doi:10.14720/aas.2019.114.1.2 Original research article / izvirni znanstveni članek

Population fluctuations of the pistachio twig borer, *Kermania pistaciella* Amsel, 1964 (Lep.: Oinophylidae) using delta pheromone trap

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Received February 28, 2019; accepted July 02, 2019.
Delo je prispelo 28. februarja 2019, sprejeto 02. julija 2019.

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Abstract: Population fluctuations of adult insects of pistachio twig borer, *Kermania pistaciella* Amsel were studied using delta pheromone traps and sampling from 2016-2017 in Kashan pistachio orchards. Delta type traps baited with sex pheromones were hung in pistachio orchards ('Akbari') at 20 lures per one hectare and the numbers of captured male insects were counted every three days. *Kermania pistaciella* males have begun to attract the traps from 18th March and 8th April in the first and second year, respectively and this trend continued to 31st April and 4th May and flight period of about 42 days in the first year and the second year that lasted 27 days. First, peak and end of each catch insects occurred on 18 March, 8-21 April and 31 April in the first year and on 8 March, 23-26 April and 4 May in the second year, respectively. There was no association in the first year and a weak positive association in the second year of study between the average daily temperature and the number of *K. pistaciella* moths captured in pheromone traps. It seems that moths capture was different because of the weather conditions of these orchards was different in two consecutive years.

Key words: pistachio; *Kermania pistaciella*; population fluctuations; pheromone trap; parasitoid

Sledenje fluktuacij populacije molja, zavrtača pistacijevih vejic, *Kermania pistaciella* Amsel, 1964 (Lep.: Oinophylidae), s fermonskimi pastmi

Izvleček: V raziskavi je bilo preučevano nihanje populacije odraslih zavrtačev pistacijevih vejic, *Kermania pistaciella* Amsel, s fermonskimi pastmi v rastnih sezonah 2016 in 2017 v nasadih pistacije v Kashanu, Iran. Pasti s spolnimi fermoni so bile obešene na pistacije ('Akbari'), po 20 na hektar, število ujetih samcev je bilo prešteto vsake tri dni. Samci vrste *Kermania pistaciella* so se začeli pojavljati v pasteh od 18. marca in 8. aprila v prvem in drugem letu in so se pojavljali do 31. aprila, oziroma 4. maja. Obdobje njihovega izleta je trajalo v prvem letu 42 dni, v drugem letu pa 27 dni. Prvo pojavljanje, višek in konec izleta je bilo v prvem letu 18. marca, od 8 do 21 aprila, in 31. aprila in 8. marca, od 23 do 26 aprila in 4. maja v drugem letu. Med številom ujetih moljev v fermonskih pasteh in povprečno dnevno temperaturo v prvem letu opazovanja ni bilo povezave, v drugem letu opazovanja pa je bila ta povezava rahlo pozitivna. Izgleda, da je bil ulov moljev v obeh letih različen zaradi različnih vremenskih razmer v sadovnjaku.

Ključne besede: pistacija; *Kermania pistaciella*; nihanja populacij; fermonske pasti; parazitoidi

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1 INTRODUCTION

Pistachio trees (*Pistacia vera* L.) have a lot of economic value in Iran. Pistachios are mainly planted in the eastern and central parts of Iran. In 2009, about 225,000 million tons of pistachios, about 50 % of world pistachio production, were produced in Iran (FAO, 2013). As a strategic product, pistachio has a special place in agricultural production. This product forms a major part of non-oil exports (about 40 %) (Panahi et al., 2003), which accounts for more than $ 500 million annually (Hokmabadi, 2011). Pistachio is a rich source of some important and vital nutrients, including linoleic fatty acids (Garcia et al., 1992).

The pistachio twig borer, *Kermania pistaciella* Amsel, 1964 (Lepidoptera: Oinophylidae), is an important pest of pistachio trees throughout the main pistachio-producing areas of Iran and Southeast Anatolia regions of Turkey (Mart et al., 1995; Mehrnejad, 2001; Yanik & Yücel, 2001; Abbaszadeh et al., 2006; Avand-Faghih et al., 2016). The insect has one generation per year and females lay eggs on pistachio flowers and fruit clusters in early spring. The larvae penetrate the plant tissue and bore tunnels in the twigs, feeding on xylem and pith tissues. The canals in the young wood destroy the core of branches and prevent the growth of young branches, dehydrating them (Samih et al., 2005). Larval development takes almost 10 months and the last (4^{th}) instar overwinters inside twig. Larvae leave their tunnels the following year during early March and find suitable places on twigs to form cocoons in which they pupate and, after approximately 3 weeks, emerge as adults (Küçükaslan, 1966; Mehrnejad, 2001; Achterberg & Mehrnejad, 2002; Abbaszadeh et al., 2006).

