Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1146116

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 5 - Issue 4: 406-414 / October 2022

# DETERMINATION OF FLIGHT ACTIVITIES AND POPULATIONS OF AMBROSIA BEETLES (COLEOPTERA: CURCULIONIDAE: SCOLYTINAE) IN HAZELNUT ORCHARDS IN SAMSUN, TÜRKİYE

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**Abstract:** Ambrosia beetles are highly invasive pests that cause thousands of hazelnut branches to dry out in hazelnut orchards each year. The manegement against these pests in hazelnut orchards, first of all, it is necessary to know the time of emergence of these pests during the year and the dates when their populations are concentrated. Between 2017-2019, studies were carried out in the Çarşamba and Terme districts of Samsun, which play an important role in hazelnut production in Türkiye. Populations of three invasive ambrosia beetle species (*Anisandrus dispar, Xylosandrus germanus and Xyleborinus saxesenii*) in hazelnut orchards were monitored using sticky traps for three years, from mid-March to mid-October. *A. dispar,* adults started to emerge in mid-March, their populations increased in April-May and started to decrease from mid-June. The emergence of *X. germanus* adults began in April, their populations peaked in late May and early June, and then the population began to decline. There was also a slight increase in their population in August. The emergence of *X. saxesenii* adults began in late March and a slight increase in their population was observed at the end of April. Populations of this species increased significantly in late June and early July, with a slight increase in populations in August. When these three ambrosia beetle species, which were caught in red sticky traps in hazelnut orchards for three years, were compared, the catch rates were determined as 56.28% for *A. dispar*, 24.20% for *X. germanus* and 19.52% for *X. saxesenii*, respectively. Thanks to this information obtained, it was determined when to start the combat against these pests in hazelnut orchards and when the management should be done most intensely.

**Keywords:** Hazelnut, Monitoring, *Anisandrus dispar*, *Xylosandrus germanus*, *Xyleborinus saxesenii*, Sticky traps

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**Received:** July 20, 2022
**Accepted:** August 31, 2022
**Published:** October 01, 2022

**Cite as:** Aker O. 2022. Determination of flight activities and populations of ambrosia beetles (coleoptera: curculionidae: scolytinae) in hazelnut orchards in Samsun, Türkiye. BSJ Agri, 5(4): 406-414.

## 1. Introduction

Ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) are known worldwide as one of the most successful invasive species groups and are highly destructive pests for many tree species, especially fruit trees (Ranger et al., 2016; Rassati et al., 2016; Hulcr and Stelinski, 2017). Ambrosia beetles pierce the xylem of host trees and carefully infect the walls of these galleries they open with the symbiotic fungi they carry in their bodies. Ambrosia beetles cultivate these symbiotic fungi in the galleries, thus providing a food source for the adults and larvae in the gallery walls (Kirkendall et al., 2015; Hulcr and Stelinksi, 2017). Males cannot fly and they spend their entire life cycle in the host trees (Peer and Taborsky, 2007). Female ambrosia beetles, which have the ability to fly, spend the winter in the galleries of the host trees and begin to appear in the orchards when the first warm days of spring arrive (Miller and Rabaglia, 2009; Ranger et al., 2013; Reding et al., 2013).

Ambrosia beetles generally prefer weakened or dying trees, but they can be much more harmful when their populations are excessive (Oliver and Mannion, 2001; Ranger et al., 2016; Hulcr and Stelinski, 2017; Wang et al., 2021). Most ambrosia beetles follow olfactory cues from trees to distinguish old, stressed and dying trees from healthy trees, with a particular focus on ethanol (Oliver and Mannion, 2001; Ranger et al., 2015, 2021; Werle et al., 2019; Lehenberger et al., 2021), which is induced and spread by trees exposed to stress by biotic (Kelsey et al., 2013) or abiotic factors (Kelsey et al., 2014; Ranger et al., 2019). Ethanol is highly attractive to invasive ambrosia beetles and is therefore widely used in many different types of traps to monitor and control these pests in many orchards (Coyle et al., 2005; Miller and Rabaglia, 2009; Noseworthy et al., 2012; Kelsey et al., 2013; Ranger et al., 2014; Miller et al., 2018).

Samsun province realizes approximately 17% of Türkiye's hazelnut production and continues to increase its hazelnut production amounts every year (Türkstat, 2022). Ambrosia beetles are considered as one of the most destructive pests in hazelnut orchards in Türkiye. Three invasive species of ambrosia beetle (*Anisandrus dispar*, *Xylosandrus germanus* and *Xyleborinus saxesenii*) are common in hazelnut growing areas and cause serious damage to orchards (Ak et al., 2005; Tuncer et al., 2017; Aker, 2018). Traps prepared with ethanol were used in the control and population monitoring of these invasive ambrosia beetles seen in hazelnut production areas in Türkiye (Ak et al., 2005; Saruhan and Akyol, 2012; Şahin and Özder, 2017).

Hazelnut branches infected by these pests die within a few years and new generations spread to the surrounding hazelnut orchards (Saruhan and Tuncer, 2000; Uygun et al., 2002). Hazelnut is a very valuable product and therefore it is very important to protect hazelnut orchards from these pests, so the right timing is as important as the right control technique against these pests. The aim of this study is to determine the first emergence times of these three invasive ambrosia beetle species, which are very harmful in hazelnut orchards, and the peak times of their populations during the year. In line with the information to be obtained, the most effective combat times against these pests will be determined better and the success of the combat will be increased.

