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Original article

Infestation rate and cardinal directional preference of pistachio twig borer [*Kermania pistaciella* Amsel. (Lepidoptera: Tineidae)]

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ABSTRACT

Background: Pistachio twig borer [*Kermania pistaciella* Amsel, 1964 (Lepidoptera: Tineidae)] is one of the most important pests of pistachio that opens galleries in the shoots and causes blind and sparse-grained clusters and all these damage fruit clusters. However, the infestation rates and cardinal direction preference are unknown for the pest.

Methods: This study determined infestation rate and cardinal direction preference of *K. pistaciella* in pistachio orchards during 2019 and 2020. The orchards located in in 25 different locations, i.e., Birecik, Bozova, Ceylanpınar, Eyyübiye, Halfeti, Haliliye, Hilvan and Karaköprü districts Şanlıurfa province Turkey. Surveys were carried out in three or four orchards representing each district included in the study. Twenty-five trees were randomly selected from each orchard and one shoot from each side of the tree was collected (100 shoots per orchard) for determining infestation and cardinal directional preference. A total 2500 shoots were observed from the study area and infestation was recorded.

Results: The highest infestation rate was recorded for Yaslıca village in Bozova district (70%) during 2019, and Göklü village of Halfeti and Akziyaret village in Karaköprü district (29%) during 2020. The lowest infestation rate (2%) was noted for Akrepli village of Ceylanpınar district during both years of the study. Bozova and Halfeti were the most infested districts compared to the rest of the districts included in the study. The highest and the lowest infestation rate was recorded for north and west directions, respectively during both years of study. The average of two years data revealed that infestation rate for the shoots collected from the north direction was 23.68%, while it 20.33% for the shoots collected form west direction. Statistical analysis revealed non-significant difference for infestation rates of the shoots collected from different directions ($\chi 2$ = 0,9468; p = 0,8141).

Conclusion: The results revealed that all tree directions should be considered for the application of management practices since the pest does not prefer a specific direction. The cost of chemical control is high, but the efficacy is low, which necessitates alternative control methods for the management of the pest.

1. Introduction

Pistachio (*Pistacia vera* L.) is a member of the Anacardiaceae family, having origin in Central and Western Asia (Surucu et al., 2020), currently distributed throughout the Mediterranean basin (Tomaino et al., 2010). Pistachio was first cultivated in Anatolia by Hittite Civilization (Açar, 2018). The highest pistachio producing countries of the world are the United States (USA), Iran and Turkey

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(Bayram, 2011; Sabuncu et al., 2021; Surucu et al., 2020). According to United Nations Food and Agriculture Organization (FAO), 84% of the world's pistachio production comes from Iran, the USA and Turkey (FAO, 2019). Turkey ranks third after Iran and the USA, with approximately 240,000 tons annual production of pistachio (FAO, 2019).

Numerous diseases and insect pests negatively affect pistachio production by infesting pistachio orchards (Farivar-Mehin, 2001; Kaplan et al., 2018; Mehrnejad, 2020, 2001; Mourikis et al., 1997). Pistachio twig borer [*Kermania pistaciella* Amsel, 1964 (Lepidoptera: Tineidae)] is one of the most important pests negatively affecting pistachio production in the southeastern Anatolia region of Turkey (Bolu, 2002; Bolu, 2020; Mamay and Şimşek, 2017; Özgen et al., 2012; Sabuncu et al., 2021). The adults of the pest start flying at the end of March and beginning of April in the spring and lay their eggs on flowers and fruit clusters. Moreover, the pest lays eggs on shoots and leaf stalks during the peak population periods (Şengel, 2020; Tezerji, 2009).

The larvae emerge one week after egg laying and form galleries by entering the shoot or cluster where the eggs are attached (Abbaszadeh et al., 2006). Mature larvae pupate after forming cocoons, a few cm from the exit hole on the shoot from where they emerge. Generally, the cocoons develop the color of bark; thus, difficult to notice (Şengel, 2020).