Larval feeding inside the twig causes severe economic damage by fruit drop, twig weakening, and death. Most pistachio plantations in Iran and Turkey are treated every year with insecticides to suppress *K. pistaciella* populations. Insecticides, however, pose a serious threat to the environment and are harmful to natural enemies. Therefore, insecticide applications should be used during the main periods of parasitoids' activity (Mehrnejad, 2002; Özgen et al., 2012). Toward this aim, the sex pheromone of the pistachio twig borer was identified, and it is now used in the field for monitoring activity of males and timing of the insecticidal sprays (Gries et al., 2006). The situation calls for the development of new pest control methods that would be based on more environment-friendly practices, which in turn, require better knowledge of *K. pistaciealla* biology and ecology.

Awareness of the distribution of insects and their range in a region in biological control, assessment of the potential distribution of species in the field of ecology, the development and preservation of biological resources, paleontology, invasive species of pests and diseases, assessment of the impact of environmental changes in spatial distribution has been used (Tognelli et al., 2009; Barber-mussin et al., 2012). Determining the distribution of species helps us to understand the geographical distribution and the appropriate habitat selection in the form of animal geography in order to better manage pests (Pearson et al., 2007; Tognelli et al., 2009).

Today, the study of pest population changes is one of the most important parameters that have a significant role in controlling it in each specific region with its study of the biology of pests. This plays an important role in determining the time of non-chemical control, the natural enemies releasing time, the appropriate time for using mineral compounds, the time of installation of pheromone traps etc., as well as determining the exact time of using chemical pesticides (Bassirat, 2008). Awareness of insect dispersion and its range in a region is important in biological control, evaluation of the distribution potential of species and selection of crops for cultivation (Gressitt, 1958).

Detection of pest populations, pest biology and the development of mass-trapping method for direct control of pests was used by pheromones and other attractants, practically all over the world against a wide range of pest infestations, and these methods are an essential part of pest control programs (Carde, 1990; Cronin et al., 2000; Devetak et al., 2014; Trdan et al., 2019). They can use many of the chemicals used by pest insects to communicate with each other as a tool. It was valuable to manage them (Crade, 1990). In order to increase the efficiency of pheromone traps and turn them into more accessible tools in pest control programs, factors such as shape, size, the location of the correct installation of traps and other things have been considered (Zamani et al., 2012).

Because the population of hibernating larvae of the pistachio twig borer depends on the continuity of extreme cold during the cold season (Mollaei et al., 2016), the appearance and the flight peak of the pest in different years depends on the different conditions of the region weather. Many experiments have been carried out in recent years to use the natural pheromone of *K. pistaciella* in pistachio orchards. Use of pheromone traps to estimate the population of the pest, studying the biology and behavior, the time of emergence and the flight peak, and the end of the period of insect flight in nature, investigate on the effective rate of insecticides, pest dispersion, mating disruption method and, most importantly, the mass trapping to reduce population and prevent damage in pistachio orchards (Fakhri et al., 2016). Different types of traps such as delta, funnel, colorful sticky cards, indoor tubs, cylinders, and trays of water are used. The experi-

ments show that the pistachio twig borer is not sensitive to specific colors, but delta traps, cylinders, and trays have the highest rate of capturing.

Considering the importance of this pest in pistachio orchards in Kashan region of Iran and the necessity of adopting the best method of control, it is necessary to study the population fluctuations and factors that cause these changes. Despite the importance of *K. pistaciella* as an important pest of pistachio, any information has been published on its population fluctuation using delta traps. The aim of this study was to investigate the population fluctuations of adult moths of the pistachio twig borer, *K. pistaciella* using delta traps in Kashan pistachio orchards, in order to determine the time of occurrence of flight peak and to know about the most optimal time for chemical control.

