ASSESSMENT OF TRAP COLOR AND TRAP HEIGHT ABOVE THE GROUND ON THE CAPTURE OF *IPS SEXDENTATUS* AND *THANASIMUS FORMICARIUS*

**SUMMARY**

The six-toothed pine bark beetle *Ips sexdentatus* is one of the most devastating bark beetles of Eurasian pine forests. Pheromone traps are used to monitor and control *Ips sexdentatus* populations. In this study, the effect of trap color and trap height on the capture of *Ips exdentatus* and its predator the ant beetle *Thanasimus formicarius* was investigated. The research was conducted in *Pinus sylvestris* stands within Yayla Forest Enterprise Chief (Kastamonu-Dayad) in Turkey. In the study area, 25 Scandinavian type three-funnel traps of 5 different colors (yellow, white, green, black, and red traps with five replications) were used. Traps were placed at the same height, 1.5 m above ground. For the second part of the study, a total of 20 traps (5 per height category) was placed 1.0 m, 1.5 m, 2.0 m, and 2.5 m above ground. Traps were controlled at intervals of 7-10 days and captured *Ips exdentatus* and *Thanasimus formicarius* were counted. The results of the study were as follows: 1) Significant differences in the number of captures by trap color, and 2) No significant differences in the numbers of *Ips sexdentatus* and *Thanasimus formicarius* captured between the trap heights.

**KEY WORDS:** Six-toothed pine bark beetle, ant beetle, trap height, trap color, pine

**INTRODUCTION**

Bark beetles, belong to the subfamily Scolytinae within the family Curculionidae (Coleoptera), are one of the most destructive groups among the xylophagous species on trees (Cebeci and Baydemir 2018). Although most of the bark beetle species are secondary pests, defined as infesting freshly killed trees or killing living trees of subnormal physiological condition (Rudinsky 1962, Stark 1982, Lausch et al. 2013, Lieutier et al. 2016), they cause tremendous amount of mortality and/or growth loss of conifers.

The six-toothed pine bark beetle, *Ips sexdentatus* (Boerner, 1776), is one of the most devastating pests of the most of the European pine forests (Jactel and Gaillard, 1991) feeding predominantly on *Pinus* spp. but during outbreaks may attack even *Picea* spp. (Rener and Maja 2001, Ozcan et al. 2011, Avtzis et al. 2019). Althouh this species mainly prefers trees that are somehow weakened or otherwise under stress, it can even attack and kill healthy trees at high population levels (Rossi et al. 2009, Pineau et al. 2017). Various control and monitoring methods have been established to reduce bark beetle’s adverse effects on forests.

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Among them, commercially produced pheromone traps against bark beetles and wood-boring insects have been used in forestry practice for more than 40 years (Galko et al. 2016).

The eyes of scolytids have about 100-240 ommatidia, relatively less than many insects (Chapman 1972, Byers et al. 1989). Although scolytids have low visual acuity (Byers et al. 1989, Byers 1995), many factors such as trap design and shape may influence the number of pests captured (McLean and Borden 1979, Lindgren et al. 1983, Borden et al. 1986).

*Thanasimus formicarius* (Linnaeus, 1758) (Col. Cleridae), one of the main predators of *Ips sexdentatus* (Martin et al. 2013), are saproxylic predators of Scolytinae (bark beetles), both as adults and as larvae (Thomaes et al. 2017). Although pheromone traps are used for monitoring and mass trapping of bark beetles, there are some negative effects on natural enemies. Many insect predators are attracted to pheromone traps and thus are removed along with target insects (Chapman 1972, Byers et al. 1997, Dahlsten et al. 2003).

The aim of this study was to compare the positive effects of pheromone baits on the capture of *Ips sexdentatus* and their negative effects on *Thanasimus formicarius*.

### MATERIAL AND METHODS

**MATERIJALI I METODE**

**Study area – Područje istraživanja**

The study area – Forest Enterprise Chief of Kastamonu-Yayla (41°24'52″N–41°31'42″E) is situated in Western Blacksea region of Turkey. The total area of the study area is 9259.3 ha out of which 6693.9 ha covered with forests. Sites are located on the southern inclination and at altitudes ranging from 1200-1270 m asl.

The main tree species of the study area is Scotch pine (*Pinus sylvestris*), covering about 90% of the stem basal area mixed with Pedunculate oak (*Quercus robur*) and Uludag fir (*Abies bornmülleriana*).

**Experimental Design and Procedure – Eksperimentalni dizajn i postupak**

The study was conducted from June 9 to August 18, 2017 in Scotch pine dominated stands mixed with pedunculate oak and Uludag fir. SMC IPSEK lures targeted for *Ips sexdentatus* were used in this study. The active ingredient in the lures was 100 mg Ipsdienol/Dispenser. The lure was replaced every 4 weeks on each pheromone trap. The pheromone traps were checked at 7-10 day intervals from June to August 2017. The captured insects were collected in the field and brought into the Entomology Laboratory of Kastamonu University Faculty of Forestry for identification, counting, and photographing.