Pistachio twig borer results in the formation of blind clusters in pistachios and sparseness of grains in the clusters (Basirat and Mehrnejad, 2019; Fakhri and Abbasipour, 2019; Rezaei et al., 2020; Tezerji, 2009; Ziaaddini et al., 2002). The pest causes significant losses as buds fall or their development is paused due to damage caused by the larva to the shoot (Basirat and Mehrnejad, 2019; Fakhri and Abbasipour, 2019; Küçükarslan, 1966; Rezaei et al., 2020; Tezerji, 2009; Ziaaddini et al., 2002). The damaged top bud often fails to leaf out and dries during the next developmental period. The damages caused by *K. pistaciella* reduce the quantity and quality of the harvested pistachio resulting in serious economic losses (Surucu et al., 2020; Tezerji, 2009).

Kermania pistaciella significantly decreases yield and quality in pistachio production; therefore, it is of great significance. This study was carried out in the southeastern Anatolia region, which produces >90% of Turkey's pistachio. The study was aimed at determining infestation rate and cardinal direction preference of the pest in pistachio orchards located in various districts of Şanlıurfa province. It was hypothesized that the orchards and districts will significantly differ for infestation rate. Furthermore, it was hypothesized that the pest would have cardinal direction preference. The results of the study would provide valuable insights for the management of the pest.

2. Materials and methods

2.1. Experimental site

The main material of the study were pistachio shoots infested with *K. pistaciella*. Infestation rate and cardinal direction preference were determined in 25 locations in the southeastern Anatolia region during 2019 and 2020. Şanlıurfa produces most of the pistachio grown in the region. Therefore, the studies were conducted in different villages, i.e., Birecik, Bozova, Ceylanpınar, Eyyübiye, Halfeti, Haliliye, Hilvan and Karaköprü districts of Şanlıurfa province. Three to four orchards representative of each district were selected randomly and then infestation rate and cardinal direction preference of the pest was determined. The background information on the orchards are given in Table 1.

2.2. Data collection

Twenty-five trees were randomly selected from each orchard and one shoot form each cardinal direction of the tree was observed for pest infestation. A total 100 shoots were observed from each orchard and total 2500 shoots were observed from the whole study area. For determining cardinal direction preference, shoots taken from the east, west, north and south directions were put in different bags and labeled. Afterwards, these shoots were cut vertically in the laboratory and checked for the pest infestation. If *K. pistaciella* larvae was found in the shoots or the damage symptoms (i.e., opened gallery) were noticed, the shoot was regarded infested. Infested and healthy shoots were recorded separately, and infestation rate was calculated for orchards and studied districts. The following formula was used to determine infestation rate (Onen et al., 2018).

$$\textit{Infestation rate}(\%) = \frac{\textit{Number of infested shoots}}{\textit{Total number of shoots observed}} \times 100$$

2.3. Data analysis

The collected data on cardinal direction preference were subjected to one-way analysis of variance (ANOVA) to infer the significance (Steel et al., 1997). The means were compared by Wilcoxon test where ANOVA indicated significant differences. The statistical computations were executed on SPSS statistical software (IBM SPSS Inc., 2012).

3. Results

The pest infestation was recorded in all studied locations and the studied orchards differed for the infestation rate (Table 2). The highest infestation rate (70%) was recorded for Yaslıca village in Bozova district during 2019, while during 2020 the highest infestation rate (29%) was noted for Göklü village of Halfeti and Akziyaret village of Karaköprü district. The lowest infestation rate (2%) was noted for Akrepli village in Ceylanpınar district during both years of the study (Table 2).

The average infestation rate in different studied districts is given in Table 3. The highest infestation rate was recorded for Bozova (44.33%) and Halfeti districts (39%) during 2019, whereas Karaköprü district recorded the highest infestation during 2020. The lowest infestation rate (3.66%) was recorded for Ceylanpınar district during both years of the study (Table 3).

The cardinal direction preference-related data of *K. pistaciella* are given in Table 4. The data of both years indicated that the highest infestation was recorded on the northern sides of the trees, whereas western side recorded the lowest infestation. Two years average indicated that infestation rate for the northern side was 23.68%, while it remained 20.33% for western direction. Statistical analysis revealed non-significant differences among infestation rate of different cardinal directions ($\chi 2$ = 0,9468; p = 0,8141).

