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# EDGE EFFECTS OF *Pinus nigra* FORESTS ON ABUNDANCE AND BODY LENGHT OF *Ips sexdentatus*

## UTJECAJ ŠUMSKOG RUBA SASTOJINE *Pinus nigra* NA GUSTOĆU POPULACIJE I DULJINU TIJELA *Ips sexdentatus*

Erol AKKUZU*, Hidayet GUZEL**

### Summary

*Ips sexdentatus* (Börner, 1776) (Coleoptera: Curculionidae: Scolytinae) is one of the most devastating pests of coniferous forests in Turkey. The pest not only kills individual host trees, but also it can outbreak readily and cause great damage under favorable conditions. Distribution and damage of this pest vary depending on some biotic and abiotic factors (e.g. edge effect, climatic factors, and host plant). The present study investigated the edge effect of *Pinus nigra* Arnold stands on the population level and the body length of *I. sexdentatus*. For this purpose, edge effects of *P. nigra* forests on *I. sexdentatus* were studied at Kastamonu Regional Directorate of State Forests located in northwestern black sea region of Turkey in the years 2012–2013. Three factors (forest interior, forest edge, and forest exterior) were used to test the effects of forest edges on the abundance and body length of *I. sexdentatus*. A number of five study sites were selected to deploy Lindgren® funnel-type pheromone traps. Fifteen-unit traps baited with commercial pheromone Ipssex® were set in 5 replicate blocks of three traps per block. The results of the study were as follows: 1) Double bark thicknesses and diameter of the trees along the forest edges were significantly higher than those in forest interior; 2) The number of *I. sexdentatus* captured from forest outside and forest edge was significantly higher than those in forest interior; 3) Body length of *I. sexdentatus* was significantly higher on trees along the forest edges than those in forest interior.

**KEY WORDS:** *Pinus nigra*, bark beetles, forest edges, Turkey

## INTRODUCTION
## UVOD

Bark beetles (Coleoptera: Curculionidae, Scolytinae) are considered as one of the most notorious biotic agents that cause extensive damage to conifer forests. Most bark beetles depend on dead or weakened trees but aggressive species switch to healthy trees during epidemic outbreaks (Jurc et al., 2006; Rossi *et al.*, 2009). Population density and attack severity of bark beetles in a forest vary with so many biotic and abiotic factors, such as, improper forest management, stand composition, edge effect, wind-felled logs, long-lasting drought period.

*Ips sexdentatus* (Börner, 1767) (Coleoptera: Curculionidae, Scolytinae), one of the most common bark beetle species of Turkey, is a Palearctic species distributed throughout Eurasia which is capable of breeding in many coniferous

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genera, including *Pinus* L., *Picea* A. Dietr. (Pinaceae), *Larix* Mill. (Pinaceae), and *Abies* Mill. (Pinaceae) (Balachowksy, 1949; Pfeffer, 1995; Lopez and Goldarazena, 2012). This pest is distributed throughout Turkish conifer forests excluding Southeastern Turkey. It occurs mostly on *Pinus* spp. and *Picea orientalis* (L.) Link. having two generations per year.

Species richness and density of forest pests depend on some biotic and abiotic factors, such as forest structure, climate, topographic conditions, parasites, pathogens, and associated organisms. Fragmentation, one of the most influential factors on forest pest population dynamics, changes the spatial structure of the landscape, increases the amount of edges and induces changes in the abiotic and biotic environment (Marozas, 2014). Ewers and Banks-Leite (2013) indicated that forest fragmentation, and the creation of forest edges, exposes parts of the forest stand to external climatic conditions, reducing the ability of a forest to buffer its internal microclimate from those more extreme macroclimate conditions. Therefore, forest fragmentation and creation of forest edges cause some changes in the environment, including changes in wind, humidity, throughfall deposition, radiation, predation, parasitism, and species interactions (Murcia, 1995; Donovan *et al.*, 1997; Brazaitis *et al.*, 2005; Wuyts *et al.*, 2008; Marozas *et al.*, 2009; Marozas, 2014). For this reasons, habitat edges exert a strong influence on spatial patterns of biodiversity for many taxa in many ecosystems (Ries *et al.*, 2004; Ewers *et al.*, 2013).

