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The Impacts of *Ips sexdentatus* on the Moisture Content of Anatolian Black Pine Trees

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Abstract: Insects interact with plants in direct or indirect way. The host selection and host sensitivity especially in bark beetles are important in terms of their population and potential. The sensitivity of host trees is important in beetle epidemic as serious damages may be given to trees during epidemics. The current study, the moisture content of wooden samples taken from Anatolian black pine trees that were damaged by *Ips sexdentatus* and healty trees has been determined. A total of 174 samples was taken from 29 trees (58,6% from damaged trees, 41,4% from healthy trees). The average moisture content of trees was 40,75% for damaged trees, and 32,68% for healthy trees. The moisture content of these trees is significantly different and invasions have negatively affected moisture content. There is no statistical difference between the moisture content of samples taken from north and south sides of damaged trees, however there is a difference among moisture contents of samples from three different heights (1.30m, 3.30m, 5.30m), but indifferent from north and south
Keywords: Infestation, moisture content, Anatolian black pine

Ips sexdentatus'un Anadolu Karaçamı Ağaçlarındaki Nem İçeriğine Etkisi

Özet: Böcekler direkt veya indirekt olarak bitkilerle etkileşim halindedir. Bu nedenle özellikle kabuk böceklerinde konukçu seçimi ve konukçu hassasiyeti bu türlerin popülasyonu ve oluşturacakları zarar açısından önemlidir. Ancak konukçu ağaçların hassasiyeti böcek salgınlarında önemli olup salgınlar ağaçlarda ciddi zararlar meydana getirebilir. Çalışmada, karaçam ağaçlarında, *Ips sexdentatus* istilasına uğramış ve uğramamış Anatolian black pine ağaçlarından alınan odun örneklerinin nem içerikleri belirlenmiştir. Toplam 29 ağaçtan alınan 174 adet örnekle çalışılmıştır. Örneklerin %58,6'sı böcekli ağaçlardan %41,4'ü ise sağlıklı ağaçlardan alınmıştır. Böcek zararı görmüş ağaçların ortalama nem içerikleri %40,75; sağlıklı ağaçların ortalama nem içerikleri %32,68 olup bu ağaçların nem içerikler istatistiksel olarak farklıdır ve istilalar nem içeriğini olumsuz yönde etkilemiştir. Sağlıklı ağaçlarda kuzey ve güney yönlerinden alınan örneklerin nem içerikleri arasında istatistiksel bir fark bulunamamıştır. Böcek zararı görmüş ağaçlarda kuzey ve güney yönlerinden alınan örnek disklerin nem içerikleri arasında istatistiksel bir fark bulunamazken üç farklı yükseklikten (1.30m, 3.30m, 5,30m) alınan örnek disklerin nem içerikleri arasında istatistiksel bir fark vardır. Ayrıca böcek zararı görmüş ve kuzey yönündeki örneklerdeki nem içeriğinin istatistiksel olarak anlamlı olduğu görülmüştür
Anahtar kelimeler: Infestation, moisture content, Anatolian black pine

Introduction

The fast changing process, which is experienced in the world affecting habitat qualities and ecosystems both on global and local bases (Aydın, 2010), causes the destruction of the nature, air, water and soil pollution, thus creating economic imbalance. Plants have also been affected considerably from the ongoing destruction processes in the nature, many species have faced the threat of extinction. Thus, studies towards the plant health have gained importance in recent period (Sevik et al., 2013; Sevik and Cetin, 2015; Cetin, 2016).

Environmental factors that cause changes on tree resistance may create effects on an individual tree, tree groups and all forest scale (Powers et al., 1999). During the invasion of bark beetles on the host (Wood, 1982), host resistance is efficient (Raffa and Berryman, 1987; Wainhouse et al., 1990). Powers et al. (1999) state on the study they do with bark beetles that weak trees are affected from higher rate beetles compared to vigorous trees and express that trees on areas, which are negatively affected in terms of growth, are more sensitive to beetle invasions. Factors that negatively affect forest ecosystem may cause increases on the damage potential of bark beetles (Özcan et al., 2016).