4. Discussion

The results of the current study revealed that different districts significantly differed for infestation rate of *K. pistaciella* during both years of the study as hypothesized. The highest infestation rate was recorded for Bozova (44.33%) and Halfeti districts (39%) during 2019, whereas Karaköprü district recorded the highest infestation during 2020. The lowest infestation rate (3.66%) was recorded for Ceylanpınar district during both years of the study (Table 3). The differences among different districts can be explained with the

Table 1
Background information on the pistachio orchards included in the study.

District	Village	Orchard age	Area (da)	Number of trees	Coordinates	Altitude (m)
	Kesmetaş	25	100	2000	N 37° 18′ 56.16′′ W 38° 36′ 03.53″	711
Bozova	Yaslıca	40	50	900	N 37° 25′ 39.12′′ W 38° 22′ 36.18′′	521
	Hacılar	40	50	750	N 37° 21′ 43.55′′ W 38° 17′ 42.21′′	514
	Göklü	25	100	2500	N 37° 19′ 36.84′′ W 38° 02′ 39.60′′	540
Halfeti	Durak	50	40	1000	N 37° 16′ 09.46′′ W 37° 56′ 35.29′′	610
	Yeşilözen	40	60	1500	N 37° 12′ 06.51′′ W 37° 58′ 06.47′′	615
	Böğürtlen	60	200	4000	N 37° 09′ 44.28′′ W 38° 05′ 16.06′′	746
Birecik	İnnaplı	30	30	600	N 37° 04′ 02.68′′ W 37° 56′ 09.98′′	369
	Keskince	40	150	2750	N 37° 04′ 33.50′′ W 37° 53′ 23.10′′	424
	Geçittepe	60	200	4000	N 37° 03′ 21.02′′ W 37° 55′ 24.17′′	363
	Payamlı	20	20	400	N 37° 03′ 27.93″ W 38° 31′ 57.65″	677
Eyyübiye	Akçamescit	30	30	600	N 37° 06′ 37.58″ W 38° 51′ 07.33″	451
	Kadıkendi	40	30	600	N 37° 08′ 29.48″ W 38° 44′ 03.04″	658
	Kırbaşı	50	20	300	N 37° 30′ 31.79″ W 38° 53′ 19.66″	658
Hilvan	Söğütlü	30	60	1100	N 37° 30′ 46.51″ W 38° 41′ 55.36″	622
	Ovacık	40	50	900	N 37° 30′ 07.38″ W 38° 46′ 52.75″	673
	Akziyaret	25	150	3000	N 37° 19′ 52.08″ W 38° 48′ 51.18″	726
Karaköprü	İlhan	30	100	2000	N 37° 25′ 11.87″ W 38° 45′ 04.04″	679
	Kızlar	40	40	750	N 37° 15′ 32.61″ W 38° 46′ 25.30″	661
	Çamlıdere	30	40	800	N 37° 09′ 32.82″ W 39° 04′ 19.10″	475
Haliliye	Mağaracık	30	50	900	N 37° 12′ 41.91″ W 39° 02′ 35.96″	534
	Kalecik	25	20	360	N 37° 17′ 15.72″ W 38° 49′ 35.99″	733
	Beyazkule	30	400	8000	N37° 01′ 50.24″ W 39° 56′ 57.05″	458
Ceylanpınar	Akrepli	30	100	2000	N 36° 52′ 28.32″ W 40° 03′ 12.60″	382
	Merkez	30	60	1000	N 36° 50′ 52.79″ W 40° 02′ 19.73″	361

microclimatic conditions, and management options used to manage the pest (Onen et al., 2018; Ozaslan et al., 2016). The studied area was infested with the pest with the lowest and the highest infestation rate of 2 and 70%, respectively. Şengel (2020) reported 8–16% infestation rate of the pest in pistachio orchards of Euphrates valley. Küçükarslan (1966) reported that infestation rate of *K. pistaciella* in Gaziantep province changed between 5 and 35% during 1962–1964. Mamay et al. (2016) reported that average infestation rate of the pest was 50.16% in pistachio orchards where no chemical was sprayed and this rate reduced to 5.01% after three years of mass trapping in Şanlıurfa province. Basirat and Mehrnejad (2019) reported that the pest's infestation in pistachio fruit clusters varies between 0.58% and 6.58%, although it varies according to the varieties. Similarly, Arbabtafti et al. (2012) reported that infestation rate in pistachio fruit clusters was 10.3% in control orchards in Iran, which was reduced to 3.6% in the orchards where chemicals were sprayed several times. However, they also reported that was not economical.