Effects of forest edges on bark beetles are poorly understood. Many factors (e.g. tree species, bark thickness, topographic factors, and edge effect) may affect the ecology and biology of bark beetle species. Previous studies have shown that the effects of forest edges differ significantly between bark beetle species. Peltonen and Heliovaara (1999) reported that attack density, number of offspring emerging and number of new bark beetles per mother gallery were lowest in open area bolts and increased towards the forest interior. On the other hand, Jakuš *et al.*, (2003) indicated that *I. typographus* usually attacks trees on forest edges and on borders of clearings.

Further studies are needed to establish the linkage between effects of forest edges and population dynamics of bark beetles. The present study investigated the edge effect of *Pinus nigra* Arnold stands on the population level and the body length of *I. sexdentatus*.

## MATERIALS AND METHODS
## MATERIJALI I METODE

### Study area – *Područje istraživanja*

The sampling was carried out in 2012–2013 in the Dikmen Forest District of Kastamonu Regional Directorate of State Forests located in northwestern Black sea region of Turkey (Figure 1). The study area is mostly covered by natural *P. nigra* stands. In the study area, mean tree age was 47±7.35, mean tree diameter was 26±6.12 cm, and mean tree density was 2158 stems/ha. The altitude of the study area various from 1340 m to 1400 m (a.s.l.). Climate is generally characterized by cold winters and semi-arid summers. In winter, the ground is covered with snow, which accumulated more heavily on the upper elevations than lower elevations in the study area. The annual mean precipitation is 478.5 mm and the annual mean temperature is 9.8 °C. Average monthly temperature ranges from –1.0 °C in January to 20.3 °C in July (1954–2013 meteorological data from Kastamonu Meteorology Station) (Anonymous, 2015).


**Figure 1.** Location of the study area, Dikmen State Forest District
Slika 1. Područje istraživanja u Turskoj, državne šume okruga Dikmen

### Sample sites and field methods – *Pokusne plohe i terenski rad*

In this study, three factors (forest interior, forest edge, and forest exterior) were determined to evaluate the effects of forest edges on the abundance and body length of *I. sexden-*

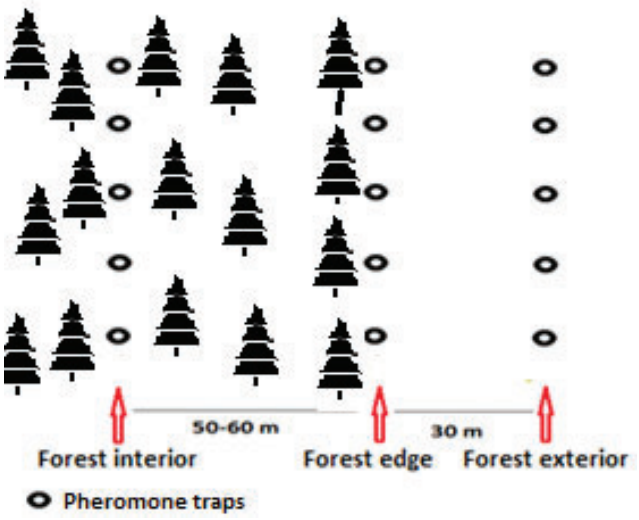


**Figure 2.** Schematic view of experimental design in the study area
Slika 2. Shematski prikaz terenskog pokusa (crvene strelice označavaju unutrašnjost šume, rub šume i otvoreni proctor; točke označavaju redove feromonskih klopki)

*tatus*. Five study sites were chosen to deploy Lindgren® funnel-type pheromone traps baited with commercial pheromone Ipssex®. Fifteen-unit pheromone traps were set in 5 replicate blocks of three traps per block (Figure 2). Experimental periods ranged from early to mid-summer, comprising the part of the flight period of *I. sexdentatus*. Traps were placed from 02 June to 28 July 2012 along the forest edges. All traps were fastened to wooden sticks with the top of the trap at 1.5 m above the 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 area, a total of 60 pine trees (stem >8 cm diameter at breast height (DBH), 1.3 m above ground level) were measured for DBH and double bark thickness (DBT). DBT and DBH were measured with a bark gauge and a diameter tape, respectively. After that, mean DBT and mean DBH were calculated. Bark thickness values were determined by averaging two bark thickness measurements taken at the angle of 90 degree. On standing trees, DBT is the double of averaging two measurements (Sonmez *et al.* 2007).