For the first experiment, five different color of traps (black, white, yellow, red and green) were compared to determine the effect of color on the capture of *Ips sexdentatus* and *Thanasimus formicarius*. Scandinavian type three funnel traps were used for the experiment and were hung at a height of 1.5 m above the ground. The distance between traps was about 30 m, and each trap was about 5 m away from the nearest tree. A total of 25 traps were installed and each trap color was represented by five traps (replications) per location.

For the second experiment, four black colour Scandinavian type three funnel traps were hung at heights of 1.0, 1.5, 2.0, and 2.5 m as one set to compare the effect of trap height on capturing the pest *Ips sexdentatus* and the predator *Thanasimus formicarius*. Five sets of traps (total of 20 traps) were placed along a line in west-east direction in the field. The distance between traps was about 50 m.

**Statistical Analysis – Statistička analiza**

All statistical analyses were performed using SPSS® 22 software. The normality of the distributions was tested using Kolmogorov–Smirnov and Shapiro-Wilk tests. Trap catch data were subjected to Kruskal-Wallis test at a significance limit of p<0.05 followed by multiple comparison test (Post hoc Dunn’s test). Pearson’s correlation analysis was also used to investigate the corelations between the pest *Ips sexdentatus* and associated predator *Thanasimus formicarius*.

### RESULTS AND DISCUSSION

**REZULTATI I RASPRAVA**

**Trap color – Boja klopki**

In the color-response experiment the highest number of *Ips sexdentatus* was captured by black color traps followed by red, green, yellow and the lowest was white color trap. Si-

| Table 2. Effect of trap colors on *Ips sexdentatus* and *Thanasimus formicarius* capture (Kruskal-Wallis Test) |
|---------------------------------------------------------------|
| **Chi-square** | **T. formicarius** | **I. sexdentatus** |
| Hi-kvadrat       | 15,063             | 7,832             |
| Df               | 4                  | 4                 |
| Asymptotic significance | 0.005 | 0.998 |
significant differences in the mean total capture of *Ips sexdentatus* were noted among the five trap colors (df = 4, p < 0.005) (Figure 3). Post hoc Dunn’s test showed that significantly more *Ips sexdentatus* were captured by black traps than white ones (p<0.003) (Table 2). No significant differences were occurred among the other trap colors (Table 3). Although there were no statistically significant differences in numbers of *Thanasimus formicarius* captured between the trap colors (p<0.098), white-color trap was the least attractive pheromone trap followed by yellow, red, green, and black traps (Fig. 1).

Pearson correlation analysis was performed to determine the relationship between the number of *Ips sexdentatus* and *Thanasimus formicarius* captured by pheromone traps. The test indicated a significant and positive relationship existed between the pest and the predator (p <0.01) (Table 4).

In this study, dark traps (Black, Green and Red) were found to be more effective in attracting insects than light traps in general (Yellow and White). This result is consistent with Chen et al. (2009)’s findings on *I. duplicatus*. In addition, Strom et al. (1999) and Strom and Goyer (2001) showed that funnel-type black-colored traps caught more *Dendrocotos frontalis* and *D. brevicomis* than white-colored traps. Dubbel et al. (1985) found that for *I. typographus* and *Trypodendron lineatum* no significant differences were observed in clear, black, green, grey and red-brown traps, whereas catches in white traps were significantly lower. Mizell III and Tedders (1999) reported that dark colored

**Figure 1.** Mean catch (±SE) of *Ips sexdentatus* and *Thanasimus formicarius* according to tested pheromone trap colors.

Slika 1. Srednji ulov (± SE) *Ips sexdentatus* i *Thanasimus formicarius* u odnosu na boje ispitivanih feromonskih klopki.

**Table 3.** Post hoc Dunn’s test of *Ips sexdentatus* according to trap color

| Sample-1 | Sample-2 | Test Statistic | Standard Deviation | Standard Test Statistic | Significance | Modified Significance |
|----------|----------|----------------|--------------------|-------------------------|--------------|----------------------|
| White - Green | 16,750 | 14,106 | 1,187 | 0,235 | 1,000 |
| White - Yellow | 23,940 | 14,106 | 1,697 | 0,090 | 0,897 |
| White - Red | -35,080 | 14,106 | -2,487 | 0,013 | 0,129 |
| White - Black | 51,530 | 14,106 | 3,653 | 0,000 | 0,003 |
| Green - Yellow | 7,190 | 14,106 | 0,510 | 0,610 | 1,000 |
| Green - Red | -18,330 | 14,106 | -1,299 | 0,194 | 1,000 |
| Green - Black | -34,780 | 14,106 | -2,466 | 0,014 | 0,137 |
| Yellow - Red | -11,140 | 14,106 | -0,790 | 0,430 | 1,000 |
| Yellow - Black | -24,590 | 14,106 | -1,956 | 0,050 | 0,505 |
| Red - Black | 16,450 | 14,106 | 1,166 | 0,244 | 1,000 |