## 2. Materials and Methods

### 2.1. Materials

The population monitoring study of these three species was carried out between 2017-2019 in Samsun province Çarşamba and Terme districts where hazelnut production is intense. Four hazelnut orchards (8 orchards in total) were selected from each of the two districts, and these selected orchards are a few meters above sea level, and there are mostly Tombul and Palaz cultivars in these orchards. Hazelnut trees were about 30-40 years old and were usually positioned in orchards with a distance of 3x4 meters between trees. Problems caused by ambrosia beetles in these selected hazelnut orchards had been experienced for years and growers were helpless. Coordinates of the 8 selected hazelnut orchards: 41°14'30.22"N-36°47'24.30"W, 41°14'39.45"N- 36°47'37.78"W, 41°14'55.78"N-36°47'50.98"W, 41°15'9.20"N- 36°48'8.97"W, 41°17'41.13"N- 36°49'54.11"W, 41°17'45.86"N-36°50'5.18"W, 41°17'47.31"N- 36°50'25.47"W, 41°18'0.09"N- 36°50'39.47"W. Rebell®rosso sticky traps were used to catch ambrosia beetles (made by Andermatt Biocontrol AG-Switzerland). Plastic drums, which were located at the bottom of the sticky traps and will carry the attractive solution, were hung under these sticky traps with the help of a rope.

### 2.2. Preparation of the Attractive Solution

Dilute a mixture of 96% Ethanol (99.5% purity) (Merck-818760) + 1% Toluene (99% purity) (Merck-108323) (1:1) with distilled water at a ratio of 1:1 (Aker, 2018).

### 2.3. Method

Four sticky traps were hung in each of the four hazelnut orchards selected from each district. A total of 32 traps were hung on hazelnut branches 1.5 meters above the ground. Traps were placed in the same row in each orchard, 30 meters apart. Five hundred ml of attractive solution was placed in each of the plastic drums of the sticky traps. All traps were counted weekly, ambrosia beetle species in sticky traps were identified by the author and counted-recorded ambrosia beetles were removed from sticky traps with tweezers. After count-recorded processing, fresh attractive solutions were placed in the plastic drums of each sticky trap. Sticky traps were replaced with new traps every six weeks. All these studies were carried out for 30 weeks each year. The 2017 trials started on March 19 and ended on October 15, the 2018 trials started on March 18 and ended on October 14, and the 2019 trials started on March 17 and ended on October 13. Three years of climate data were prepared using the data provided by the Turkish State Meteorological Service (TSMS, 2020) (Figure 1).

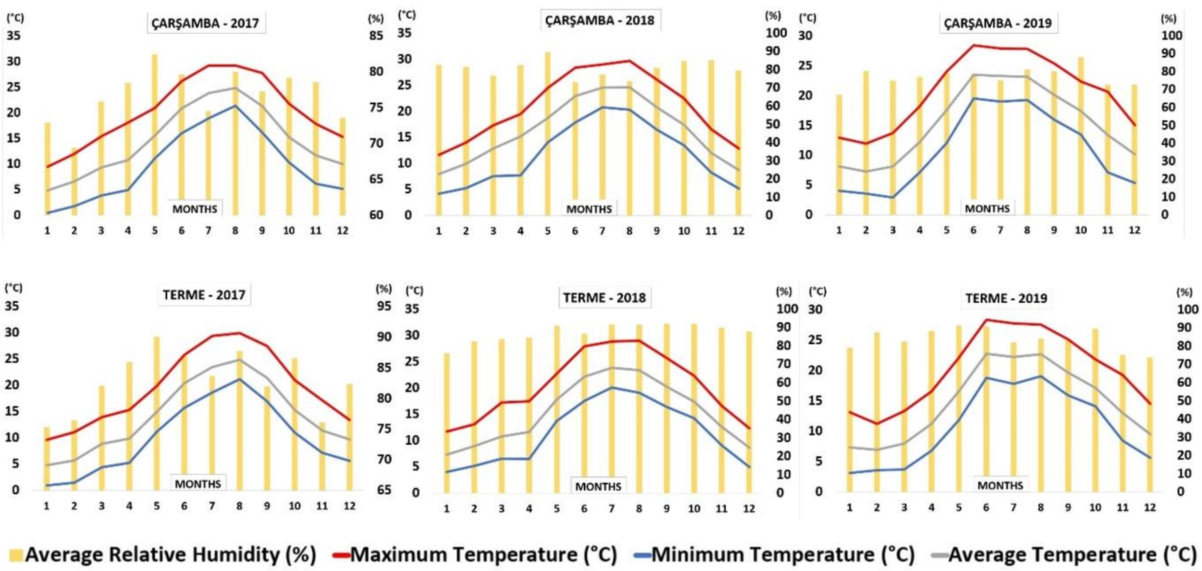


**Figure 1.** Monthly values of mean average relative humidity and temperature (maximum, average, minimum) in Çarşamba and Terme districts between 2017-2019.

### 2.4. Statistical Analysis

Shapiro Wilk-W Test was used to control the normal distribution of the obtained data and it was determined that the data did not show normal distribution. Results were expressed as mean ± SE. The significance of the differences in values was determined by the one-way ANOVA test and Duncan's multiple interval tests. *P* <0.05 was accepted as a significant difference. Graphs were prepared weekly based on numerical averages per sticky trap of different ambrosia beetle species caught in sticky traps each week for 30 weeks.