### Statistical analysis – *Statistička raščlamba*

All statistical analyses were performed using SPSS® 19.0 for Windows®. We analyzed the edge effects on *I. sexdentatus* abundance and body length of the developed adults using one-way analysis of variance (ANOVA). Independent samples t-test was applied to test the DBT of the trees. If differences were significant, a LSD multiple comparison test was performed to identify variation between pairs of means. Means were considered to be significantly different when $P<0.05$.

## RESULTS
## REZULTATI

An aim of this research is to find out whether forest edges had any significant effect on the DBT and DBH of the trees. This study showed that DBT of the trees along the forest edges were significantly higher than those in forest interior ($p<0.05$) (Table 1 and 2).

**Table 1.** Effect of forest edges on double bark thickness (DBT) of trees
Tablica 1. Utjecaj šumskog ruba na dvostruku debljinu kore (DBT) stabala crnog bora

| Location of trees<br>*Položaj stabla u sastojini* | N | Mean (mm)<br>*Sredina (mm)* | Std. Deviation<br>*Standardna devijacija* | Std. Error Mean<br>*Standardna pogreška* |
|---|---|---|---|---|
| Forest edge (1)<br>*Šumski rub (1)* | 60 | 31,2800 | 3,82201 | ,31207 |
| Forest interior (2)<br>*Unutrašnjost šume (2)* | 60 | 29,8800 | 2,70279 | ,22068 |

Diameter of tree trunks (DBH) along the forest edge and in the forest interior significantly differentiate ($p<0.05$) in the study area (Table 3, 4). Diameter of tree trunks (DBH) was higher along the forest edge.

**Table 2.** Resulting independent samples t-test for the influence of edge effect on double bark thickness (DBT) of trees
Tablica 2. Rezultati t-testa utjecaja šumskog ruba na dvostruku debljinu kore (DBT) stabala crnog bora

| | Levene's Test for Equality of Variances<br>*Levene test jednakosti varijanci* | | t-test for Equality of Means<br>*t-test jednakosti sredina* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | Lower | Upper |
| Equal variances assumed<br>*pretpostavljene jednake varijance* | 8,287 | ,004 | 2,132 | 298 | ,034 | ,02292 | ,01075 | ,00176 | ,04407 |
| Equal variances not assumed<br>*pretpostavljene različite varijance* | | | 2,132 | 277,008 | ,034 | ,02292 | ,01075 | ,00175 | ,04408 |

**Table 3.** Effect of forest edges on diameter (DBH) of tree trunks
Tablica 3. Utjecaj šumskog ruba na prsni promjer (DBT) stabala crnog bora

| Location of trees<br>*Položaj stabla u sastojini* | N | Mean (cm)<br>*Sredina (mm)* | Std. Deviation<br>*Standardna devijacija* | Std. Error Mean<br>*Standardna pogreška* |
|---|---|---|---|---|
| Forest edge (1)<br>*Šumski rub (1)* | 60 | 21,2700 | 3,59699 | ,29369 |
| Forest interior (2)<br>*Unutrašnjost šume (2)* | 60 | 20,3433 | 2,93105 | ,23932 |

**Table 4.** Resulting independent samples t-test for the influence of edge effect on the diameter (DBH) of tree trunks
Tablica 4. Rezultati t-testa utjecaja neovisnih uzoraka šumskog ruba na prsni promjer (DBT) stabala crnog bora

| | Levene's Test for Equality of Variances *Levene test jednakosti varijanci* | | t-test for Equality of Means *t-test jednakosti sredina* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | Lower | Upper |
| Equal variances assumed<br>*pretpostavljene jednake varijance* | 4,542 | ,034 | 2,446 | 298 | ,015 | ,92667 | ,37885 | ,18110 | 1,67223 |
| Equal variances not assumed<br>*pretpostavljene različite varijance* | | | 2,446 | 286,326 | ,015 | ,92667 | ,37885 | ,18098 | 1,67236 |

