Türk. entomol. derg., 2014, 38 (1): 31-41
ISSN 1010-6960

Orijinal araştırma (Original article)

Attack strategy and development of *Dendroctonus micans* (Kug.) (Coleoptera: Curculionidae) on oriental spruce in Turkey

Dendroctonus micans (Kug.) (Coleoptera: Curculionidae)'ın Türkiye'de doğu ladinindeki saldırı stratejisi ve gelişimi

Hazan ALKAN-AKINCI[1]* Mahmut EROĞLU[2] Gonca Ece ÖZCAN[3]

Summary

Dendroctonus micans has been continuously colonizing the native oriental spruce forests after its discovery in 1966 in Turkey. Solitary females attack the trees and they usually do not kill its hosts. This study aims to contribute the understanding of this solitary attack strategy and development of *D. micans* on oriental spruce in Turkey. The pattern of tree infestation was analyzed from 2001 to 2004 and 2006 in 120 experimental plots. Field surveys were carried out in the north east of Turkey in Artvin, Giresun, and Maçka (Trabzon) from May to October of each year. A total 3010 trees were examined in plots. *D. micans* infestation up to 2 m of trees were examined and the successful and aborted attacks were recorded. Development stages and numbers of the beetles were recorded in the galleries. The sizes of the old brood chambers were measured in the abandoned and infested trees.

The beetle was found in 95.8% of the plots, attacked 21.7% of the spruce trees, and was active in 11.1% of the attacked trees. The majority of the attacked trees had only one successful attack. 69.3% of the entry holes, were up to 1m, and 30.7% of them were between 1 and 2 m. The attack rate was limited in many trees but it was rather high (40 to 160 attacks on a tree) in certain trees. Females laid 51.4 eggs on average with maximum of 200. 3.7% larval and 4% young adult galleries were coalesced. 24.3% attempts of *D. micans* was aborted and 75.7% of them was successful. Numbers of wounded and unwounded infested trees indicated a significant statistical difference. *D. micans* attacked and established more often on wounded trees. 83% of the wounded trees, were attacked by *D. micans*.

Keywords: Attack density, *Dendroctonus micans*, oriental spruce

Özet

Dendroctonus micans Türkiye'de tespit edildiği 1966 yılından itibaren doğal doğu ladini ormanlarını istila etmeye devam etmektedir. Dişiler ağaçlara münferit olarak saldırırlar ve genellikle konukçularını öldürmezler. Bu çalışma, böceğin Türkiye'de doğu ladindeki bu münferit saldırı stratejisi ve gelişimi konusundaki bilgilere katkı yapmayı amaçlamaktadır. Ağaçları istila etmedeki saldırı yapısı 2001-2004 ve 2006 yıllarında 120 deneme alanında incelenmiştir. Arazi çalışmaları Türkiye'nin kuzeydoğusunda, Artvin, Giresun ve Maçka (Trabzon)'da yürütülmüştür. Büyüklüğü 30 × 10 m olan deneme alanlarında toplam 3010 ağaç incelenmiştir. Arazi çalışmaları her yıl Mayıs'tan Ekim'e kadar sürdürülmüştür. Ağaçlar üzerinde 2 m'ye kadar olan *D. micans* saldırıları incelenmiş ve başarılı ve başarısız saldırılar kaydedilmiştir. Başarılı galerilerdeki böceklerin bulunduğu gelişim basamağı ve sayıları kaydedilmiştir. Terk edilen ağaçlardaki ve istila edilmiş ağaçlardaki eski kuluçka sistemlerinin büyüklükleri ölçülmüştür.

Böceğin deneme alanlarının %95,8'inde bulunduğu, ladin ağaçlarının %21,7'sine saldırdığı ve saldırıya uğrayan ağaçların %11,1'inde de aktif olduğu tespit edilmiştir. Saldırıya uğrayan ağaçların çoğunda sadece bir tane başarılı giriş deliği bulunmaktadır. Giriş deliklerinin %69,3'ü ağaç gövdelerinin yerden itibaren ilk 1 m'lik bölümünde, %30,7'si 1 ile 2 m arasında bulunmaktadır. Saldırı yoğunluğu saldırıya uğrayan ağaçların birçoğunda sınırlı kalırken, belli ağaçlarda oldukça yüksek olmuştur (tek bir ağaçta 40 ile 160 saldırı girişimi). Dişiler, maksimum yumurta sayısının 200 olmasıyla birlikte, ortalama 51,4 yumurta koymuştur. Toplam 219 larva galerisinin %3,7'si ve 25 genç ergin galerisinin %4'ü birleşik galerilerdir. Böceğin toplam saldırı girişimlerinin %24,3'ü başarısız, %75,7'si başarılı olmuştur. Böceğin istila ettiği yaralı ve sağlıklı ağaç sayıları arasındaki fark istatistiksel olarak anlamlıdır. *D. micans* çoğunlukla yaralı ağaçlara saldırmış ve bu ağaçlara başarılı şekilde yerleşmiştir. Yaralı ağaçların %83'ü saldırıya uğramıştır.

Anahtar sözcükler: Saldırı yoğunluğu *Dendroctonus micans*, doğu ladini,

[1] Artvin Çoruh University, Faculty of Forestry, Department of Forestry Engineering, 08000, Artvin, Turkey
[2] Karadeniz Technical University, Faculty of Forestry, Department of Forestry Engineering, 61080, Trabzon, Turkey
[3] Kastamonu University, Faculty of Forestry, Department of Forestry Engineering, 37100, Kastamonu, Turkey
* Corresponding author e-mail: hazan.akinci@artvin.edu.tr
Alınış (Received): 10.09.2013 Kabul ediliş (Accepted): 09.01.2014

Introduction

The greater European spruce bark beetle, *Dendroctonus micans* (Kugelann) (Coleoptera: Curculionidae) is a pest of spruce across its entire distribution range in Eurasia (Grégoire, 1988). *D. micans* has shown a well-developed capacity to spread and to establish in so far unattacked forests including in Georgia (Khobakhidzeet al., 1970) and Turkey (Benz, 1984; Eroğlu et al., 2005) during its spread westward from its original location, the east (Sackhalin peninsula and north Japan) (Fielding et al., 1991; Fielding and Evans, 1997).