## 3. Results

### 3.1. Flight Activity and Population Monitoring of *Anisandrus dispar*

Female adults of this species were observed in hazelnut orchards for three years starting from mid-March, the first week of the trials, and many female adults were caught in sticky traps (125.31±3.02, 149.69±4.17, 17.88±1.02 for Çarşamba in 2017, 2018, 2019, respectively and 102.25±4.16, 117.94±3.67, 22.25±1.71 for Terme in 2017, 2018, and 2019, respectively). In the following weeks, the number of female adults caught in the sticky traps started to increase and the maximum number of catches in sticky traps was reached in late May and early June (857.5±19.74, 942.19±13.62, 951.69±13.46 for Çarşamba in 2017, 2018, 2019, respectively and 608.19±55.73, 593.63±36.29, 429.13±24.63 for Terme in 2017, 2018, 2019, respectively). After reaching the maximum number of adults caught in sticky traps, the number of adults caught in traps gradually decreased. While the number of adults caught in the trap decreases significantly in September and October, the number of adults caught in some sticky traps in the last week of trapping is negligible (2.31±0.18, 2.13±0.2, 1.81±0.2 for Çarşamba in 2017, 2018, 2019, respectively and 2.25±0.25, 0.75±0.21, 1.25±0.17 for Terme in 2017, 2018, 2019, respectively) (Figures 2 and 3).

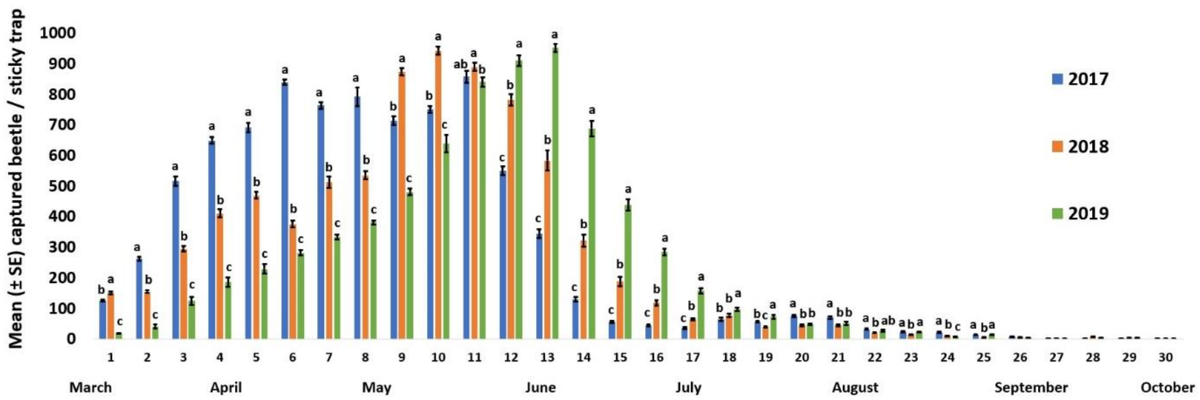


**Figure 2.** Weekly mean (± SE) number of new captures of *Anisandrus dispar* adults caught in sticky traps in Çarşamba district (P <0.05).

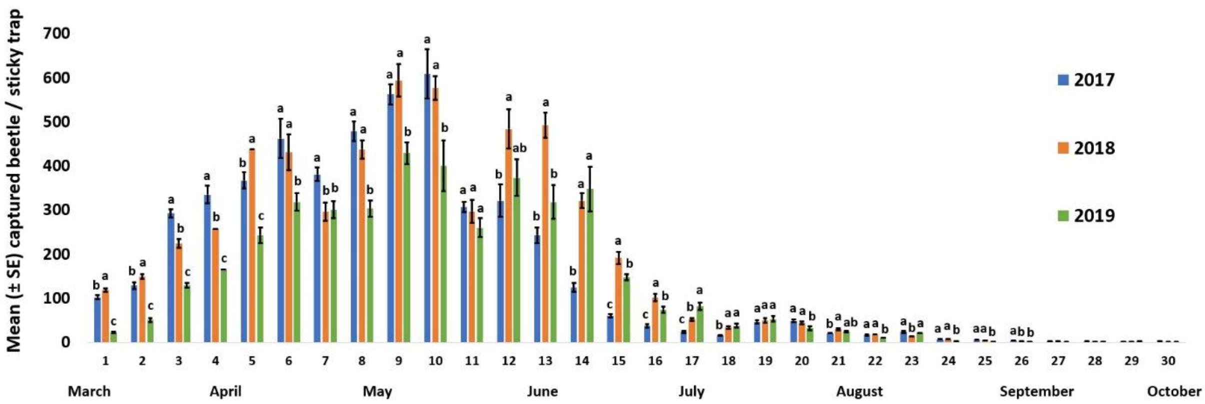


**Figure 3.** Weekly mean (± SE) number of new captures of *Anisandrus dispar* adults caught in sticky traps in Terme district (P <0.05).