The host selection and colonization behaviour of bark beetles are very complex (Graves et al., 2008). The strength of host tree, which is to be affected from climate effects, also affects the success of bark beetle populations to colonization on the tree (Bentz et al., 2010). Especially stressful trees are more sensitive to beetle invasions (Seedre, 2005). *Ips sexdentatus* (Boerner) (Coleoptera, Curculionidae, Scolytinae),, which is one of the bark beetles that can kill lots of trees within the same year (Christiansen et al., 1987; Özcan et al., 2011) due to having high spreading potential (Jactel and Gaillard, 1991) and heavy invasions may kill weak trees, if they reach to high number of host trees, their invasion grows and deaths may happen at healthy trees due to the increase of the beetle population (Schimitschek, 1953; Jactel and Lieutier 1987; Öymen and Selmi, 1997; Selmi, 1998; Seedre, 2005; Fettig et al., 2007). *I. sexdentatus* is a pest of conifer forests, while Europe and Asian continents (Anonymous, 2007) and so Turkey are the natural areas for the species (Öymen, 1992). Also the species use logs in forest depot as host (Akbulut et al., 2008). The usage of pheromone traps and biotechnical control are important measures against these beetle (Bakke, 1991; Suckling and Karg 2000; Anonymous, 2007; Özcan et al., 2011; 2014) along with the removal of dead or dried trees next to healthy stands (Fernández Fernández, 2006).

The aim of the current study is to determine the moisture content differences of trees that were damaged by *I. sexdentatus* or healty trees on Anatolian Black Pines with same raising conditions and same diameter range. The change of moisture content in section height and section direction on the tree according to invasion condition of the beetle is also examined

Material and Metod

Study area

This study is conducted in Anatolian Black Pine stands at Çankırı Forest Enterprise, Çankırı Forest Planning Unit borders in August 2016 (Figure 1).