D. micans was first discovered in oriental spruce, *Picea orientalis* (L.) Link. forests in Georgia in 1957 and by 1963, the beetle had heavily infested Georgian oriental spruce stands (Khobakhidze et al., 1970; Benz, 1984; Fielding et al., 1991). Oriental spruce is a native tree species of Turkey and Georgia. In Turkey, *D. micans* infestations were first discovered in 1966 in a stand adjacent to the Georgian border (Acatay, 1968) and, immediately afterward, in all the oriental spruce forests neighboring this country (Serez, 1979; Alkan, 1985). This expanding population built up a wide front in the early 1980s (Benz, 1984; Özder, 1984) and it was recorded in nearly all stands in the eastern part of oriental spruce forests in the late 1990s (Eroğlu, 1995; Alkan, 2000). In 1986, timber trade contributed to the movement of the beetle to the spruce forests in the western part of their distribution. By the early 2000s, *D. micans* had established extensively in these forests (Eroğlu et al., 2005). Presently, almost all the oriental spruce forests are infested in Turkey (Alkan-Akıncı et al., 2009).

Pheromone-mediated mass-attack is a common strategy to exhaust the hosts' defenses among bark beetles that attack living trees (Lieutier, 2007). In contrast, *D. micans* does not use aggregation pheromones. The trees are attacked by solitary females and successful brood establishment does not depend on tree mortality (Storer et al., 1997). Since there is no need for exhausting tree defenses and cooperation (Grégoire, 1985, 1988; King and Fielding, 1989) and the beetles behave individually (Lieutier et al., 1992), this colonization strategy is called individual or solitary strategy (Lieutier, 2007).

Host colonization is the most important factor affecting the population dynamics of bark beetles (Raffa and Berryman, 1987; Amezaga and Rodríguez, 1998) and host finding is the most risky event in their life cycle (Byers et al., 1998). The insects have to find a suitable host and a suitable spot on this host. In contrast with the cooperative attack strategy observed in tree-killing species, where a threshold exists above which all attacks succeed, in *D. micans*' solitary strategy, attacks can succeed at one place, but can fail at other places of the same tree (Vouland, 1991). Instead of exhausting the tree's defenses, *D. micans* minimizes the development of any induced reaction. Since the beetle has a solitary strategy and resistance depends on local tree characteristics, the effectiveness of tree resistance against an attack does not depend on the population level (Lieutier, 2007).

Starting with the first records of outbreaks in Europe (Severin, 1902; Brichet and Severin, 1903), plenty of detailed researches have focused on all aspects of the beetle attacks. General descriptions of the status in different countries, dispersal characteristics, attack strategy, biology, development, chemical ecology, host preferences, host resistance, pest management strategies have been studied (Carle, 1975; Bejer, 1985; Grégoire, 1985, 1988; King and Fielding, 1989; Storer et al., 1997; Gilbert et al., 2003; Byers, 1989; Lieutier , 2007 - only some selected works mentioned here -). In Turkey some aspects in damage status, biology, pest management strategies have been investigated up to day (Besçeli et al., 1968; Serez, 1978, 1979, 1981; Alkan, 1985; Keskinalemdar et al., 1986; Alkan ve Aksu, 1990; Eroğlu, 1995; Selmi, 1998; Aksu, 2011 - only some selected works mentioned here -).

This study aims to contribute to the understanding of the solitary attack strategy and development of *D. micans* on oriental spruce in Turkey, whilst they have, so far, been analyzed on Norway spruce in Europe. Results of the study will contribute to the perception of integrated pest management strategies, forestry operations and future researches.

Materials and Methods

Study area

Field surveys were carried out in Artvin, Giresun, and Maçka (Trabzon) in the north east of Turkey where pure and mixed natural oriental spruce forests shelter *D. micans* (Figure 1). Plots were parts of wider spruce stands that were under attack. Stands selected randomly from a pool of attacked stands, but place of the experimental plots were selected at the spots that can represent the stand in point of stand closure and type.