### 3.2. Flight Activity and Population Monitoring of *Xylosandrus germanus*

This species, which was not observed when the traps were first set in hazelnut orchards, started to be counted in the sticky traps from the beginning of April, which corresponds to the third week in the traps (2.31±0.28, 0.25±0.08, 0±0 for Çarşamba in 2017, 2018, 2019, respectively and 1.38±0.2, 0.44±0.13, 0.31±0.12 for Terme in 2017, 2018, 2019, respectively). In the following weeks, the number of adults caught in sticky traps started to increase and the highest catch rate was reached in late May and early June (462.5±14.1, 687.94±6.48, 627.38±38.9 for Çarşamba in 2017, 2018, 2019, respectively and 400.69±26.1, 537.81±33.06, 407.38±21.56 for Terme in 2017, 2018, and 2019, respectively). While a decrease was observed in the number of adults caught in the traps in the following weeks, a slight increase was observed in the number of adults caught in the traps again in August. It was observed that the sticky trap catching decreased in the following weeks and almost no adults were caught in the sticky traps in the last week of trapping (0.69±0.12, 0.69±0.12, 0.69±0.12 for Çarşamba in 2017, 2018, 2019, respectively and 0.69±0.12, 0.69±0.12, 0.69±0.12 for Terme in 2017, 2018, 2019, respectively) (Figures 4 and 5).

### 3.3. Flight Activity and Population Monitoring of *Xyleborinus saxesenii*

Adults of *X. saxesenii* species, which have stuck to the traps since the first week when the sticky traps were hung in the hazelnut orchards, started to be seen more frequently in the hazelnut orchards as of the end of March (2.31±0.27, 1.94±0.21, 1.94±0.21 for Çarşamba in 2017, 2018, 2019, respectively and 1.0±0.27, 1.31±0.12, 0±0 for Terme in 2017, 2018, 2019, respectively). In the following weeks, the number of adults caught in sticky traps started to increase, and a significant increase was observed in the number of adults caught in the traps in late April and early May. Although the number of adults caught in the traps decreased in the following weeks, an increase curve was observed again from mid-June. The end of June and the beginning of July were recorded as the period when the adult females were caught in sticky traps the most (433.69±18.71, 442.25±18.05, 332.75±14.91 for Çarşamba in 2017, 2018, 2019, respectively and 451.75±20.62, 441.5±13.17, 333.5±18.93 for Terme in 2017, 2018, 2019, respectively). Gradual reductions followed in the following weeks. In the first weeks of August, a final increase in catches with sticky traps was observed, after which the catches of the traps started to decrease rapidly. Almost no adults were observed in the sticky traps during the last week of the trapping (0.63±0.13, 0.63±0.13, 1.06±0.21 for Çarşamba in 2017, 2018, 2019, respectively and 0.25±0.11, 0.75±0.11, 0.38±0.2 for Terme in 2017, 2018, and 2019, respectively) (Figures 6 and 7).

### 3.4. Comparison of population ratios of ambrosia beetle species in hazelnut orchards

The rates of catching of these three ambrosia beetle species in red sticky traps set in a total of eight hazelnut orchards were compared. In the studies carried out in hazelnut orchards for three years, it was determined that *A. dispar* was the most caught species in red sticky traps. *X. germanus* was identified as the second highest population species caught in sticky traps. *X. saxesenii* was determined as the species with the lowest rate of being caught in sticky traps set up in hazelnut orchards (Figures 8, 9, 10, 11, 12, 13 and 14). When the three-year general averages of these three species caught in red sticky traps are taken, it was determined as 56.28%, 24.20% and 19.52% for *A.dispar*, *X.germanus* and *X.saxesenii*, respectively.

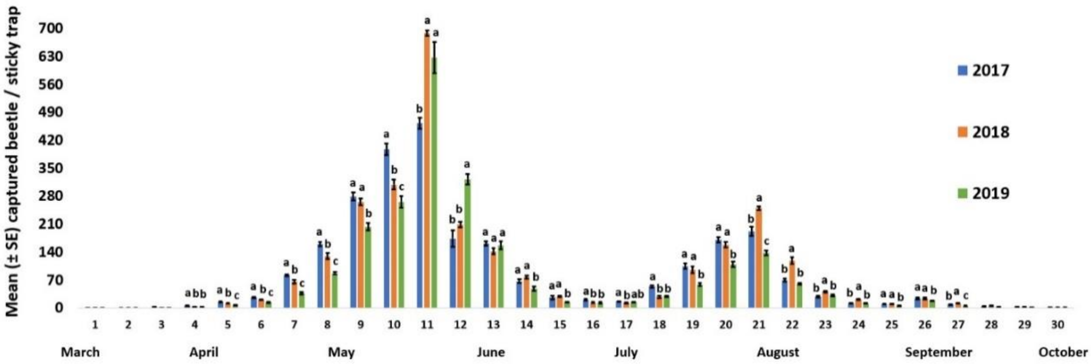


**Figure 4.** Weekly mean (± SE) number of new captures of *Xylosandrus germanus* adults caught in sticky traps in Çarşamba district (P <0.05).

