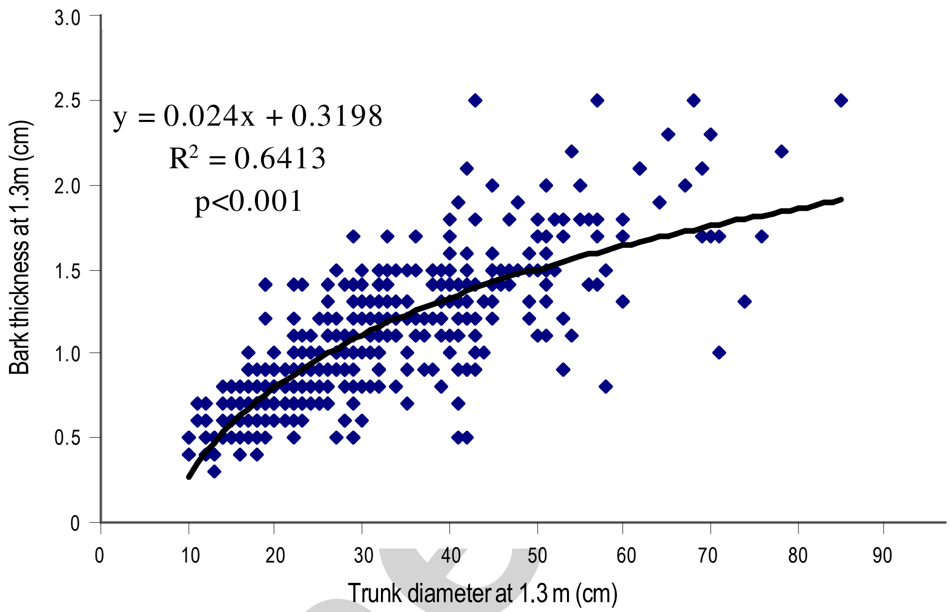


**Fig. 1:** Relationship between trunk diameter and bark thickness of *P. orientalis* (L.) (n=450)

repelling boring attempts than thin-barked low resin trees (Nihoul and Nef, 1992; Baier, 1996; Wermelinger, 2004). On the other hand, bark thickness generally increases with stem diameter and tree age. Therefore, as forests age they become more vulnerable to agents of disturbance, such as high winds, fire, fungi, and bark beetles (Christiansen *et al.*, 1987).

There were significant differences between the mean diameters of tree trunks recorded per defoliation levels. Mean trunk diameters of dead trees (level 4) were significantly greater than those with defoliation levels 0, 1 and 2 (Table 5). In other words, the most susceptible trees were those having the thick-diameter trunks.

There were significant differences between the mean body lengths of *I. typographus* captured from lower, middle and upper zones. We found that mean body length of *I. typographus* at upper zones was significantly higher than those at middle and lower zones (Table 6). The reaction of *I. typographus* populations to better environmental conditions is expressed as an increase in the infestation density on trees and greater body length of beetles (Grodzki, 2004).

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