**Table 5.** Resulting one-way ANOVA test for the influence of edge effect on the density of Ips sexdentatus
Tablica 5. Jednostrana ANOVA utjecaja šumskog ruba na gustoću populacije Ips sexdentatus

| Source of variation<br>*Izvor varijacije* | Sum of Squares<br>*Suma kvadrata* | df<br>*Stupnjevi slobode* | Mean Square<br>*Sredina kvadrata* | F-value<br>*F* | P-value<br>*P* |
|---|---|---|---|---|---|
| Between Groups<br>*Između grupa* | 15,415 | 2 | 7,708 | 4,110 | ,019 |
| Within Groups<br>*Unutar grupa* | 217,511 | 116 | 1,875 | | |
| Total<br>*Ukupno* | 232,926 | 118 | | | |

**Table 6.** Resulting Least Significant Difference (LSD) Test for the mean number of Ips sexdentatus captured by pheromone traps
Tablica 6. Test najmanje značajne razlike (eng. LSD) za srednji broj imaga Ips sexdentatus ulovljenih feromonskim klopkama

| (I) Number<br>*(I) Broj* | (J) Number<br>*(J) Broj* | Mean Difference (I-J)<br>*Razlika aritmetičkih sredina (I-J)* | Std. Error<br>*Standardna pogreška* | Sig.<br>*Signifikantnost* | 95% Confidence Interval<br>*95 % Interval pouzdanosti* | |
|---|---|---|---|---|---|---|
| | | | | | Lower Boundary<br>*Donja granica* | Upper Boundary<br>*Gornja granica* |
| 1,00[1] | 2,002 | -,67845* | ,30619 | ,029 | ,0720 | 1,2849 |
| | 3,003 | -,14742 | ,30815 | ,633 | -,7578 | ,4229 |
| 2,00[2] | 1,00 | -,67845* | ,30619 | ,029 | -1,2849 | -,0720 |
| | 3,00 | -,82587* | ,30815 | ,008 | -1,4362 | -,2155 |
| 3,00[3] | 1,00 | ,14742 | ,30815 | ,633 | ,4629 | ,7578 |
| | 2,00 | ,82587* | ,30815 | ,008 | ,2115 | 1,4362 |

* The mean difference is significant at the 0.05 level. – * *Srednja razlika aritmetičkih sredina značajna je na razini 0,05*
[1] refers to forest edge – *šumski rub*
[2] refers to forest interior – *unutrašnjost šume*
[3] refers to forest exterior – *otvoreni prostor izvan šume*

**Table 7.** Resulting one-way ANOVA test for the effect of forest edges on body length of Ips sexdentatus
Tablica 7. Jednostrana ANOVA utjecaja šumskog ruba na duljinu tijela Ips sexdentatus

| Source of variation<br>*Izvor varijacije* | Sum of Squares<br>*Suma kvadrata* | df<br>*Stupnjevi slobode* | Mean Square<br>*Sredina kvadrata* | F-value<br>*F* | P-value<br>*P* |
|---|---|---|---|---|---|
| Between Groups<br>*Između grupa* | ,048 | 2 | ,024 | 9,753 | ,001 |
| Within Groups<br>*Unutar grupa* | ,563 | 231 | ,002 | | |
| Total<br>*Ukupno* | ,611 | 233 | | | |

In this study, edge effect of *P. nigra* forests on the population size of *I. sexdentatus* was analyzed. One-way analysis of variance (ANOVA) indicated significant differences ($p<0.05$) in the number of *I. sexdentatus* captured by pheromone traps across the three sample sites (forest edge, forest interior and forest outside) (Table 5, Table 6).