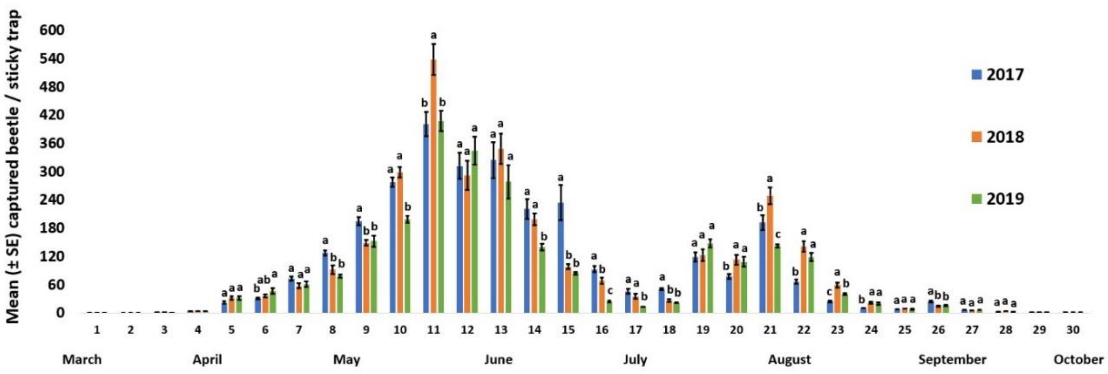


**Figure 5.** Weekly mean (± SE) number of new captures of *Xylosandrus germanus* adults caught in sticky traps in Terme district (P <0.05).

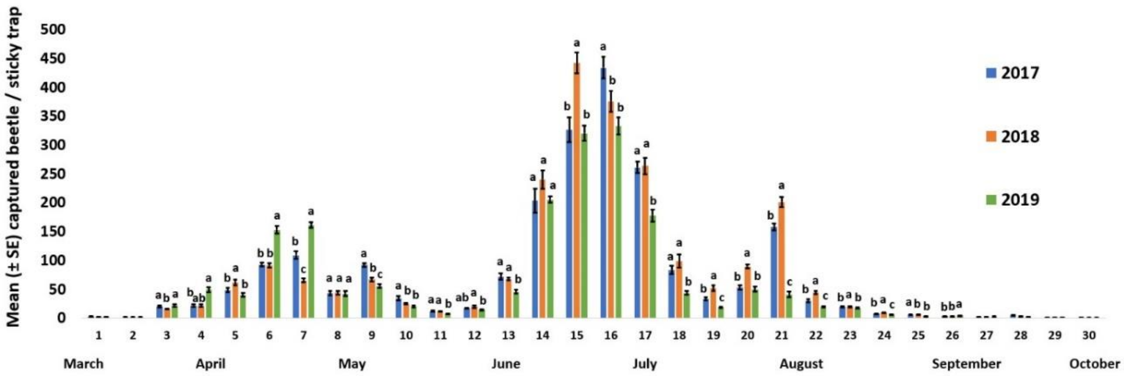


**Figure 6.** Weekly mean (± SE) number of new captures of *Xyleborinus saxesenii* adults caught in sticky traps in Çarşamba district (P <0.05).

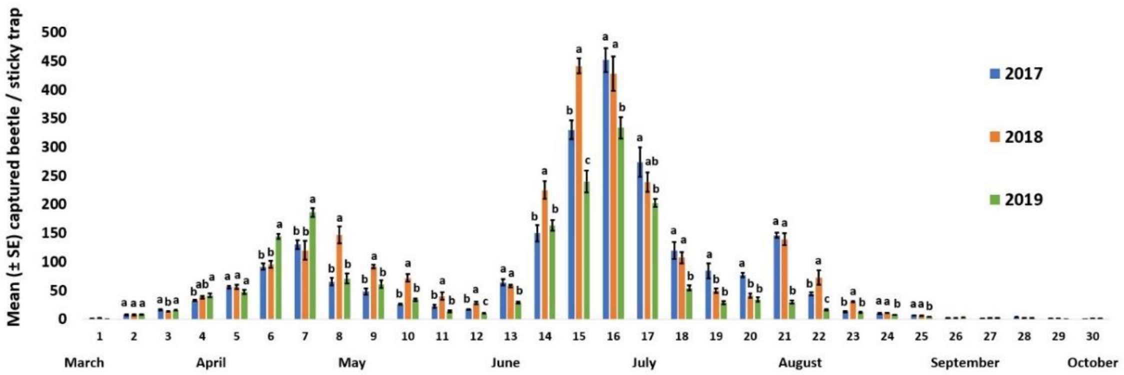


**Figure 7.** Weekly mean (± SE) number of new captures of *Xyleborinus saxesenii* adults caught in sticky traps in Terme district (P <0.05).

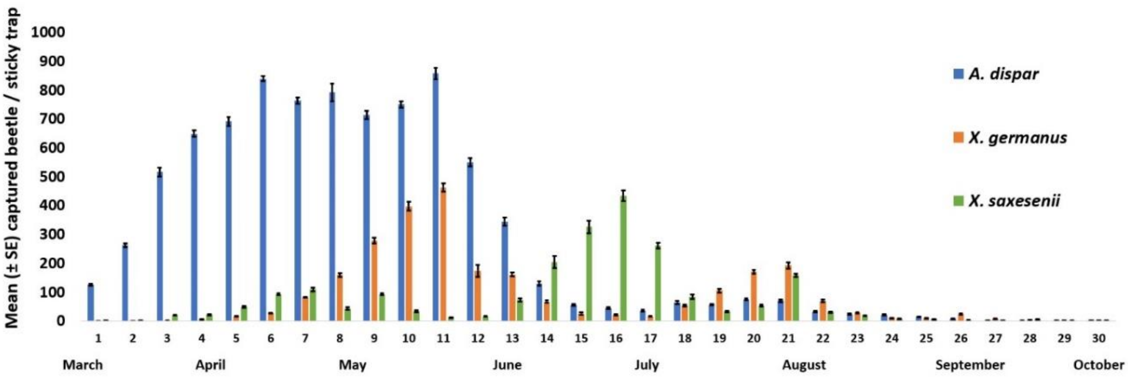


**Figure 8.** Weekly mean (± SE) number of new captures of ambrosia beetles caught in sticky traps in Çarşamba district in 2017 (P <0.05).

