African Journal of Biotechnology Vol. 8 (5), pp. 877-882, 6 March, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Ips typographus (L.) and *Thanasimus formicarius* (L.) populations influenced by aspect and slope position in Artvin-Hatila valley national park, Turkey

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Accepted 5 January, 2009

This study investigated the effects of aspect (north and south) and slope position (top slope: 1100 - 1700 m and bottom slope: 1700 - 2200 m) on *Ips typographus* (L.) and its major predator *Thanasimus formicarius* (L.) populations and body length and weight of the pest *I. typographus* (L.) in oriental spruce [*Picea orientalis* (L.) Link.], dominated stands in Artvin-Hatila Valley National Park, Turkey for two years (2006-2007). A total of 120 pheromone traps were used to assess the population levels of both insect species. The results of the study were as follows: 1.) *I. typographus* (L.) population on each aspect was significantly higher at the top slope stands than the other sites whereas *T. formicarius* (L.) population was higher at the bottom slope stands on the north-facing site. 2.) There was no correlation between the number of *T. formicarius* (L.) and *I. typographus* (L.) caught by pheromone traps. 3.) Body length and weight of *I. typographus* (L.) were significantly higher on south aspect and at the top slope on each aspect.

Key words: *Ips typographus* (L.), *Thanasimus formicarius* (L.), pheromone, Hatila Valley, Turkey, aspect, altitude.

INTRODUCTION

The spruce bark beetle [*Ips typographus* (L.) (Col., Scolytidae)] is one of the most destructive bark beetle species attacking mostly oriental spruce [*Picea orientalis* (L.) Link] forests in Turkey. The pest 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 (Akkuzu and Güner, 2008). In this region, one of the most destructive damage caused by *I. typographus* (L.) has occurred in Artvin-Hatila National Park over the last decade. Today, it has been estimated that the bark beetle *I. typographus* (L.) has infested and damaged 15,000 ha spruce forest in Hatila National Park (Sunar Erbek et al., 2005).

In latent conditions, the bark beetle *I. typographus* (L.) preferably attacks stressed and wind-thrown trees, which have a lower level of resistance (Chararas, 1962; Lindelöw et al., 1991). Epidemic population developments are only observed following storms and large scale wind-felled spruce damage providing abundant breeding material (Warzee et al., 2006). During outbreaks, high population levels make it able to kill healthy trees that have a higher critical threshold of attack density (Mulock and Christiansen, 1986). A detailed description of the ecology and biology of the species can be found in Christiansen and Bakke (1988) and Wermelinger (2004).

The ant beetle [*Thanasimus formicarius* (L.) (Col., Cleridae)], one of the most common predators of *I. typographus* (L.) in Turkey, feeds on 27 bark-beetle species belonging to 15 genera (*Dendroctonus*, *Dryocoetes*, *Hylastes*, *Hylesinus*, *Hylurgops*, *Hylurgus*, *Ips*, *Leperesinus*, *Orthotomicus*, *Pityogenes*, *Pityokteines*, *Polygraphus*, *Scolytus*, *Tomicus* and *Trypodendron*) (Gauss, 1954; Mills, 1983; Tommeras, 1988). *T. formicarius* (L.) exerts a significant impact on the population dynamics of *I. typographus* (L.) (Mills, 1985; 1986; Weslien, 1992; Weslien and Regnander, 1992) because of its high fecundity [106 – 162 eggs/female (Dippel et al., 1997; Weslien and Regnander, 1992)] and its high voracity at the adult stage [0.86 to 2 – 3 adult *I. typographus* (L.) per day [Faccoli and Stergulc, 2004; Weslien and Regnander, 1992)] as well as at the larval stage (44 – 57 prey larvae during the whole larval life: (Dippel et al., 1997; Hérard and Mercadier, 1996; Mills,