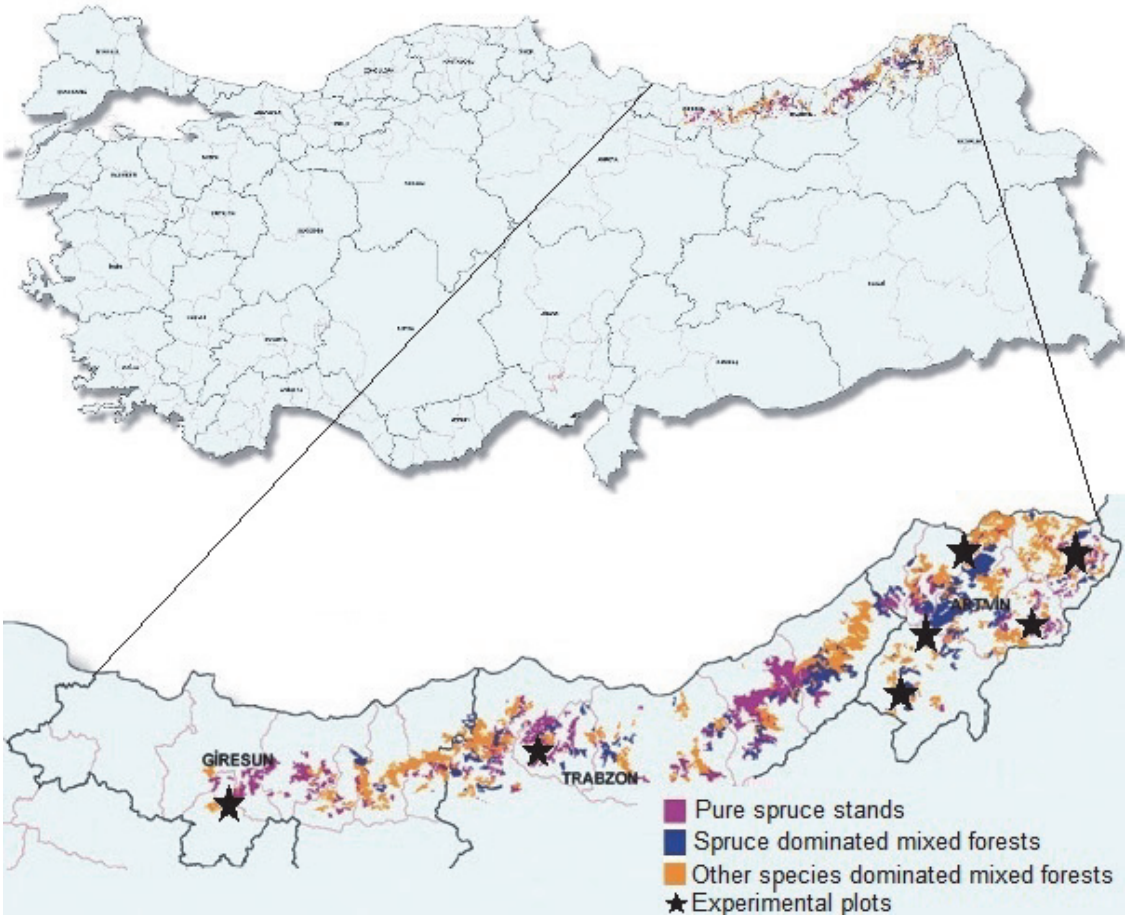

Figure 1. Distribution of oriental spruce (URL 1) and place of experimental plots.

The average elevation of the plots was 1670 m (900–2075 m), and the average slope was 40% (5–90%). There were 37, 23, 11, and 49 experimental plots in the north, south, east, and west aspects, respectively. Sixty-nine of the experimental plots were pure spruce stands, and 51 were spruce-dominated mixed stands. Oriental spruce trees were examined for beetle attacks. The percentages of tree species in stand mixture were as follows: *Picea orientalis* (L.) Link. (88.6%), and other trees, such as fir, *Abies nordmanniana* (Stev.) Spach. (6.4%), Scotch pine, *Pinus sylvestris* L. (1.8%), beech, *Fagus orientalis* Lipsky., (1.8%), chestnut, *Castanea sativa* Mill., aspen, *Populus tremula* L., hornbeam *Carpinus orientalis* Mill., alder *Alnus glutinosa* (L.) (1.4%). Tree species other than oriental spruce were not attacked by *D. micans*.

Place of the experimental plots were marked on distribution map of oriental spruce that is produced by General Directorate of Forestry (Figure 1) (URL 1).

Data Collection

A total 3010 trees were examined from May to October in each year in 120 experimental plots, 30 × 10 m in size. The attacked, unattacked, or wounded trees were identified and recorded in 2001-2004, and 2006 in the plots. There were axe wounds or production wounds on some trees in stands. *D. micans* attacks up to 2 m on trees were examined. Positions of the entry holes were measured. Attacks were recorded as successful if there were eggs or any other developing stages under the bark, and as aborted if there was no gallery beyond the entrance hole. Development stages and numbers of the beetles were recorded in galleries.

There were old and fresh aborted and successful attacks. Trees with old successful attacks (where brood development had occurred and where there was no *D. micans* remaining) were recorded as abandoned trees. Trees with fresh successful attacks (with developing broods under the bark) were recorded as infested trees. Trees with aborted attempts, abandoned and infested trees together were mentioned as attacked trees. The sizes of the old brood chambers were measured in the abandoned and infested trees.

The numbers of trees and brood chambers with eggs, larvae, pupae, or adults, the total and average numbers of individuals in these trees and brood chambers were arranged as a table. The tendency of initiating new infestations by fertilized females was assessed as the proportion of adult females in reproductive activities as compared to the total individuals and adults.

Larvae that were in different developing stages in the brood chambers in each infested tree were carefully studied. Cephalic capsule's widths of five to ten larvae that were taken from galleries in infested trees were measured. These measurements compared with the mean values in Bayramoğlu (2007) while determining larval stages. Mean value for each larval instar was 0.44 mm ± 0.08, 0.71 mm ± 0.09, 1.05 mm ± 0.10, 1.37 mm ± 0.10, and 1.78 mm ± 0.13 (Bayramoğlu, 2007).

Synchronization in attacks on trees was assessed, as it can explain coalesced galleries in these trees. The percentage of coalesced galleries was calculated based on the maximum number of eggs in the galleries. We assessed a larval gallery as coalesced if the number of larvae was higher than the maximum number of eggs in chambers.

Statistical analyses

Statistical data analyses were carried out using IBM SPSS statistics version 19.0. Numbers of wounded and unwounded actively infested trees were compared using Chi-squared tests. The sizes of old brood chambers on abandoned trees and currently infested trees were compared with t-test. Normality tests were performed prior the t-test. The sizes of old brood chambers were far from normality, so these data were log-transformed to normalize its distribution.

Results

Colonization rates and attack densities of *Dendroctonus micans* (Kug.) (Coleoptera: Curculionidae)

Dendroctonus micans was observed in 95.8% (115) of the sampled sites. Of the examined trees, 88.6% (2668) were spruce. *D. micans* attacked 21.7% (578) of the spruces, and 2.2% (59) of them died. There were active *D. micans* galleries in 11.1% (296) of these trees.