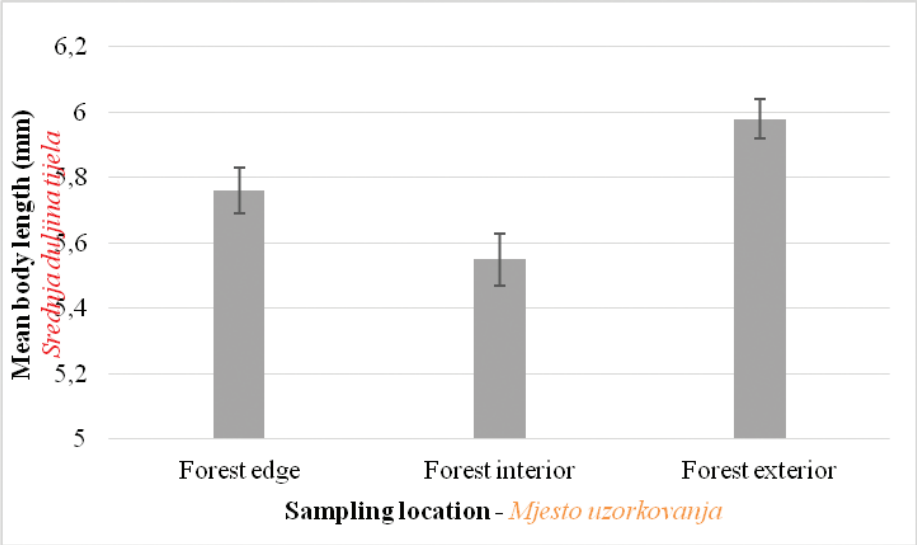


**Figure 3.** Mean body length of Ips sexdentatus in the sampling locations
Slika 3. Srednja duljina Ips sexdentatus prema lokaciji ulova

**Table 8.** Resulting Least Significant Difference (LSD) Test for the effect of forest edges on the mean lengths of I. sexdentatus
Tablica 8. Test najmanje značajne razlike (eng. LSD) utjecaja šumskog ruba na srednju duljinu tijela Ips sexdentatus

| (I) VAR1 | (J) VAR1 | Mean Difference (I-J) *Razlika aritmetičkih sredina (I-J)* | Std. Error *Standardna pogreška* | Sig. *Signifikantnost* | 95% Confidence Interval *95 % Interval pouzdanosti* | |
|---|---|---|---|---|---|---|
| | | | | | Lower Boundary *Donja granica* | Upper Boundary *Gornja granica* |
| 1,00[1] | 2,00 | ,01816* | ,00835 | ,031 | ,0017 | ,0346 |
| | 3,00 | -,01584* | ,00789 | ,046 | -,0314 | -,0003 |
| 2,00[2] | 1,00 | -,01816* | ,00835 | ,031 | -,0346 | -,0017 |
| | 3,00 | -,03400* | ,00770 | ,000 | -,0492 | -,0188 |
| 3,00[3] | 1,00 | ,01584* | ,00789 | ,046 | ,0003 | ,0314 |
| | 2,00 | ,03400* | ,00770 | ,000 | ,0188 | ,0492 |

* The mean difference is significant at the 0.05 level – **Srednja razlika aritmetičkih sredina značajna je na razini 0,05*
[1] refers to forest edge – *šumski rub*
[2] refers to forest interior – *unutrašnjost šume*
[3] refers to forest exterior – *otvoreni prostor izvan šume*

The results from the LSD multiple comparison test showed that the number of *I. sexdentatus* captured outside of the forest and forest edge was significantly ($p<0.05$) higher than those from forest interior (Table 6).

Body length of *I. sexdentatus* was measured to test the effect of forest edge via bark thickness and stem temperature regime on their growth. We found that mean body length of the pest was 5.76±0.07 mm at the forest edge, 5.55±0.08 mm at the forest interior, and 5.98±0.06 mm at the forest exterior in the study area (Figure 3). Therefore, body length of *I. sexdentatus* was significantly ($p<0.05$) higher on trees along the forest edges than those in forest interior (Table 7, Table 8).

## DISCUSSION
## RASPRAVA

Bark is an important part of the tree that provides protection of the inner living tissues against climatic effects, air pollution, mechanical damage, and biotic agents that attack the tree (Michel *et al.*, 2011; Mmolotsi *et al.*, 2012). Bark anatomy and the physiological condition of a potential host tree are crucial for the success of a bark beetle attack (Wermelinger, 2004). Bark thickness, as an important factor in breeding success for *I. sexdentatus*, generally increases with stem diameter and tree age. As forests age they become more vulnerable to agents of disturbance, such as high winds, fire, fungi, and bark beetles (Christiansen *et al.*, 1987). In the present study, DBT and DBH of the trees along the forest edges were significantly greater than those in forest interior. Similar findings were obtained for *Pinus radiata* D. Don. in New Zealand (Berg, 1973), *Quercus robur* Linnaeus, and *Fraxinus excelsior* Linnaeus in the eastern part of the Czech Republic (Sálek et al. 2013). Gorte (2009) indicated that the adult mountain pine beetles (*Dendroctonus ponderosae* Hopkins, 1902), disperse with preference for trees of larger diame-

ter (thicker trees have thicker phloem, and thus more food) and trees under stress (e.g., injured, diseased, or suffering from drought, and thus offering less resistance to attack).