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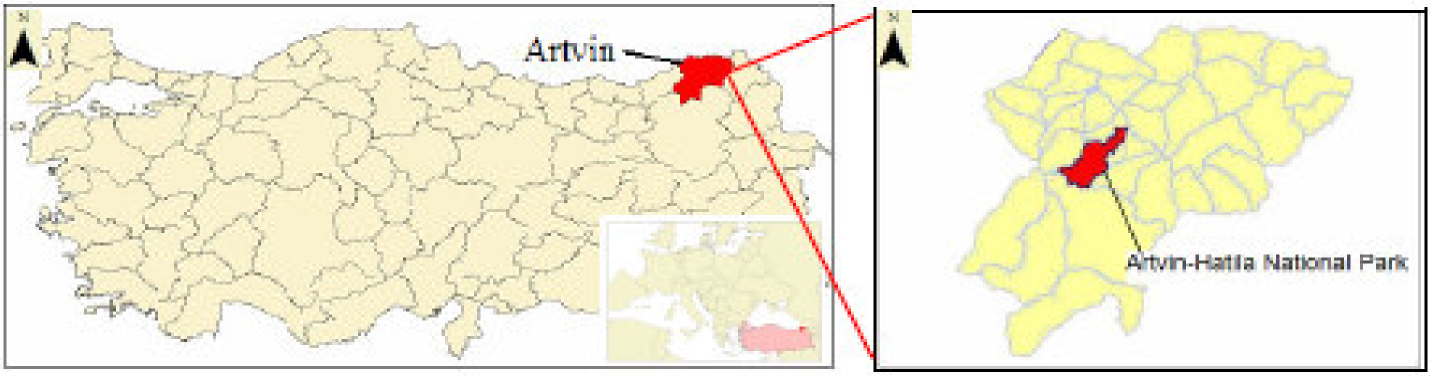

Figure 1. Location of the Artvin-Hatila National Park in Turkey.

1985)]. Adults of *T. formicarius* (L.) live 4 to 10 months (Gauss, 1954) and respond to the pheromones of *I. typographus* (L.) (Bakke and Kvamme, 1981).

A number of studies have shown that climate and topographic factors influence the population dynamics of *I. typographus* (L.) and *T. formicarius* (L.) (Funke and Petershagen, 1994; Lobinger, 1994; Lobinger and Skatulla, 1996; Lexer, 1997; Jakus, 1998; Grodzki, 2004; Rouault et al., 2006). In local areas, it is well known that topographic conditions such as slope and aspect can have a strong influence on microclimatic factors (especially temperature and rainfall). In Northeast Turkey, in which this present study was carried out, aspect and slope positions are very important topographical factors influencing local site microclimate, soil chemistry, litter quality, and litter decomposition rates (Sariyildiz et al., 2005; Sariyildiz et al., 2008). Over the last decade, *I. typographus* (L.) attack rates on pure oriental spruce in the Artvin-Hatila Valley National Park also seem to be influenced by topographical landforms (aspects and slope positions) (Sariyildiz et al., 2008).

To our knowledge, there have been no detailed studies on the effects of topographic conditions on the spruce bark beetle *I. typographus* (L.) and its predator *T. formicarius* (L.) populations. The objectives of the present study were to investigate the effects of aspects and slope positions on *I. typographus* (L.) and *T. formicarius* (L.) populations, and the body length and weight of *I. typographus* (L.).

MATERIALS AND METHODS

Study area

The study was conducted during the summer of 2006 and 2007 in Artvin-Hatila National Park (41°51' N, 41° 06' E), a protected state park located in Eastern Blacksea Region of Turkey (Figure 1). Within the study area, there are mixed stands made up of spruce, hornbeam, fir, beach and oak, but over the altitude of 1700 m up to 2100 m forest formation type are almost pure oriental spruce trees, and has been under attack by *I. typographus* (L.) over the last two decades (Table 1). The soil type in the study area was mainly a well-drained inceptisol soil with the texture of sandy loam.

Climate is generally characterized by cold winters and semi-arid summers (1948 – 2000 meteorological data from Artvin Meteorology Station) (Sariyildiz et al., 2005). Average monthly temperature ranged from 32°C in August to -2.5°C in January in the year 1948 - 2000. The mean annual precipitation in higher slopes reached over 1100 mm and the lowest temperature was recorded as -6.1°C in January 2000 (Damar meteorology station at 1550 m) (Sariyildiz et al., 2005).

Field experiment

Four oriental spruce study plots were selected from north and south aspects at two zones of altitude [1. 1100 - 1700 m (bottom slope), 2. 1700 - 2200 m (top slope)]. A total of 120 multifunnel pheromone traps with commercial pheromone Pheroprax® were deployed in four study plots (30 traps for each). The most important attractants for *T. formicarius* (L.) are the volatiles produced by *I. typographus* (L.) (Hansen, 1983). *T. formicarius* (L.) is strongly attracted to ipsdienol and ipsenol, less to cis-verbenol and not at all to methylbutenol (Bakke and Kvamme, 1981). Furthermore, *T. formicarius* (L.) has been shown to exploit pheromonal products of several bark beetles besides *I. typographus* (L.) (Tommeras, 1988; Zumr, 1988). Thus, commercial pheromone Pheroprax® was used to assess the distribution of *T. formicarius* (L.) in the study area. All traps were fastened to wooden sticks at a height of 1.5 m above ground. The quantification of captured insects took place every 7 - 10 days by counting insects, or by measuring volume of the insects if the catch were greater than 500 insects per trap.