The attack density of *D. micans* on the first two meters of spruce boles is depicted in Figure 2. The majority of the attacked trees had only one successful attack and 10 emergence holes; the median value was 3 successful attacks and 26 emergence holes per tree. A total of 3578 successful entry holes were counted in 69.4% of the attacked trees, and 1149 aborted holes were counted in 47.2% of the attacked trees. There were one aborted attack in the majority of the trees and median value was 2 aborted attacks per tree. The aborted holes represented 24.3% of the total attempts.

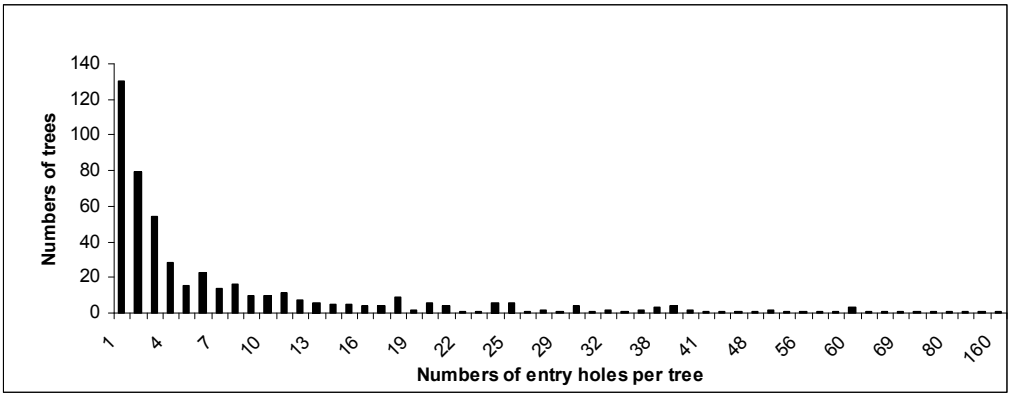

Figure 2. Attack density of *Dendroctonus micans* on oriental spruce trees.

When the percentages of the entry holes to the height up to 2 m on the bole of the trees were evaluated, 69.3% were up to 1 m, and 30.7% were between 1 and 2 m.

A total of 17918 *D. micans* individuals were counted in 780 brood chambers in 296 spruce trees in a total of 3.6 ha experimental plots area. The average number of beetles at each development stage per tree and brood chamber, and the adults in different activities are depicted in Table 1.

A total of 4521 eggs were counted in 88 egg chambers in 64 infested trees. The average number of eggs per gallery was 51.4 Most of the egg clusters (78.1%) were distributed solitarily on the infested trees (Figure 3).

Table 1. Average number of beetles of each development stage per brood chamber ± SE

Development stages	Number of	Number of	Number of	Average	Average	Percentage
Eggs	64	88	4521	70.6 ± 7.2	51.4 ± 4.4	25.2
Larvae	136	219	11392	83.8 ± 9.2	52.0 ± 3.7	63.6
Pupae	15	17	263	17.5 ± 16.6	15.5 ± 4.9	1.5
Young adults performing maturation feeding	25	25	1193	47.7 ± 13.7	47.7 ± 13.7	6.7 (68.5)[1]

[1]Number in the parentheses show the percentage of *D. micans* adults in total number of adults.

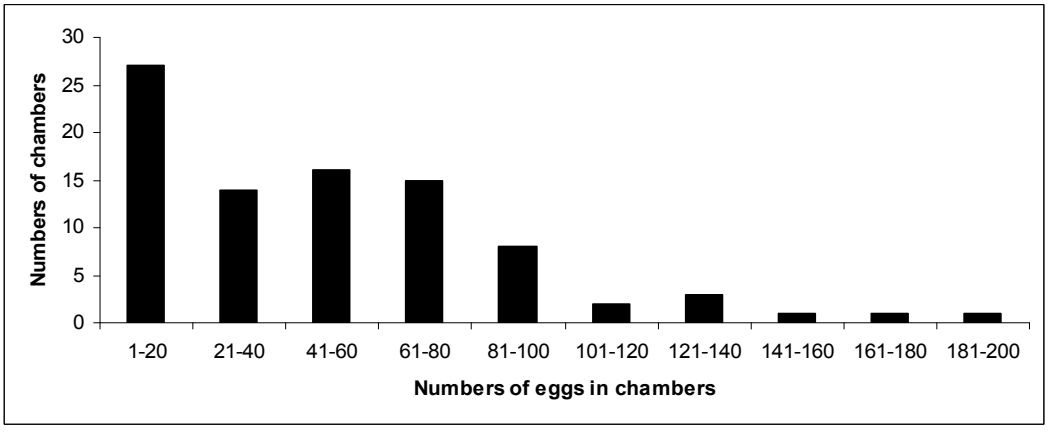

Figure 3. Numbers of eggs in chambers.

A total of 11392 larvae were counted in 219 galleries in 136 infested trees. The average number of larvae per gallery was 52.0. Trees mostly host one (82.4%) or two (17.7%) different instars larvae at the same time. The average numbers of larvae per gallery and the percentages of possible coalesced galleries are provided in Table 2. The average numbers of larvae in the coalesced galleries was 242. The coalesced galleries were 3.7% of the total larval galleries. Of the examined larvae, 52.2% of them were counted in 16.9% of the trees.

Table 2. Average numbers of larvae in galleries and possible coalesced galleries ± SE

Larval instars	Numbers of trees with larvae	Numbers of larval galleries	Numbers of trees with more than one gallery	Numbers of trees with coalesced galleries	Average numbers of larvae per tree	Average numbers of larvae per gallery	Percentages of coalesced galleries (%)	Average numbers of larvae in coalesced galleries	Average numbers of larvae in non-coalesced galleries
L1	36	50	8	1	61.6 ± 6.9	44.4 ± 5.9	2.0	222	40.7 ± 4.7
L2	42	64	13	2	82.9 ± 7.3	54.4 ±.5.9	3.1	238	48.5 ± 4.4
L3	29	36	3	2	67.3 ± 9.8	54.2 ± 8.8	5.6	218	44.6 ± 6.1
L4	20	22	2	1	78.2 ± 19	71.1 ± 18.1	4.5	390	55.9 ± 10.3
L5	37	47	7	2	58.8 ± 9.3	46.3 ± 8.2	4.3	206	39.2 ± 6.7

There were 263 pupae in 17 galleries on 15 trees. The average number of pupae per gallery was 15.5. A total of 1742 adults were counted in 574 galleries on 231 trees. Of the adults, 68.5% (1193) were young adults. There were 47.7 young adults per gallery on average (Table 1). There was a coalesced gallery where there were 313 young adults.

