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Effects of Stand Composition and Site Index of Pine Forests on Bark Beetle, *Ips sexdentatus* (Coleoptera: Curculionidae: Scolytinae) Population

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Authors' Contribution
EA designed the research plan and organized the study. EA and HG did experiments and field work. ÖE, EA and HG contributed in the data-analysis and the wrote the manuscript.

Key words
Ips sexdentatus, Site index, Forest management, *Pinus nigra, Pinus sylvestris.*

ABSTRACT

Various biotic and abiotic factors influence the population dynamics and severity of damage in a forest. This study investigated the effects of stand composition and site index of pine forests on *Ips sexdentatus* (Boerner) populations. Two main objectives of this study were a) to compare the effects of two different black pine stands of site index-I (high site productivity) and site index-III (low site productivity) and b) to compare the pure and mixed pine forests concerning the abundance and body length of *I. sexdentatus*. The results showed that 1) density of *I. sexdentatus* were greater in pure forests than mixed ones, 2) density of *I. sexdentatus* were grater in stands with site index-III than those with site index-I, and 3) the body length of the pest did not differ significantly between two site productivity classes and between two stand compositions.

INTRODUCTION

Six-toothed bark beetle (*Ips sexdentatus* (Boerner)) is one of the most destructive insects of coniferous forests in Eurasia. It is capable of breeding in many coniferous species, such as *Pinus* L., *Picea* A. Dietr. (Pinaceae), *Larix* Mill. (Pinaceae), and *Abies* Mill. (Pinaceae) (Balachowksy, 1949; Pfeffer, 1995; Yüksel, 1996; Ünal, 1998; Yüksel *et al*., 2000). This bark beetle can also act as a vector of fungi, which also may cause tree mortality in conifer forests (Romon *et al*., 2007; Bueno *et al*., 2010; Panzavolta *et al*., 2014).

I. sexdentatus usually behaves as a secondary pest at endemic levels (Gil Sanchez and Pajares Alonso, 1986). However, it can suddenly outbreak under suitable conditions (Sierra and Martin, 2004; Etxebeste *et al*., 2013), leading to serious damages to conifer forests (Gardiner *et al*., 2010). The bark beetle mostly colonizes weakened, recently dead, windbreak or snowbreak trees while populations remain at endemic levels (Gil Sanchez and Pajares Alonso, 1986). Stand factors, long lasting extreme climate conditions, forest fires, drought periods and other adverse effects can cause severe outbreaks of *I. sexdentatus*. Stand factors that contribute to tree mortality include structure, composition, and productivity (Kane *et al*., 2014). Stand characteristics deeply affect density and severity of damage caused by *I. sexdentatus* in a forest. Stand composition and site productivity are two of those stand characteristics.

Clutter *et al*. (1983) defined the site index as the average total height of dominant and co-dominant trees (*i.e.* site trees) at a specified reference or base age. Site index is widely used as a measure of site productivity, but its use is confined to even-aged stands of known age (Vanclay and Henry, 1988). Site productivity influences many facets of stand development including growth, yield, regeneration and rates of other ecological processes (Johnson *et al*., 2005).

Forest composition and temperature belong to the main environmental factors affecting tree suitability to herbivorous insects and, hence, management decisions concerning the control of forest pests (Speight and Wainhouse, 1989; Faccoli and Bernardinelli, 2014). Body length of the bark beetles is also affected by environmental conditions, such as elevation, stand composition and aspect (Grodzki, 2004; Akkuzu and Guner, 2008). According to the stand composition we distinguish pure and mixed forest stands. Faccoli and Bernardinelli (2014) pointed out that better knowledge of the relationships between forest composition and pest outbreaks could help foresters in applying silvicultural practices suitable for minimizing the present and future damage by forest pests.

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Table I.- Main features of the study sites in Kastamonu province.