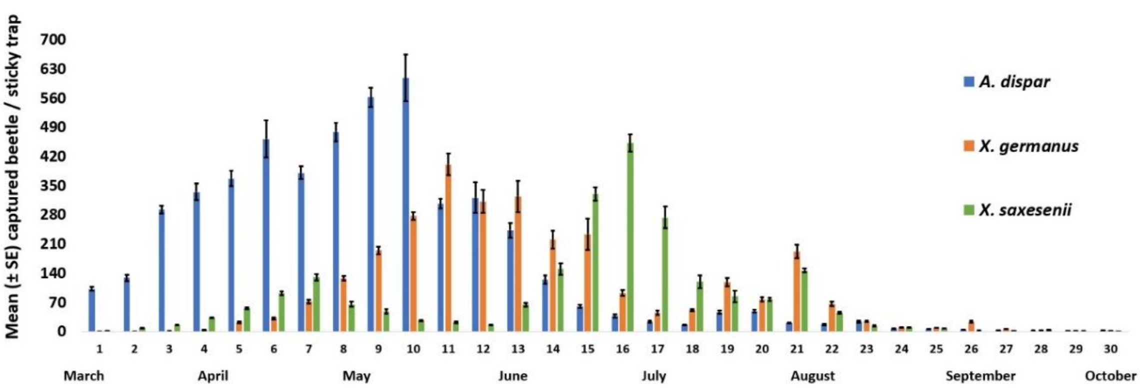


**Figure 9.** Weekly mean (± SE) number of new captures of ambrosia beetles caught in sticky traps in Terme district in 2017 (P <0.05).

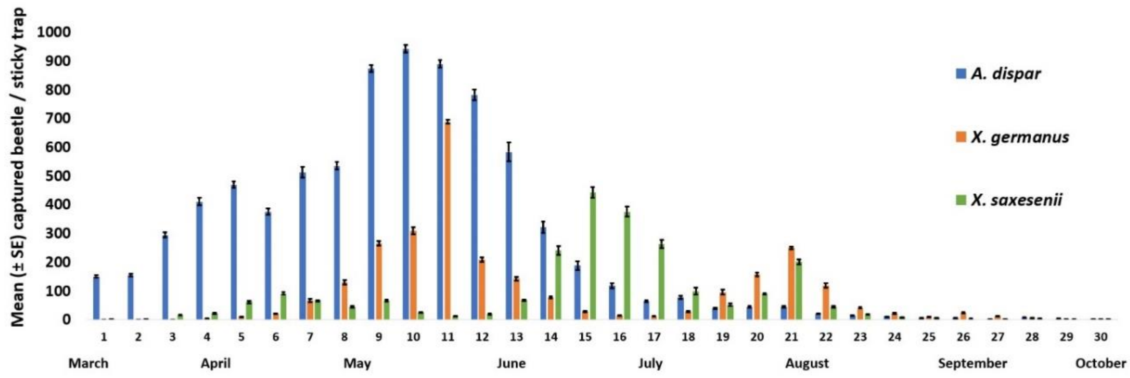


**Figure 10.** Weekly mean (± SE) number of new captures of ambrosia beetles caught in sticky traps in Çarşamba district in 2018 (P <0.05).

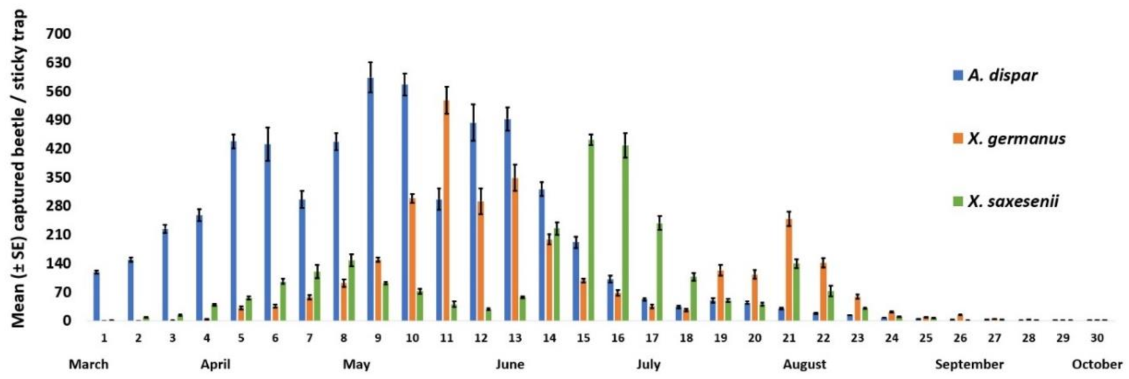


**Figure 11.** Weekly mean (± SE) number of new captures of ambrosia beetles caught in sticky traps in Terme district in 2018 (P <0.05).