In each study sites, a total of 100 spruce tree (stem >8 cm diameter at breast height, 1.3 m above ground level) was measured for height, diameter, age and double bark thickness. Tree age was determined by counting each annual growth ring in the trunk of the tree. Tree heights, double bark thickness and diameters at the breast height were measured with a Blume-Leiss altimeter, a bark gauge and a diameter tape, respectively. After that, mean stand age, height, double bark thickness and tree diameter were calculated. The location and stand characteristics of the studied sites are shown in Table 2.

A total of 720 adult *I. typographus* (L.) (180 beetles in each site) were collected from bark beetle-infested spruce trees for the purpose of measuring body length and weight of the beetles. Each oven-dried (60°C for 24 h) *I. typographus* (L.) was weighed and its length measured by a trinocular stereozoom microscope and a computer image analyzer program (ImPA®).

Table 1. Primary features of the study sites in Artvin-Hatila National Park.

Feature	North		South	
	Top Slope	Bottom Slope	Top Slope	Bottom Slope
Slope angle (%)	55	65	60	65
Slope (m)	1700 - 2200	1100 - 1700	1700 - 2200	1100 - 1700
Mineral soil texture	Sand	Sandy loam	Sandy loam	Sandy loam
Canopy cover (%)	61.7	78.4	57.3	75.4
Stand mixture	Spruce (80 - 95 %), others (fir, beach) (5 - 20%)	Spruce (50 - 80%), others (hornbeam, fir, beach, oak) (20 - 50%)	Spruce (80 - 95%), others (fir, beach) (5 - 20%)	Spruce (50 - 80%), others (hornbeam, fir, beach, oak) (20 - 50%)

Table 2. Location and stand characteristics of oriental spruce from two slope positions on north and south aspect.

Characteristic	North		South	
	Top Slope	Bottom Slope	Top Slope	Bottom Slope
Age (year) ±SE	109,02±1.47b	101.88±1.04c	123.04±1.29a	103.62±1.21c
Height (m) ±SE	25.54±0.38b	21.78±0.37c	29.42±0.32a	21.14±0.36c
Double bark thickness (cm) ±SE	2.66±0.60b	2.29±0.57c	3.09±0.52a	2.24±0.37c
Tree diameter (cm) ±SE	40.66±1.24b	27.62±0.72c	47.80±1.00a	24.22±0.70d

Different letters after the means indicate a significant difference between the means (Least Significant Difference (LSD) Test, $p \leq 0.05$)

Statistical methods

A two-way MANOVA analysis was employed to examine the effects of both slope and aspect on *I. typographus* (L.) and *T. formicarius* (L.) densities and on body length and weight of *I. typographus* (L.) in the study area. After that, a separate two-way ANOVA was subsequently carried out for each species. When significant differences occurred in these two-way ANOVAs, LSD test with $p < 0.05$ was used for mean separation after a significant factor effect was confirmed by one-way ANOVAs. The Pearson Correlation test was used to evaluate the relationship between the number of *T. formicarius* (L.) and *I. typographus* (L.) captured by pheromone traps. All statistical analyses were performed with the significance level of $\alpha = 0.05$ using SPSS® 15.0 for Windows® software.

RESULTS

There is a significant effect of slope ($p < 0.001$), aspect ($p < 0.001$) and slope-aspect interaction ($p < 0.001$) on *I. typographus* (L.) and *T. formicarius* (L.) densities (Two-way MANOVA, $\alpha = 0.05$) (Table 3). Separate two-way ANOVAs showed that slope ($p < 0.001$), aspect ($p < 0.001$) and slope-aspect interactions ($p < 0.001$) were all significant (Table 3). Both slope and aspect affected the density of *I. typographus* (L.) and *T. formicarius* (L.) in the region.

Subsequent one-way ANOVAs revealed significant differences in captured species by pheromone traps among the four study plots (treatments) of *I. typographus* (L.) ($F_{3,956}$ = 34.798) and *T. formicarius* (L.) ($F_{3,956}$ = 26.117). LSD test with $p < 0.05$ was showed that number of *I. typographus* (L.) captured by pheromone traps was significantly higher at top slope positions on the south aspect than the other sites (Table 4).