Wounded versus unwounded trees

Actually, 9.3% (247) and 90.7% (2421) of the spruces were wounded and unwounded in the sampled sites, respectively. *D. micans* attacked 21.7% (578) of the spruces. Of the attacked trees, 35.5% (205) were wounded trees and 64.5% (373) were unwounded trees. *D. micans* infested 11.1% (296) of the spruce trees. Of these infested trees, 39.9% (118) were wounded and 60.1% (178) were unwounded. Numbers of wounded and unwounded infested trees indicated a significant difference ($\chi^2 = 5.127$, df: 1, $P = 0.024$).

There were 1 to 160 successful attacks on unwounded trees and 1 to 77 successful attacks on wounded trees. The majority of the attacked unwounded trees had only one successful attack; the median value was 2 successful attacks. The majority of the attacked wounded trees had only one successful attack; the median value was 3 successful attacks. Numbers of successful attacks per unwounded and wounded trees were given in Figure 4.

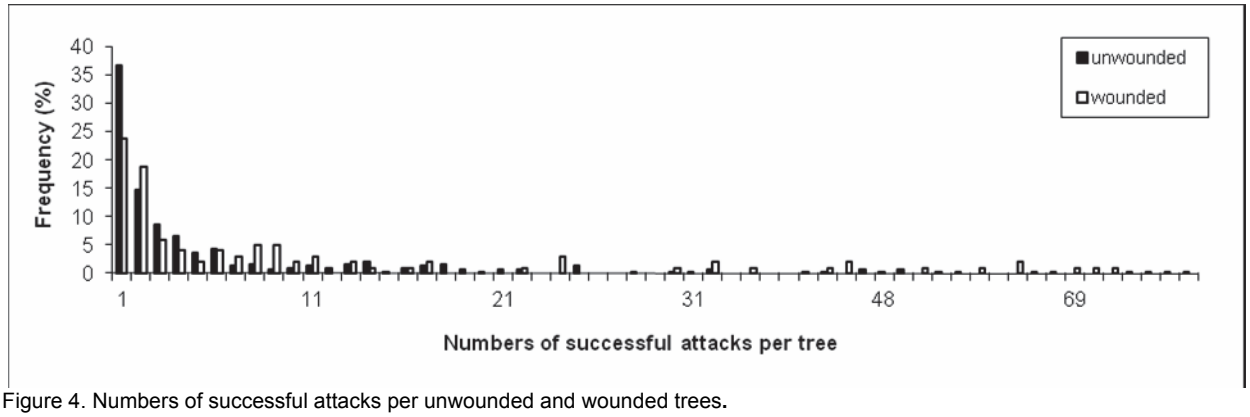

Figure 4. Numbers of successful attacks per unwounded and wounded trees.

There were 1 to 35 aborted attacks on unwounded trees and 1 to 33 aborted attacks on wounded trees. The majority of the attacked unwounded trees had only one aborted attack; the median value was 2 aborted attacks. The majority of the attacked wounded trees had only one aborted attack; the median value was 3 aborted attacks. Numbers of aborted attacks per unwounded and wounded trees were given in Figure 5.

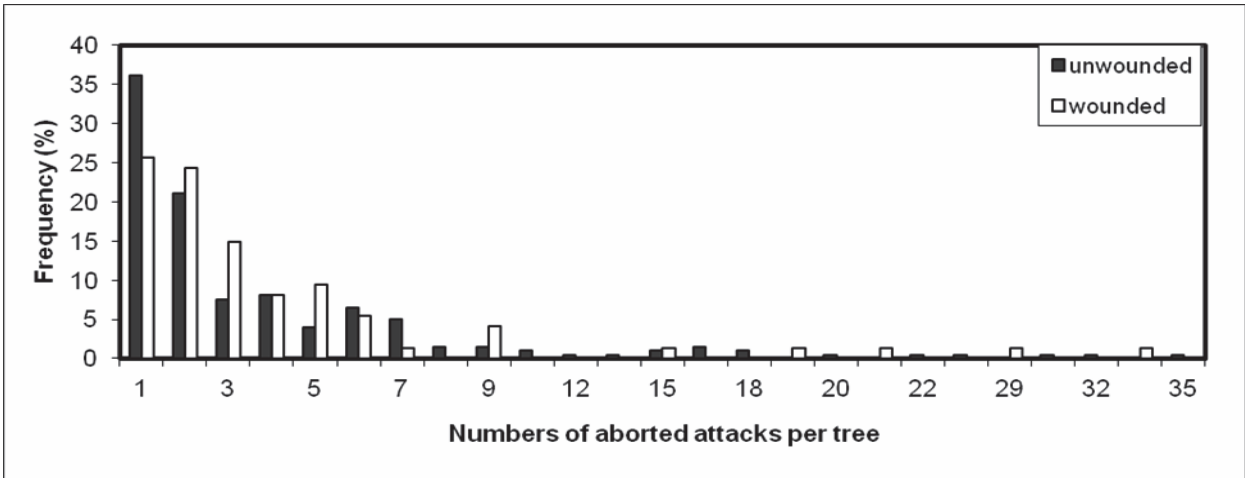

Figure 5. Numbers of aborted attacks per unwounded and wounded trees.

Only 9.3% of the spruce trees were wounded, but 45.7% of the entry holes, 50.8% of the eggs, and 56.8% of the larvae were found on these trees.