Experiment	Study site (stand)	Composition	Species	Altitude	Exposure	Mean stand age
Stand	1	Pure	*P. nigra*	1400	SW	44
productivity	2	Pure	*P. nigra*	1420	SW	46
Composition	3	Pure	*P. sylvestris*	1470	SE	41
	4	Mixed	*P. sylvestris, C. betulus*	1450	SE	43

There are some studies concerning the distribution of *I. sexdentatus* in Turkey. However, few studies (*e.g.,* Akkuzu and Guzel, 2015) have considered stand features that influence the density and morphological characteristics of the pest *I. sexdentatus.* The aims of this research were to investigate the effects of stand composition and site index on body size and density of *I. sexdentatus.* Therefore, we aimed to find new strategies in controlling *I. sexdentatus* populations. In this study, site index-I and site index-III were used to indicate the high and low site productivities, respectively.

MATERIALS AND METHODS

Study area

This study was conducted in the years of 2012-2013. To address our research questions, Dikmen Forest Enterprise (latitude 41°17'02"-41°24'48" N and longitude 34°19'32"-34°29'17" E) in Kastamonu Province of Turkey was selected as the study area. The province is located in Western Blacksea Region of Turkey. This area was selected because of occurrence of pine forests in large areas in Kastamonu and having similar ecological and topographical conditions of the study sites.

Climate data from 2002 to 2012 taken from the Kastamonu Meteorology Station (800 m ASL) show that the region is characterized by cold winters with the mean temperature in January is -1.2 and warm summers with the mean temperature in July is 19.7. Mean annual precipitation is 501.9 mm in the area. Climate for the study area was cooler and wetter than the weather station (800 m ASL) data due to higher altitudes (about 1400 m ASL).

A total of two stands (40–50 years old) with site index-I and site index-III were selected at the study area. The main characteristics of the observed stands are described in Table 1. Four mature forest cover types were represented in the study area: 1) *P. nigra* dominated (>90%), 2) *P. nigra* dominated (>90%), 3) *P. sylvestris* dominated (>90%), and 4) mixed (*P. sylvestris* and deciduous trees) (Table I).

Field and laboratory experiments

We carried out two different field experiments to determine the effects of stand composition and site index on *I. sexdentatus*. A total of 20 multifunnel pheromone traps with commercial pheromone Ipssex® were deployed in 4 study plots (5 traps for each). All traps were fastened to wooden sticks at a height of 1.5 m above ground. Trap contents were collected at 7 to 10 day intervals from June to August, 2012. The quantification of captured insects was done by counting insects, or by measuring volume of the insects if the catch were greater than 500 insects per trap. The body length of *I. sexdentatus* collected from pheromone traps in each study site was measured by a digital micrometer calipers.

Statistical analysis

In this research, the independent samples t-test was used following a log transformation of the data to compare the mean numbers of *I. sexdentatus* captured by pheromone traps. These analyses were conducted with the significance level of α=0.05 using SPSS® (Statistical Package for the Social Sciences) 21.0 for Windows® software.

Table II.- Effect of stand composition on the population density and body length of *I. sexdentatus.*

Density	N	Mean	SD	SEM
Mixed stand-I	40	12.6003	24.76003	3.91490
Pure stand-II	40	20.6001	21.74882	3.43879
Body length				
Mixed stand-I	82	5.8504	0.57362	0.06335
Pure stand-II	97	5.7966	0.84726	0.08603

SD, standard deviation; SEM, standard error mean.

RESULTS AND DISCUSSION

In this study, the effect of stand composition on the population size and body length of *I. sexdentatus* is presented in Tables II and III. The number of captured *I. sexdentatus* did significantly differ between study plots that were situated in the pure and mixed stands (Independent samples t-test, $p< 0.05$; Tables II and III). We found that *I. sexdentatus* population size was more common in the pure stands than those in the mixed stands. On the other hand, the body length of *I. sexdentatus* did not differ significantly between two stand compositions (Independent samples t-test, $p> 0.05$; Tables II and III).