Table 3. Results of two-way MANOVA and two-way ANOVAs applied to the effects of the slope and aspect on the number of *I. typographus* (L.) and *T. formicarius* (L.).

	df	*F*	p
Two-way MANOVA			
Slope	2	26.167	<0.001
Aspect	2	32.604	<0.001
Slope x Aspect	2	32.214	<0.001
Two-way ANOVA			
Slope (I) *	1	37.294	<0.001
Aspect (I)	1	31.066	<0.001
Slope x aspect (I)	1	36.036	<0.001
Error (I)	956		
Slope (T) **	1	15.665	<0.001
Aspect (T)	1	34.989	<0.001
Slope x aspect (T)	1	27.697	<0.001
Error (T)	956		

* (I): I. typographus (L.).
** (T): T. formicarius (L.).

Mean number of the pest captured was similar at bottom slope positions on both south and north-facing site and top slope positions on north-facing site. It means there were no significant differences among these sites (Table 4).

On the other hand, LSD test revealed that number of *T. formicarius* (L.) captured by pheromone traps was significantly higher at bottom slope on north-facing sites

Table 4. Mean number of *I. typographus* (L.) and *T. formicarius* (L.) captured by pheromone traps.

Slope (m)	Aspect	Traps*	Mean number of *I. typographus* ±SE	Mean number of *T. formicarius* ±SE
Bottom slope	South	240	4.5625±0.4614b	0.0917±0.0229b
	North	240	18.5792±1.7871b	1.1625±0.1820a
Top slope	South	240	399.9375±65.2432a	0.2167±0.0393b
	North	240	21.9708±1.9438b	0.2792±0.0388b

Different letters after the means indicate a significant difference between the means (LSD test, $p < 0.05$). * Number of traps controlled throughout the study period.

Table 5. Pearson correlation coefficients showing the relationships between the number of *I. typographus* (L.) and *T. formicarius* (L.) captured by pheromone traps.

Species		*I. typographus*	*T. formicarius*
I. typographus	Pearson correlation	1	-0.035
	Sig. (2-tailed)		0.275
	N	960	960
T. formicarius	Pearson correlation	-0.035	1
	Sig. (2-tailed)	0.275	

Table 6. Results of two-way MANOVA and two-way ANOVAs applied to the effects of the slope and aspect on body weight and length of *I. typographus* (L.).

	df	*F*	p
Two-way MANOVA			
Slope	2	5.157	0.006
Aspect	2	7.240	0.001
Slope x Aspect	2	0.026	0.975
Two-way ANOVA			
Slope (L) *	1	8.314	0.004
Aspect (L)	1	9.211	0.003
Error (L)	716		
Slope (W) **	1	9.441	0.002
Aspect (W)	1	14.346	<0.001
Error (W)	716		

* (L): body length of *I. typographus* (L.).
** (W): body weight of *I. typographus* (L.).

Table 7. Summary of measurements of body length and weight of *I. typographus* (L.) by slope and aspect.

Parameter	Body lenght		Body weight	
	Mean	SD	Mean	SD
Slope				
Bottom	4.9073	0.2843	0.0040	0.0007
Top	4.9921	0.3112	0.0042	0.0008
Aspect				
South	4.9943	0.2811	0.0042	0.0007
North	4.9051	0.3135	0.0039	0.0007

than the other sites. There were no significant differences among the other sites (Table 4).

There was an insignificant correlation between the number of *T. formicarius* (L.) and *I. typographus* (L.) captured by pheromone traps (Pearson correlation: $r = -0.035$, $N = 960$, $P = 0.275$) (Table 5).

Both slope ($p = 0.006$) and aspect ($p = 0.001$) significantly affected the body length and weight of *I. typographus* (L.). No significant slope x aspect interaction ($p = 0.975$) effect was however revealed by two-way MANOVA ($\alpha = 0.05$) (Table 6). The length and weight of the beetles were significantly bigger at top slope positions and south aspects than the other sites (Tables 6 and 7). Significant positive linear corelations were found between body length and weight of the beetles (Figure 2).