Currently infested trees versus abandoned trees

The sizes of the old brood chambers on the abandoned trees and infested trees were 2456.5 cm^2 and 1356.7 cm^2 on an average, respectively (Table 3). The sizes of old brood chambers on abandoned trees and currently infested trees were not different (t: 1.278,df: 198, P = 0.203).

Table 3. Average chamber sizes in abandoned trees and infested trees ± SE

Type of chamber	Average chamber size (cm^2)
Old brood chambers on the abandoned trees	2456.5 ± 641.3
Old brood chambers on the currently infested trees	1356.7 ± 183.9

Discussion

Colonization rates and attack densities of *Dendroctonus micans* (Kug.) (Coleoptera: Curculionidae)

The attack density of *D. micans* was limited in many of the attacked trees. Solitary attacks constituted the majority but there were also rather high numbers of attacks (40–160 attacks on a tree) in certain trees. The attack of the beetle was repeated more intensively in some trees. This similar scene has been reported by Eroğlu (1995) in the region. Some trees may not be attacked despite multiple *D. micans* attacks on neighboring trees within a spruce stand, and in addition, individual trees may have a number of aborted attacks on them, as well as some successful attacks (Bevan and King, 1983). In Belgium, the attack density per tree is solitary within the stands on Norway and Sitka spruce. At most, there are 9 attacks on a tree. Solitary attacks constitute the majority, indicating low infestation density and also no aggregation pheromone in this beetle (Grégoire, 1984).

Vertical distribution of *D. micans* attacks on oriental spruce trees was similar to situation in Georgia (Khobakhidze, 1967) and other spruce species in mainland Europe (Grégoire, 1984). *D. micans* preferred to settle to the lower parts of oriental spruce trees. But under outbreak conditions *D. micans* attacks upper parts of the trees, such as in Turkey during 1980s (Benz, 1984). In Britain, attacks may occur anywhere from the root collar. Attack frequency is greatest between breast height and base of live crown (Fielding and Evans, 1997).

One of every four attempts was aborted in oriental spruce trees in Turkey. *D. micans* has more abortive attacks in Europe. Grégoire (1984) reports more than 70% (72–78%) abortive attacks in Belgium. Resin flow can contribute significantly to the failure of *D. micans* attacks, and this has been attributed to the horizontal direction of the maternal gallery that cuts both radial ducts and a high number of vertical ducts during the whole tunneling activity of the beetle (Lieutier et al., 1992; Lieutier, 2007).

Female beetles laid maximum 200 eggs as reported by Khobakhidze (1967) and Serez (1979) on oriental spruce before. The average numbers of eggs laid in the field varies from 100 to 150 with maxima of 283 on Sitka spruce and 293 on Norway spruce (Grégoire, 1988). Maximum numbers of individuals per brood chambers at the larval and young adult stage were higher than maximum number of eggs. Average numbers of larvae were nearly 5 times higher in these brood chambers than average number of larvae in all chambers. The increase in the average number of larvae per gallery shows that the larval galleries may coalesce (Grégoire et al., 1989) in the later instars. When several females oviposit close to one another, individual brood systems frequently coalesce, extensively wounding the tree (Fielding and Evans, 1997).

In Belgium, average number of larvae per brood chambers is higher, however, average number of individuals in the systems containing only pupae and young adults is lower (Grégoire, 1984;Grégoire et al., 1989) than average number of young adults in Turkey.

Wounded versus unwounded trees

Beetles attacked and established significantly more often on wounded trees in oriental spruce stands. *D. micans* has been reported to attack wounded or forked trees and stand edges (Granet and Perrot, 1977) and are also known as being sensitive to host odors (Vasechko, 1978; Tømmerås, 1989). Concentration of starch and nitrogen, moisture content and resin content of wounded bark affects the success of attack. There will be changes in these features by wounding bark. In wounded bark, concentration of starch and nitrogen increases and moisture content reduces. There is initial decrease in resin content but in the 11-month-old wounds concentrations are higher than in unwounded bark (Storer and Speight, 1996).

Currently infested trees versus abandoned trees

The sizes of old brood chambers on abandoned trees and currently infested trees were not different. Trees have subjected to several attacks in the same year or several generations during consecutive years. In homogeneous sites, such as our study plots, Gilbert et al. (2001) reported that the first attacks in a new stand are made at random, that all or most of the beetles emerging from a tree disperse and resample the stand, and that they settle preferentially on trees that were colonized successfully by previous generations. In solitary strategy, as a consequence of the non-exhaustion of tree defenses, the host is not killed by the successful attacks and the whole beetle life cycle takes place in a living tree. With *D. micans*, tree death always occurs after several years and several generations in the same tree (Vouland, 1991; Lieutier, 2007).

Brood areas were similar to those on Norway spruce. The size of the brood area varies according to the number of larvae present, larger broods reaching areas of up to 30-60 cm long and 10-20 cm wide in Norway spruce (Fielding and Evans, 1997).

In conclusion, the attack density of *D. micans* was limited in many of the attacked trees and solitary attacks constituted the majority. There were also rather high numbers of attacks in certain trees. Trees have subjected to several attacks in the same year or several generations during consecutive years and

the beetle preferred to settle to the lower parts of the trees. One of every four attempts was aborted. *D. micans* seems to be more successful on oriental spruce than Norway spruce based on the results from European literature. Beetles attacked and established significantly more often on wounded trees in oriental spruce stands. Fragmented forests in north east of Turkey, more stand edges along these fragmented areas and wounded trees may contribute these two latter conclusions. There were coalesced larval galleries. The effect of coalesced larval galleries in exhaustion of tree defenses should be analyzed specifically in the future researches.

Acknowledgements

We are grateful to Dr. Jean-Claude Grégoire, Lutte biologique et écologie spatiale (LUBIES), Université Libre de Bruxelles, Brussels, Belgium for his insightful reviews of the manuscript. He critically read the manuscript and provided valuable comments and suggestions.