We found that the number of *I. sexdentatus* captured from forest outside and forest edge was significantly higher than those from forest interior. Previous studies have shown that compared with the forest-interior environment, solar incidence on the edges brings about an increment in light intensity and it's duration and, therefore, both soil and air temperatures can be both higher and more variable (Wales, 1972; Ranney *et al.,* 1981; Lovejoy *et al.,* 1986; Williams-Linera, 1990; Brothers and Spingarn, 1992). Bark beetle development is directly affected by phloem temperature, which in turn is dependent on air temperature and direct solar radiation (Wermelinger and Seifert, 1999). Therefore, sunlit trees are preferably attacked, especially after abrupt increases in solar radiation levels (Jakuš, 1998; Lobinger and Skatulla, 1996; Wermelinger, 2004).

In this study, body length of the pest was used to characterize *I. sexdentatus* populations in relation to the breeding sites (forest edge and forest interior). Body length of *I. sexdentatus* was significantly higher on trees along the forest edges than those in forest interior. Grodzki (2004) conducted a research on a similar subject concerning closely related *I. typographus* on Picea abies (Linneaus). Grodzki (2004) indicated that 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).

## CONCLUSIONS
## ZAKLJUČCI

*I. sexdentatus* is distributed naturally throughout Europe, Northern Asia, South and Southeast Asia. Forest fragmentations and forest edges influence the abundance and body length of the pest in its distribution range because they may alter forest structure, species composition, biodiversity, microclimate, physical and chemical properties of soil. In this study, we examined the edge effects of *P. nigra* forests on abundance and body length of *I. sexdentatus*. We revealed that forest edges may contribute to *I. sexdentatus* population increases and also cause increase in body length of the pest.

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## Sažetak


*Ips sexdentatus* (Börner, 1776) (Coleoptera: Curculionidae: Scolytinae), velik šestozubi borov potkornjak, jedan je od najvažnijih štetnika iz porodice potkornjaka na području Turske. Ne samo da je sposoban napasti pojedinačna stable, već u povoljnim okolnostima može ući u prenamnoženja uzrokujući štete većih razmjera. Prostorna raširenost i štetnost ovog štetnika varira ovisno o različitim biotskim i abiotičkim čimbenicima (primjerice utjecaju šuimskog ruba i fragmentiranosti, klimi i vitalitetu biljaka domaćina). Provedeno istraživanje imalo je za cilj utvrditi utjecaj šumskog ruba sastojina crnog bora (*Pinus nigra*) na populacijsku gustoću i duljinu tijela (veličinu) potkornjaka *I. sexdentatus*. Za ovu je svrhu postavljena serija pokusa u regiji Kastamonu na sjeverozapadu crnomorske obale Turske u razdoblju od 2012. do 2013. godine. Tri mikropozicije na pet pokusnih lokaliteta testirane su na spomenuta dva obilježja *I. sexdentatus*: unutrašnjost šume, šumski rub i otvoreni prostor izvan šume (Slika 2). Odrasli potkornjaci hvatani su linijski postavljenim lijevkastim tipom feromonskih klopki (Lindgren®) opremljenim feromonom Ipssex®. Klopke sastavljene od 15 lijevkastih segmenata postavljene su u blokovima od 5 replikacija s tri klopke po bloku.

Rezultati istraživanja mogu se svesti na sljedeće: 1) Dvostruka debljina kore i promjer stabala na šumskom rubu veća je od stabala u unutrašnjosti sastojine; 2) Broj ulovljenih imaga *I. sexdentatus* izvan šume i na šumskom rubu značajno je veći od ulova u unutrašnjosti sastojine; 3) Duljina tijela *I. sexdentatus* iz kore stabala na šumskom rubu značajno je veći od jedinki izdvojenih iz kore stabala u unutrašnjosti sastojine.


**KLJUČNE RIJEČI:** *Pinus nigra*, potkornjaci, šumski rubovi, Turska