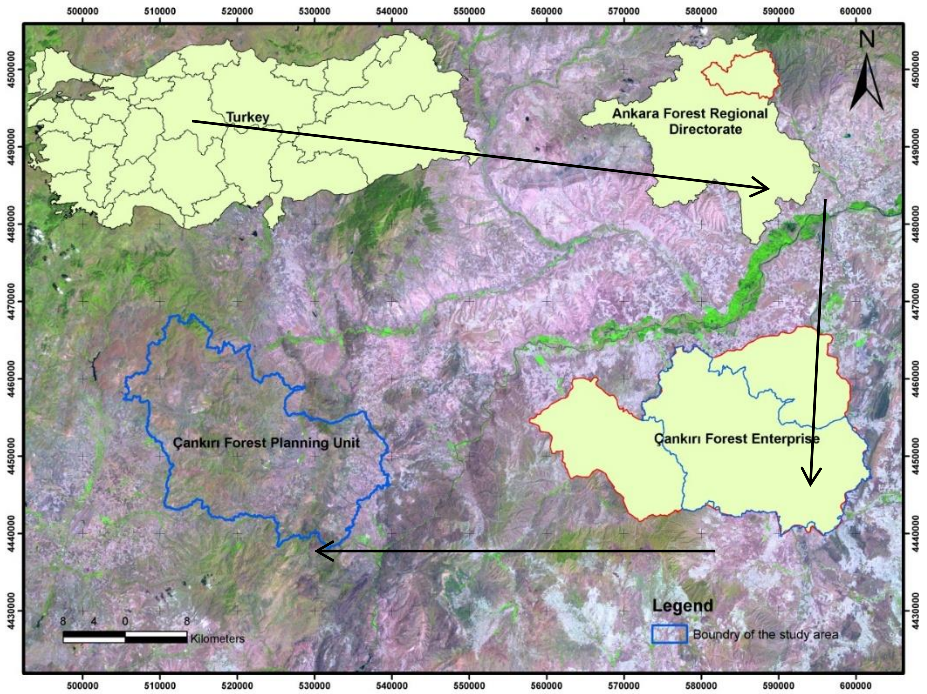

Figure 1. The study area location

Data Collection

Samples were taken from 17 damaged by *I. sexdentatus*, 12 healthy trees between 20 and 24 cm diameter at breast height. North and south direction of sample trees which are determined and numbered in the study area were marked. Then, 1.30-3.30 or 5.30 m's heigh level from ground of cut trees were measured and 4 – 5 cm. disks were taken from each of these heights. Each sample disk is separated into 4 parts considering the directions, while quarter parts in north and south directions were separated with cutting (Figure 2). A total of 174 samples were taken from 29 trees. In order to prevent moisture loss of separated parts, they were covered with aluminum folios and brought to the laboratory and their fresh weights were measured with 0,5 gr sensitive precision scales during the same day (Reid, 1961). After, samples were dried for 72 hours in order to have an unchangeable weight at 105±3 ˚C (Mısır et al., 2011), they were measured again and their moisture content (1) were calculated.

$$\text{Moisture } \% = \frac{\text{Fresh weight} - \text{Dry weight}}{Dry\ weight} * 100$$

(1) (Reid, 1961; Simpson, 1999; Kılınç, 2006)