The use of pesticides and other management options used to tackle the pest in different districts could be another reason of the differences among infestation rates. However, there is no such data available to support this inference. The data relating to pesticide use and other management options should be collected in the future studies and linked with the infestation rate of the pest. Nonetheless, economic losses caused by the pest in the region are still unknown by farmers. Therefore, future studies relating to the relationship between infestation rate and economic damages must be conducted to educate the pistachio growers regarding the importance of the pest.

The pest did not prefer any cardinal direction. Although there were differences in infestation rate of different cardinal directions, these were statistically non-significant. No differences in the cardinal directions could be explained with similar microclimatic conditions and site-specific management options used against the pest (Onen et al., 2018; Önen et al., 2018; Ozaslan et al., 2016). There is no study in the literature reporting the cardinal direction prefer-

Table 2
Infestation rate of *Kermania pistaciella* in pistachio orchards located in southeastern Anatolia region during 2019 and 2020.

District	Village	Infestation Rate (%)	
		2019	2020
Birecik	Böğürtlen	50	25
	Geçittepe	26	10
	İnnaplı	16	6
	Keskince	36	14
Bozova	Hacılar	31	22
	Kesmetaş	32	12
	Yaslıca	70	16
Ceylanpınar	Akrepli	2	2
	Beyazkule	7	6
	Merkez	2	3
Eyyübiye	Akçamescit	26	15
	Kadıkendi	26	19
	Payamlı	32	27
Halfeti	Durak	40	20
	Göklü	44	29
	Yeşilözen	33	18
Haliliye	Çamlıdere	9	3
	Kalecik	10	11
	Mağaracık	13	12
Hilvan	Kırbaşı	17	11
	Ovacık	10	10
	Söğütlü	2	8
Karaköprü	Akziyaret	36	29
	İlhan	14	21
	Kızlar	14	12

Table 3
The average infestation rate of *Kermania pistaciella* in different districts of Şanlıurfa province.

District	Infestation Rate (%)	
	2019	2020
Birecik	32.00	13.75
Bozova	44.33	16.66
Ceylanpınar	3.66	3.66
Eyyübiye	28.00	20.33
Halfeti	39.00	22.33
Haliliye	10.66	8.66
Hilvan	9.66	9.66
Karaköprü	21.33	20.66

Table 4
The infestation rate of *Kermania pistaciella* on pistachio trees according to different cardinal directions.

Direction	Infestation Rate (%) (±SE)		
	2019	2020	Two-year average
East	20.71 ± 4.03a	16.95 ± 4.35a	20.33 ± 2.90a
West	24.41 ± 6.84a	17.24 ± 3.62a	20.82 ± 3.85a
North	25.65 ± 6.46a	21.72 ± 4.52a	23.68 ± 3.84a
South	22.11 ± 4.77a	19.92 ± 4.00a	21.01 ± 3.02a
Chi-Square (χ^2)	*0.4460*	*0.8484*	*0.9468*
p-Value	*0.9306*	*0.8379*	*0.8141*

*Means sharing different letters within a column are statistically significant by each pair Wilcoxon test ($p < 0.05$).

ence of the pest. Zamani et al. (2012) reported that there was no statistical difference between the number of pests trapped by the traps installed in different directions to determine the effectiveness of cardinal direction on the trapping of *K. pistaciella* adults.

5. Conclusion

The current study revealed that Pistachio twig borer infests pistachio trees in the studied orchards with infestation rate ranging from 2 to 70%. Alternative methods should be developed for the control of the pest since it causes great economic losses by opening gallery on the shoots and damaging the fruit clusters. Nonetheless, all cardinal directions should be considered for the application of control strategies as the pest did not prefer any cardinal direction. It is recommended that future studies should be conducted to develop a relationship between infestation ratio and damages caused by the pest in pistachio orchards.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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