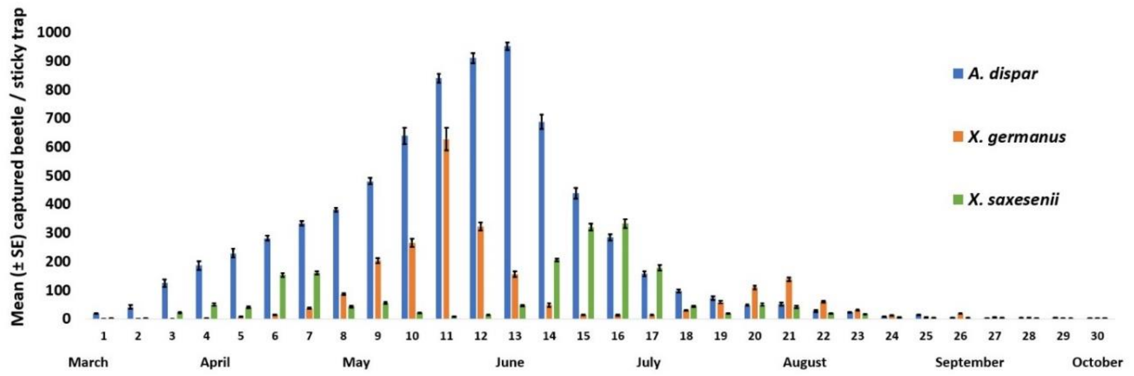


**Figure 12.** Weekly mean (± SE) number of new captures of ambrosia beetles caught in sticky traps in Çarşamba district in 2019 (P <0.05).

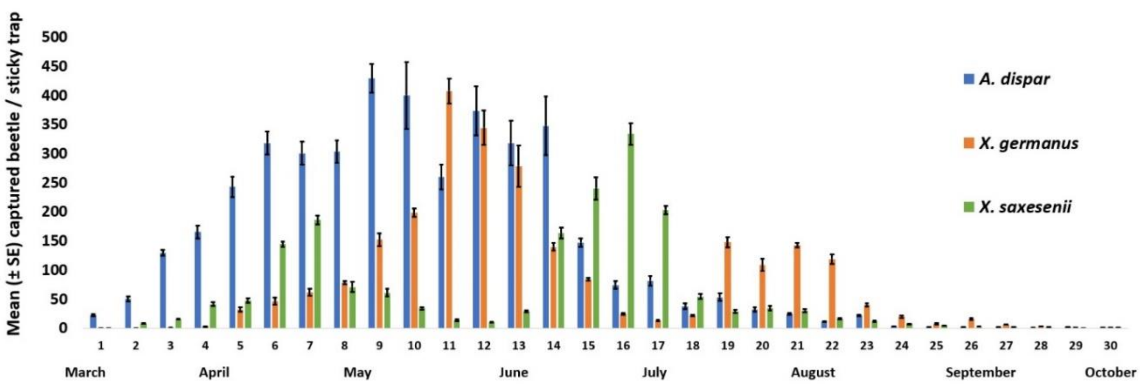


**Figure 13.** Weekly mean (± SE) number of new captures of ambrosia beetles caught in sticky traps in Terme district in 2019 (P <0.05).

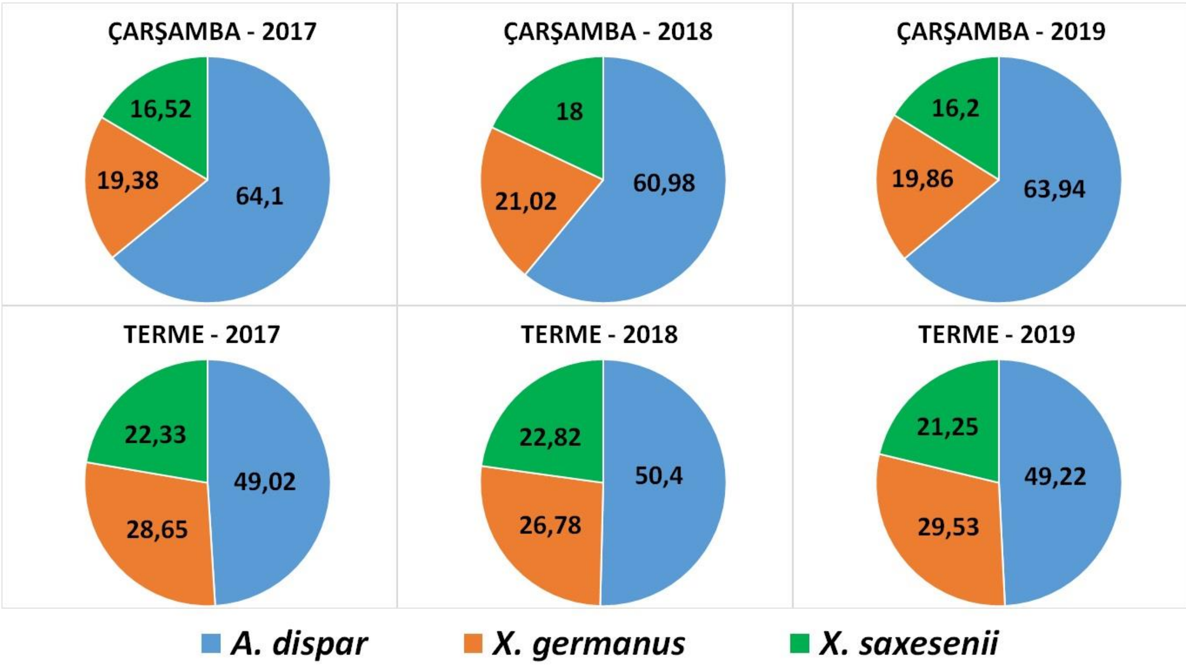


**Figure 14.** Capture rates (%) of ambrosia beetle species caught with red sticky traps in hazelnut orchards in Çarşamba and Terme districts between 2017-2019.