References

Acatay, A., 1968. Türkiye'de yeni bir ladin tahripçisi, *Dendroctonus micans* Kug. İ.Ü. Orman Fakültesi Dergisi, 18 (1): 18–36.

Aksu, Y., 2011. *Rhizophagus grandis* Gyll. (Coleoptera: Rhizophagidae)'in biyolojisi, laboratuarda üretim yöntemleri, ormanlara salınması ve mücadele sonuçları. Türkiye I. Orman Entomolojisi ve Patolojisi Sempozyumu, Bildiriler, 23–25 Kasım 2011, Antalya, 73-79.

Alkan, Ş., 1985. Şavşat İşletmesi Ormanlarında *Dendroctonus micans* Kug. (Dev soymuk böceği). Orman Mühendisliği Dergisi 1: 59–62.

Alkan, Ş., 2000. Ladin ormanlarına zarar veren *Dendroctonus micans* ve *Ips typographus* zararlılarına karşı sürdürülen mücadele uygulamaları. Eğitim Semineri, 22–26 Mayıs, İstanbul, 10–18.

Alkan-Akıncı H, G.E. Özcan &M. Eroğlu, 2009. Impacts of site effects on losses of oriental spruce during *Dendroctonus micans* (Kug.) outbreaks in Turkey. African Journal of Biotechnology 8 (16): 3934–3939.

Alkan, Ş. and Y. Aksu, 1990. *Rhizophagus grandis* Gyll. (Coleoptera, Rhizophagidae)'in Üretilmesinde Yeni Bir Metodun Uygulanması Üzerine Araştırmalar. Türkiye II. Biyolojik Mücadele Kongresi, 26–29 Eylül, Ankara, Bildiriler Kitabı, 173–179.

Amezaga, I. & M.Á. Rodríguez, 1998. Resource partitioning of four sympatric bark beetles depending on swarming dates and tree species. Forest Ecology and Management 109: 127–135.

Bayramoğlu, F., 2007. *Dendroctonus micans* (Kugelann) (Coleoptera:Scolytidae)'ın Laboratuar Koşullarında Biyolojisi. KTÜ Fen Bilimleri Enstitüsü, (basılmamış) Yüksek Lisans Tezi, Trabzon, 43 s.

Bejer, B., 1985. "*Dendroctonus micans* in Denmark, 2-19". Proceedings of the EEC Seminar Biological Control of Bark Beetles (*Dendroctonus micans*), (3–4 October 1984, Brussels, Belgium), 141 pp.

Besçeli, Ö., M. Varol & M. Ekici, 1968. Posof Ormanlarında Tahribat Yapan *Dendroctonus micans* Kug. Üzerinde Bir Etüt. Ormancılık Araştırma Enstitüsü Dergisi 14 (2): 26–40.

Benz, G., 1984."*Dendroctonus micans* in Turkey: The situation today, 43-47". Proceedings of the EEC Seminar Biological Control of Bark Beetles (*Dendroctonus micans*), (3–4 October 1984, Brussels, Belgium), 141 pp.

Bevan, D. & C.J., King, 1983. *Dendroctonus micans* Kug. – A new pest of spruce in UK. Commonwealth Forestry Review 62: 41–51.

Byers, J.A., 1989. Chemical ecology of bark beetles. Experientia 45: 271–283.

Byers, J.A., Q.H., Zhang, F., Schlyter & G., Birgersson, 1998. Volatiles from nonhost birch trees inhibit pheromone response in spruce bark beetles. Naturwissenschaften 85: 557–561.

Brichet, O. & G. Severin, 1903. Le *Dendroctonus micans* Dégats, moyens préventifs et destructifs. Bulletin de la Société Centrale Forestiére de Belgique 10: 244-261.

Carle, P., 1975. *Dendroctonus micans* Kug. (Col: Scolytidae), l'hylésine géant où dendroctone de l'épicéa (note bibliographique). Revue Forestière Française 27: 115–128.

Eroğlu, M., 1995. "*Dendroctonus micans* (Kug.) (Coleoptra, Scolytidae)'ın populasyon dinamiğine etki eden faktörler üzerine araştırmalar, 148-159". I. Ulusal Karadeniz Ormancılık Kongresi Bildirileri, (23–25 Ekim 1995, Trabzon), 3. Cilt.

Eroğlu, M., H., Alkan-Akıncı &G.E.,Özcan, 2005. "Ladin ormanlarımızda Kabuk Böceği yıkımlarına karşı izlenebilecek kısa ve uzun dönemli mücadele ve iyileştirme çalışmaları, 184-194". Ladin Sempozyumu Bildiriler Kitabı, I. Cilt, (20–22 Ekim 2005, Trabzon), 526 s.

Fielding, N.J. & H., Evans, 1997. Biological control of *Dendroctonus micans* (Scolytidae) in Great Britain. Biocontrol News and Information 18 (2): 51–60.

Fielding, N.J., H.F., Evans, J.M., Williams & B., Evans, 1991. Distribution and spread of the Great European Spruce Bark Beetle, *Dendroctonus micans*, in Britain–1982 to 1989. Forestry 64 (4): 345–358.

Gilbert, M., N. Fielding, H.F. Evans and J.C. Grégoire, 2003. Spatial pattern of invading *Dendroctonus micans* (Coleoptera: Scolytidae) populations in the United Kingdom. Can. J. For. Res. 33: 712–725.

Gilbert, M., G., Vouland & J.C., Grégoire, 2001. Past attacks influence host selection by the solitary bark beetle *Dendroctonus micans*. Ecological Entomology 26: 133–142.

Granet, A.M. & J.M., Perrot, 1977. *Dendroctonus micans* Kug. dans le sud-est du Massif central. Aires d'extension et premier essai d'interprétation des dommages. Mémoire de 3éme année E.N.I.T.E.F., pp. 1-127. Les Bars, France.