Table III.- Resulting independent samples t-test for the influence of stand composition on the density and body length of *I. sexdentatus.*

	Levene's Test for Equality of Variances						t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
Density								Lower	Upper
Equal variances assumed	12.942	0.001	-2.488	78	0.015	-2.10424	0.84565	-3.78779	-0.42068
Equal variances not assumed			-2.488	70.933	0.015	-2.10424	0.84565	-3.79044	-0.41803
Body length									
Equal variances assumed	4.607	0.033	0.822	177	0.412	0.01734	0.02109	-0.02428	0.05895
Equal variances not assumed			0.858	156.673	0.392	0.01734	0.02020	-0.02257	0.05724

Table IV.- Resulting independent samples t-test for the influence of stand productivity on the density and body length of *I. sexdentatus.*

	Levene's Test for Equality of Variances						t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
Density								Lower	Upper
Equal variances assumed	62.936	.000	-4.791	78	0.000	-5.27723	1.10156		
Equal variances not assumed			-4.791	51.805	0.000	-5.27723	1.10156	-7.48786	-3.06660
Body length									
Equal variances assumed	5.916	0.016	-1.796	197	0.074	-0.02896	0.01613	-0.06077	0.00284
Equal variances not assumed			-1.870	193.925	0.063	-0.02896	0.01549	-0.05952	0.00159

Table V.- Effect of stand productivity on the population density and body length of *I. sexdentatus.*

Density	N	Mean	SD	SEM
Site index-I	40	12.6000	24.76018	3.91493
Site index-III	40	67.8000	63.02714	9.96547
Body length				
Site index-I	82	5.8504	0.57362	0.06335
Site index-III	117	6.0377	0.71535	0.06613

SD, standard deviation; SEM, standard error mean.

Monoculture plantation are considered more susceptible to outbreaks than natural forests (Kareiva, 1983; Andow, 1991; Jactel *et al*., 2005), because monospecific and even-aged aggregations of host trees are relatively easy for insects to locate in the landscape (Kelty, 2006; Jactel *et al*., 2009). In general, natural enemies of bark beetles also prefer mixed forests to monocultures for breeding and living. In mixed forests, compared to monocultures, the abundance of predators and parasitism are higher (Jäkel and Roth, 2004).

The effect of site productivity on the density and body length of *I. sexdentatus* is presented in the Tables IV and V. The results showed that density of *I. sexdentatus* was significantly higher in the study area with the site index-III than in the study area with the site index-I (Independent samples t-test, p< 0.05; Table IV). The body length of the pest, however, did not differ significantly between two site indexes (Independent samples t-test, p> 0.05; Tables IV and V). Maffei *et al*. (2012) indicated that even though the site productivity values imply that a certain stand density can be carried on a site, susceptibility to bark beetles occurs at densities below that carrying capacity threshold. Habitat conditions also effect the stand preferences of bark beetles. Most bark beetles prefer to invade trees that are in poor physiological condition (Rudinsky, 1962).

The body size of the pest *I. sexdentatus* did not differ significantly between two stand compositions and two site indexes. Furuta (1989) indicated that high population density causes reduced body size. In our case, interspecific and intraspecific competition for food may have not occurred because of low population density of the pest in the study area.

This study showed that pure pine stands with low site index increase *I. sexdentatus* density. This kind of stands should be monitored periodically for outbreak risks of *I. sexdentatus*. Consequently, in terms of sustainable management of pine forest ecosystems, it is crucial to take necessary silvicultural measures for lowering the density of *I. sexdentatus* populations and minimizing the outbreak risk.

CONCLUSIONS

Results of this paper indicate that density of *I. sexdentatus* population in pure pine stands was higher than those in mixed stands. Density of the pest was also grater in stands with site index-III than those with site index-I. There was no difference in body length of I. sexdentatus between two site productivity classes and between two stand compositions.

The results of this study show that mixed stands may play an important role in controlling bark beetle populations of coniferous forests. Besides mixed forests, for forest managers, site productivity is also very important in afforestation studies in terms of considering the pest management.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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