DISCUSSION

I. typographus (L.) was trapped in higher numbers at top slope positions on south-facing site than the other sites (Table 3 and 4). This is in agreement with the results by Grodzki (2004) on *I. typographus* (L.). Many studies have also shown that south-exposed and sunlit trees are preferably attacked, especially after abrupt increases in solar radiation levels (Lobinger and Skatulla, 1996; Jakus, 1998). Most studies have noted that there is a strong relationship between the number of insects per trap and the number of trees attacked by *I. typographus*

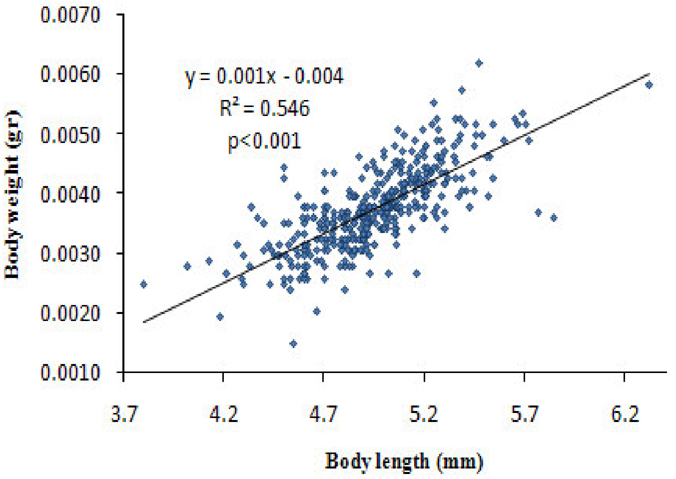

Figure 2. Relationship between body length and weight for *I. typographus* (L).

(L.) (Faccoli and Stergulc, 2004). Weslien et al. (1989) reported that the risk of trees being killed by *I. typographus* (L.) increases with increasing beetle population density.

In the study area, stands at bottom slope positions are made up of diverse tree composition (that is, hornbeam, fir, beach and oak) and ground vegetation. Stands at upper elevations are however formed by almost pure spruce trees. Jactel et al. (2005) reported that forests with highly diverse tree composition, age structure, and ground vegetation have a different tree physiology and are more resistant to windthrow and bark beetle attack.

Mean tree age, height, diameter, and double bark thickness at top slope positions on south-facing site were significantly higher than the other sites (Table 2). As forests age they become more vulnerable to agents of disturbance, such as high winds, fire, fungi, and bark beetles (Christiansen et al., 1987). Higher proportions of spruce trees in a stand were found to enhance bark beetle attack as were trees older than 70 years, with trees over 100 years being most susceptible (Becker and Schröter, 2000).

Bark anatomy and the physiological condition of a potential host tree are crucial for the success of a bark beetle attack (Wermelinger, 2004). Spruces with thick bark and dense resin ducts seem to be more efficient in repelling boring attempts than thin-barked, low resin trees (Nihoul and Nef, 1992; Baier, 1996). Trees in mixed stands had a higher primary resin flow than those in pure spruce stands (Baier et al., 2002).

This study has shown that *T. formicarius* (L.) population level does not directly depend on the *I. typographus* (L.) population level (Tables 4 and 5). Although the number of *I. typographus* (L.) caught by pheromone traps was higher at top slope on south-facing sites than the other sites, *T. formicarius* (L.) was higher at bottom slope on north-facing sites (Table 4). The result was somewhat surprising since we expected to find a significant correlation between the number of *I. typographus* (L.) and *T. formicarius* (L.) caught by pheromone traps. This result could depend on following reasons:

1) As Gauss (1954), Mills (1983) and Tommeras (1988) indicated that *T. formicarius* (L.) feeds not only on *I. typographus* (L.), but also 27 bark beetle species. Possibly, the predator feeds on some other host species at bottom slope on north-facing sites. 2) The spruce bark beetle has high dispersal abilities and can thus escape the local mortality agents (Wermelinger, 2004). At new potential infestation spots the local density of antagonists may be still low, which allows the bark beetles to build up new populations successfully (Wermelinger, 2004).

3) In the study area, bottom slopes are made up of mixed stands of spruce, hornbeam, fir, beach, and oak. In mixed forests, in comparison to monocultures, the abundance of predators and parasitism is higher (Jäkel and Roth, 2004).

The length and weight of *I. typographus* (L.) were significantly higher at top slope positions and south aspects (Tables 6 and 7). As Grodzki (2004) indicated that these stands probably offered more favorable breeding conditions for bark beetles due to the reduced resistance of individual trees, which could have resulted in the increased average length of *I. typographus* (L.) adults. In stands that sustained lower levels of mortality (that is, representing higher resistance), the beetles were smaller (Grodzki, 2004).

ACKNOWLEDGEMENTS

This project is funded by The Scientific and Technological Research Council of Turkey (TUBITAK) with the project number 106O193. The authors would like to thank Artvin Forestry Commission for permission to carry out the field studies in Artvin-Hatila Valley National Park, Turkey.

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