## 4. Discussion

In this study, the presence of ambrosia beetles was observed in hazelnut orchards from mid-March. In the 30-week studies that continued from mid-March to mid-October, it was determined that the presence of these three species in hazelnut orchards increased due to the increase in air temperatures from April (Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14). *A. dispar* has been observed in hazelnut orchards from mid-March. In similar studies, it was stated that *A. dispar* species started to appear in hazelnut orchards with the increase in air temperatures from mid-March, and an increase in adult emergence was observed from April when the daily average temperatures reached 18-20°C (Ak et al., 2005; Speranza et al., 2008; Saruhan and Akyol, 2012; Şahin and Özder, 2017; Aker, 2018). Saruhan and Tuncer (2000), stated that *A. dispar* was first seen at the beginning of April and the emergence continued until the beginning of August in hazelnut orchards between 1997-1998 in Samsun, Türkiye. Ak et al. (2005) stated that the first rises for *A. dispar* started in mid-March, peaked in May, and the second peak occurred in the July-August period in Giresun, Ordu, Samsun province between 2002-2003. Saruhan and Akyol (2012) stated that the first flights of *A. dispar* were seen in March-June and adult females were caught in the traps in hazelnut orchards between 2005-2007 in Samsun. In addition, the same researchers stated that the population densities of this species decreased in June-July, and the number of adults caught in the traps decreased significantly from the end of July. Sarıkaya and Sayin (2015) detected the first adults of *A. dispar* species in sticky traps as of the first half of April in their studies conducted in Kasnak Oak Forest Nature Reserve (Türkiye) in 2012-2013 and stated that overpopulation was observed in sticky traps in the second half of May. Şahin and Özder (2017) stated that the first emergence of *A. dispar* adults took place during the week of 13-18 March 2013, and the emergence of *A. dispar* adults took place on 12-19 March 2014 in hazelnut orchards.

*X. saxesenii* has been observed in hazelnut orchards from mid-March. In similar studies, it was stated that this species was observed in hazelnut orchards from mid-March and caught in traps and their population increased due to the increase in air temperatures (Saruhan and Akyol, 2012; Şahin and Özder, 2017; Aker, 2018). Saruhan and Akyol (2012) reported that *X. saxesenii* first appeared in March in the study they conducted in hazelnut orchards in 2005-2007, and there was a slight increase in their population in May. However, they stated that the peak population of this species was between July and August, and the number of adults caught in the traps decreased from September. Sarıkaya and Sayın (2015), in 2012-2013, detected the first adults of *X. saxesenii* in sticky traps as of the second week of April and stated that overpopulation was observed in sticky traps with the increase in air temperatures. They stated that the highest levels in the population were reached in the second half of August and the flight activities of this species continued until the end of September. Şahin and Özder (2017) stated that the first emergence of *X. saxesenii* adults took place during the week of 13-18 March in the studies in hazelnut orchards in 2013, and in the studies in 2014, the emergence of *X. saxesenii* adults took place on 20-27 March.

In this study, the first appearance of *X. germanus* started in the first days of April. In studies conducted by researchers doing similar studies on this species, it was stated that this species first appeared in hazelnut orchards in April in parallel with the increase in air temperatures (Şahin and Özder, 2017; Aker, 2018). Şahin and Özder (2017) stated that the first emergence of *X. germanus* adults took place during the week of 20-27 March in the studies in hazelnut orchards in 2013, and in the studies in 2014, the emergence of *X. germanus* adults took place in April. In similar monitoring studies on ambrosia beetles, it is thought that the similarity or difference between the flight activities and population densities of these species and the data obtained in this study are related to the climate data. As a matter of fact, it has been stated by the researchers that the main factor affecting the emergence of these beetles from their winter quarters, the increase or decrease of their populations, and the flight times are the climate factors (Coyle et al., 2005; Sarikaya and Sayin, 2015; De Souza Covre et al., 2021; Hofstetter et al., 2022).

## 5. Conclusion

Although ambrosia beetles prefer old, weak, or stressed trees that will die in a short time, it is known that they turn to many healthy trees in years when their populations increase excessively. The success of the programs in the effective and sustainable control of these pests is possible by knowing the flight activities and population monitoring of these pests in hazelnut orchards. It is thought that the information obtained from this study will increase the success of integrated control efforts against these pests in hazelnut orchards in the future.

**Author Contributions**

All task made by O.A. (100%); Concept, Design, Supervision, Data collection and/or processing, Data analysis and/or interpretation, Literature search, Writing, Critical review, Submission and revision. The author reviewed and approved final version of the manuscript.

**Conflict of Interest**

The author declared that there is no conflict of interest.

**Acknowledgments**

I would like to thank the valuable hazelnut producers in Çarşamba and Terme districts where the studies were carried out.

**Ethical Consideration**

Ethics committee approval was not required for this study due to the use of research materials that did not fall under the definition of experimental animals (The Scientific and Technological Research Council of Türkiye, Animal Experiments Local Ethics Committee Directive, 2018, Article 3-c).

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