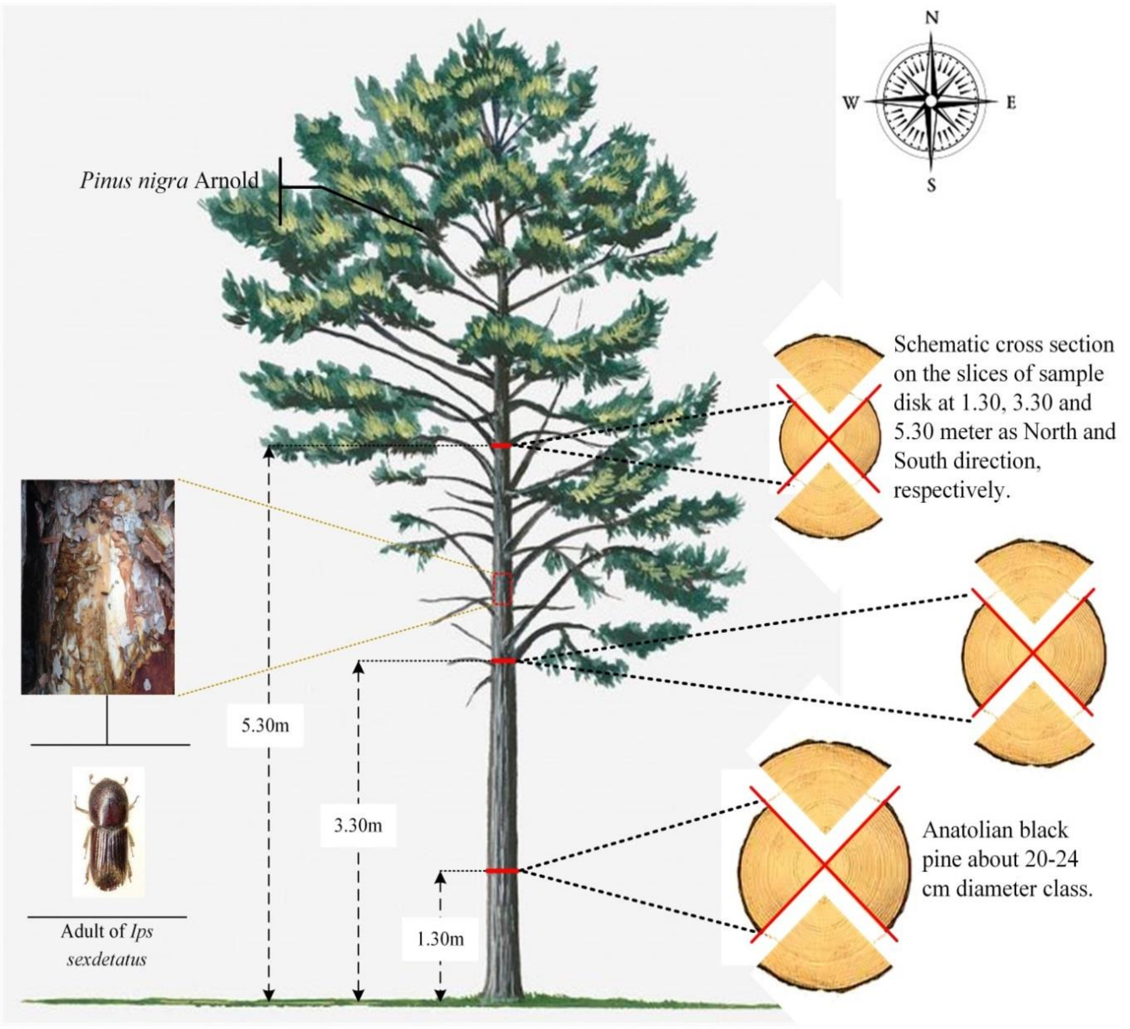

Figure 2 Schematic diagram of wood samples to determine the moisture content for two direct at damaged by *I. sexdentatus* and healty trees

Statistical analyses

Obtained data was evaluated with statistical methods. All statistical analyses were performed using SPSS® 20.0 for Windows® software. The compatibility of data to normal distribution was controlled with Kolmogorov-Smirnov (K-S) test. According to the evaluations that were conducted, it is seen that the moisture content of the samples taken from all trees and the samples taken from trees that were damaged trees by didn't distributed normally (P<0,05), while the moisture content of the samples taken from healthy trees distributed normally (P>0,05) (Table 1).

Table 1. Normality control according to Kolmogorov – Smirnov K-S test

	% Moisture content				
	N	Min	Max.	Mean±Std. Deviation	P*
Damaged	102	2,54	63,48	40,75±6,01	0,000
Healty	72	14,81	47,48	32,68±7,46	0,200
Total	174	2,54	63,48	37,41±7,74	0,000

The differences of the moisture content of trees which were damaged by beetle and healthy trees along with the differences of moisture content of the trees with beetle damage according to section direction are evaluated with Many-Whitney U test, while the differences according to section height is evaluated with Kruskal-Wallis H. The differences of moisture content of healthy trees according to section direction is evaluated with Independent-Samples T-Test, which is one of the parametric tests, while their differences according to section height is evaluated with single side variance analysis (ANOVA) (Özdamar, 2003; Çimen, 2015).

Result and Discussion

A total of 174 samples were taken from 29 trees in the study area. 52,6% of trees (17) had damages, while 41,4% of them (12) were healthy. 58,6% (102) from damaged trees, while 41,4% (72) from healthy trees. The distribution of the samples, which were taken from three different heights and two different directions are given on Table 2.

Table 2. The distribution of the samples taken from study area

Direction		1.30 m		3.30 m		5.30 m		
		n	%	n	%	n	%	Total
North	Damaged	17	29,3	17	29,3	17	29,3	51
	Healty	12	20,7	12	20,7	12	20,7	36
South	Damaged	17	29,3	17	29,3	17	29,3	51
	Healty	12	20,7	12	20,7	12	20,7	36
Total		58	100	58	100	58	100	174

The average moisture content was 37,41%. Meanwhile, the average moisture contents of damaged trees was 40,75% and the average moisture content of healthy trees was 32,68% (Table 1). According to this, it is determined that there is a statistically significant difference (p<0,05) between the averages of the moisture contents of damaged and healthy trees (Table 3). Live trees contain high amount of water, however they lose majority of the water when the tree is dry (Simpson, 1999). Moisture stress is the most important factor that may cause the colonization of bark beetles to trees and the death of conifer trees later (Safranyik 1989). In a study, which was conducted on trees that were invaded by Mountain pine beetle (*Dendroctonus ponderosae*) for a year, it is stated that alive wood moisture content of trees may decrease by 16% (Reid, 1961).