Grégoire, J.C., 1984. "*Dendroctonus micans* in Belgium: The situation today, 48-62". Proceedings of the EEC Seminar Biological Control of Bark Beetles (*Dendroctonus micans*), (3–4 October 1984, Brussels, Belgium), 141 pp.

Grégoire, J.C., 1985. "Host Colonization Strategies in *Dendroctonus*: Larval Gregariousness or Mass Attack By Adults?, 147–154". In: The Role of the Host in the Population Dynamics of Forest Insects (Ed: L.S. Safranyik). Canadian forest Service, Bannf, 240pp. Proceedings of the Symposium of IUFRO Working Parties S2.07–05 and S2.07–06, Banff, Canada, September 1983, Canadian Forestry Service and USDA Forest Service, Victoria, Canada.

Grégoire, J.C., 1988. "The Greater European Spruce Beetle, 455-478". In: Dynamics of Forest InsectsPopulations (Ed: A.A. Berryman). Plenum Press, New York, 624 pp.

Grégoire, J.C., M., Baisier & J., Merlin, 1989. "Interactions between *Rhizophagus grandis* (Coleoptera: Rhizophagidae) and *Dendroctonus micans* (Coleoptera: Scolytidae) in the Field and the Laboratory: Their Application for the Biological Control of *Dendroctonus micans* in France, 95-107". In: The Potential for Biological Control of *Dendroctonus* and *Ips* Bark Beetles (Ed: D. Kulhavy & M.C. Miller), The Stephen Austin University Pres, Nagocdoches.

Keskinalemdar, E., Y. Aksu and Ş. Alkan, 1986. *Rhizophagus grandis* Gyll.'in laboratuar şartlarında üretimi ve biyolojik mücadele uygulamalarında kullanılması olanakları üzerine araştırmalar. Türkiye I. Biyolojik Mücadele Kongresi, 12–14 Şubat, Adana, Bildiriler Kitabı, 195–205.

King, C.J. & N.J., Fielding, 1989. *Dendroctonus micans*, guidelines for forest managers. Forestry Commission Research Information Note 128, 11 pp.

Khobakhidze, D.N., 1967. Der Riesenbastkäfer (*Dendroctonus micans* Kug.) in Georgien (USSR). Anz. Schädlingsk. 40: 65-68.

Khobakhidze, D.N., M.S., Tvaradze & I.K., Kraveishvili, 1970. Preliminary results of introduction, study of bioecology, development of methods of artificial rearing and naturalization of the effective entomophage, *Rhizophagus grandis* Gyll., against the European spruce beetle, *Dendroctonus micans* Kugel., in spruce plantations in Georgia. Bulletin of the Academy of Sciences of the Georgian SSR60: 205–208.

Lieutier, F., 2007. "Host Resistance to Bark Beetles and Its Variations, 135-180". In: Bark and Wood Boring Insects in Living Trees in Europe, a Synthesis (Ed: F. Lieutier, K.R. Day, A. Battisti, J.C. Grégoire & H.F. Evans). Springer, Dordrecht, 569 pp.

Lieutier, F., G., Vouland, M., Pettinetti, J., Garcia, P., Romary & A., Yart, 1992. Defence reactions of Norway spruce (*Picea abies* Karst.) to artificial insertion of *Dendroctonus micans* Kug. (Col., Scolytidae). Journal of Applied Entomology114: 174–186.

Özder, M.Z., 1984. *Dendroctonus micans* Kug. Orman Mühendisliği Dergisi 21: 30–31.

Raffa, K.F. & A.A., Berryman, 1987. Interacting selective pressures in conifer-bark beetle systems: a basis for reciprocal adaptations? The American Naturalist 129: 234–262.

Selmi, E., 1998. Türkiye Kabuk Böcekleri ve Savaşı, İstanbul Üniversitesi Yayın No: 4042, Emek Matbaacılık, İstanbul, 196 s.

Serez, M., 1978. *Dendroctonus micans* (Kug)'ın Biyolojik Savaşında *Rhizophagus grandis* (Gyll)'in Önemi. Ormancılık Araştırma Enstitüsü Dergisi 47: 141–143.

Serez, M., 1979. Türkiye'de *Dendroctonus micans* (Kugelann) Üzerinde Araştırmalar. KTÜ Orman Fakültesi Dergisi 2 (1) 106–134.

Serez, M., 1981. Doğu Karadeniz bölümünde yaşayan Picidae (ağaçkakanlar) türleri, tanımları, yayılışları, biyolojileri ve gıdaları. KTÜ Basımevi. Trabzon 1981.

Severin, G., 1902. L'invasion de l'hylésine géante. Bulletin de la Société Centrale Forestiére de Belgique 9: 145-152.

Storer, A.J. & M.R., Speight, 1996. Relationships between *Dendroctonus micans* (Kug.) (Coleoptera: Scolytidae) survival and development and biochemical changes in Norway spruce, *Picea abies* (L.) Karst., phloem caused by mechanical wounding. Journal of Chemical Ecology22: 559–573.

Storer, A.J., D., Wainhouse & M.R., Speight, 1997. The effect of larval aggregation behaviour on larval growth of the spruce bark beetle *Dendroctonus micans*. Ecological Entomology 22: 109–115.

Tømmerås, B.A., 1989. Host selection by odorous compounds from host and non-host trees in bark beetles. Fauna Norvegica B, 36: 75–79.

URL 1. Orman Atlası. (Web page: http://web.ogm.gov.tr/Resimler/sanalkutuphane/orman_atlasi.pdf, Date accessed: January 2014).

Vasechko, G.I., 1978. Host selection by some bark beetles (Col., Scolytidae). I. Studies of primary attraction with chemical stimuli. Z. Angew. Entomol. 85: 66–76.

Vouland, G., 1991. Le dendroctone de l'épicéa: *Dendroctonus micans*(Col. Scolytidae) dans le Massif central. Dissertation, Université d'Aix-Marseille III.