Confidence Level: 0,05
Razina pouzdanosti: 0,05

**Table 4.** Correlation analysis for pheromone trap colors

| *I. sexdentatus* | **Pearson Correlation** | Pearsonova korelacija |
|------------------|-------------------------|------------------------|
| **Significance** | Značajnost | 0,589** |
| N                | 250 | 250 |

| *T. formicarius* | **Pearson Correlation** | Pearsonova korelacija |
|------------------|-------------------------|------------------------|
| **Significance** | Značajnost | 0,589** |
| N                | 250 | 250 |

**Correlation is significant at 0.01 level.
** Korelacija je značajna na razini 0.01.
Tedders traps were more effective for *Hylobius pales* (Herbst) and *Pachylobius picivorus* (Germar) insects than yellow-colored and white-colored traps. Mizell III and Tedders (1999) stated that due to the dark color of coniferous trees’ stem, the insects damaging these trees may tend to dark traps.

Yellow colored sticky traps resembling the color of flowers are used in order to catch insect species of agricultural pests. On the other hand, light colors (white or yellow) probably resemble the color of non-host angiosperm tree trunks, which is a strong visual barrier for conifer bark beetles (Strom et al. 1999, Strom and Goyer 2001, Campbell and Borden 2009).

In this study, although there was no significant difference, dark-color traps (black, green, red) attracted more *Thanasimus formicarius* than light ones (yellow and white). Since black color traps are widely used today for monitoring and mass trapping of bark beetles, this result creates an undesirable situation in terms of biological control of bark beetles.

**Trap installation height – Visina postavljanja kloipe**

Pheromone traps set at a height of 2 m had the highest mean attractiveness for *Ips sexdentatus*, followed by 1.5 m, 2.5 m, and 1 m. On the other hand, the number of trapped *Thanasimus formicarius* at 2.5 m-trap height was the highest, followed by 2 m, 1.5 m, and 1 m (Fig. 2). The results however showed that trap height on *Ips sexdentatus* (p<0.534) and *Thanasimus formicarius* (p<0.416) attraction was not significant (Table 5).

Chen et al. (2009) partially supports our findings in their study on *I. duplicatus*. Chen et al. (2009) reported that the trap height at 1.5-2 m captured more insects than the trap height at ground level or 3.5-4 m. According to Göktürk et al. (2010), the most effective trap height for *I. typographus* was 2m, followed by a height of 5, 3, 4, and as in our findings the least effective was 1 m-height traps. Göktürk et al. (2010) evaluated that shrub and herbaceous cover or forest floor may interrupt the functioning of 1 m-height pheromone traps, and since the flying height of *I. typographus* is about 2 m, most of the pest may be captured by the traps hung at height of 1 m.

Pearson correlation analysis was performed to determine the relationship between the number of *Ips sexdentatus* and *Thanasimus formicarius* captured by pheromone traps depending on trap heights from the ground (Table 4.10). The test indicated that a significant and positive relationship existed between the pest and the predator (p < 0.01) (Table 6).

*Thanasimus formicarius* is attracted to bark beetle pheromones and host plant volatile compounds that bark beetles use for locating host trees and their mates (Bakke and Kvamme 1981, Kohnle and Vite 1984, Tommeras 1988, Seybold et al. 2006). Indeed, Lopez and Goldarazena (2012) reported that the most common predator in the traps was *Thanasimus formicarius* in their study. This proves that *Thanasimus formicarius* has a strong orientation towards *Ips sexdentatus* pheromone.

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**SAŽETAK**

Šesterozubi borov potkornjak *Ips sexdentatus* jedan je od najrazornijih potkornjaka u euroazijskim borovim šumama. Za praćenje populacija *Ips sexdentatus* koriste se feromonske klopke. U ovom radu istraživali smo utjecaj boje i visine klopki na ulov *Ips sexdentatus* i njegovog predatora *Thanasimus formicarius*. Istraživanje je provedeno u sastojinama *Pinus sylvestris* unutar Yayla Forest Enterprise Chief (Kastamonu-Daday) u Turskoj. U području istraživanja koristili smo 25 skandinavskih klopki s tri lijevka u pet različitih boja (žute, bijele, zelene, crne i crvene klopke). Klopke su postavljene na istu visinu, 1,5 m iznad zemlje. U drugom dijelu istraživanja postavljeno je ukupno 20 klopki (5 po visinskoj kategoriji) na visine od 1,0 m, 1,5 m, 2,0 m, i 2,5 m iznad zemlje. Klopke smo kontroliраli u intervalima od 7-10 dana i izbrojali smo jedinke *Ips sexdentatus* i *T. formicarius*. Dobiveni podaci su obrađeni Kruskal-Wallisovim testovima i testovima višestrukih usporedbi. Rezultati ispitivanja su sljedeći: 1) Značajne razlike u broju ulova u odnosu na boju klopki, 2) Postoji značajan i pozitivni odnos između štetnika i predatora, 3) Nisu utvrđene značajne razlike u broju uhvaćenih jedinki *Ips sexdentatus* i *T. formicarius* u odnosu na visine klopki.

**KLJUČNE RIJEČI:** Šestozubi borov potkornjak, mravasti kornjaš, visina klopke, boja klopke, bor