Table 3. Comparison of healthy and damaged trees according to their moisture content (Many – Whitney U test)

	N	Mean Rank	Sum of Ranks	*P
Damaged	102	110,59	11280	0,000
Healty	72	54,79	3945	
Total	174			

*P<0,05

In the study, it is determined that the moisture contents of damaged trees is 8,07% higher compared to healthy trees.

Damaged and healthy trees are evaluated within their own structure separately. Reid (1961) states that there is a considerable decline in the moisture content of its host after the attacks realized by Mountain pine beetles. Even though the interactions between bark beetles and their hosts are determined with quantitative variables, they may be characterized with multiple thresholds, where different results are stated (Raffa et al., 2008). The moisture content did not significantly differ for height level (1.30, 3.30, 5,30 m) and direction (north and south) of logs in healty trees (P>0,05). The moisture contents of samples in north and south directions are 32,47% and 32,88% respectively (Table 4).

Table 4. Comparison of moisture content according to directions in healthy trees

	% Moisture content		
	N	Mean±Std. Deviation	P*
North	36	32,47±7,69	0,815
South	36	32,88±7,33	

P*>0,05

There is no statistical difference (P>0,05) (Table 5) between the moisture content of the sample disks taken from north and south directions in damaged trees, while there is a statistical difference (P<0,05) between the moisture content of the sample disks taken from 1.30, 3.30, 5.30. The moisture contents of the samples in north and south directions are 40,80% and 40,70% respectively, while moisture contents of the samples at three different heights are 39,26%, 41,38% and 41,62% respectively (Table 6). Even though the moisture contents of healthy trees show difference in four directions, there are no significant differences (Reid, 1961).

Table 5. Comparison of the moisture contents of damaged trees according to directions (Many-Whitney U test)

	% Moisture contents				P*
	N	Mean±Std. Deviation	Mean Rank	Sum of Ranks	
North	51	40,80±4,83	53,34	2720,50	0,529
South	51	40,70±7,04	49,66	2532,50	

P*>0,05

Table 6. Comparison of moisture contents of damaged trees according to sample height

	% Moisture contents			P*
	N	Mean±Std. Deviation	Mean Rank	
1.30	34	39,26±3,53	36,63	
3.30	34	41,38±8,23	57,00	0,001
5.30	34	41,62±5.17	60,87	

P*<0,05

The moisture contents of healthy trees from upside to downside are 33,96%, 30,80% and 33,26% respectively, while same numbers are 39,26%, 41,38% and 41,62% in damaged trees. The average moisture content for each region and tree type increases from the ground of the tree to the upper parts. The location of the stand and tree height level are important factors for moisture content (Dibdiakova and Vadla, 2012). Measures are needed to be taken in order to prevent moisture stress in order to reduce the sensitivity against bark beetle attacks towards live trees (Lee et al., 2007). As parametric tests don’t give the source of the difference, it is examined whether height has effect by itself or not by classifying the data, which were classified as damaged by beetle or healthy before, again according to their direction. According to this, it is seen that the moisture content of samples taken from damaged trees from north direction is significant in statistical terms (P<0,05) (Table 7). This result supports Dibdiakova and Vadla (2012).

Tablo 7. Moisture content of samples taken from damaged trees from their north direction

North	% Moisture contents			P*
	N	Mean±Std. Deviation	Mean Rank	
1.30	17	38,98±4,09	17,82	
3.30	17	42,06±2,13	29,00	0,019
5.30	17	41,37±6,78	31,18	

P*<0,05

The colonization of bark beetles on host trees is the most important aspect of population dynamics (Amezaga and Rodríguez, 1998), while the host selection process is affected with lots of factors (Wallin and Raffa., 2002). Especially moisture pressure causes decline of resin flow on trees and this condition reduces the resistance of host trees against attacks (Lorio 1986). Bark beetle invasions being the reason for big losses in conifer trees is an expected condition. Thus, it is important to know genetic and ecologic defense limitations of conifers (Franceschi et al., 2005). As a result, the findings show similarity with the literature. Bark beetle invasions negatively affected the humidity content of trees in different heights, accordingly causing disrupt of their health

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