2 MATERIALS AND METHODS

2.1 STUDY SITE

This research was carried out in Isfahan province, Aran and Bidgol city, and in the Kavirat region in the pistachio orchards of Hossein Abad and Abouzid Abad towns. The city of Aran and Bidgol with an area of 6051 square kilometers has a warm and dry climate, the average rainfall of the city is 120 ml, and the depth of evapo-

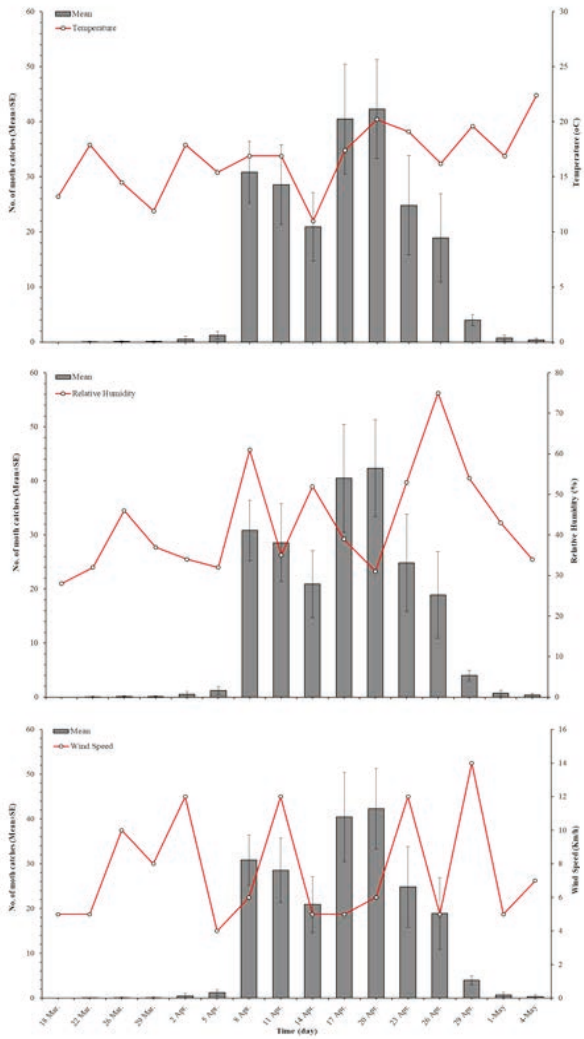

Figure 1: Population fluctuations of the pistachio twig borer, *K. pistaciella* in the pheromone traps in studied orchards in 2015-2016. The sampling dates represent the end dates of each trapping period. The solid line represents the average temperatures (°C), the relative humidity (%) and the wind speed (km h^{-1}) in each trapping interval.

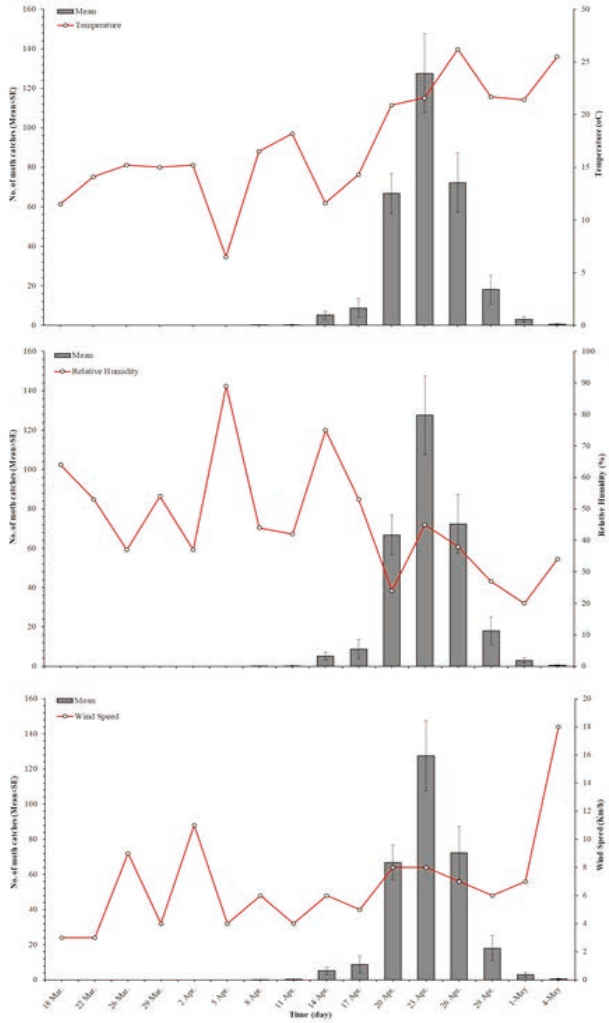

Figure 2: Population fluctuations of the pistachio twig borer, *K. pistaciella* in the pheromone traps in studied orchards in 2016-2017. The sampling dates represent the end dates of each trapping period. The solid line represents the average temperatures (°C), the relative humidity (%) and the wind speed (km h^{-1}) in each trapping interval..

ration is 2626 ml, which has also been faced with drought crisis in recent years. The geographical characteristics of pistachio orchards were with latitude 51° 38' N and longitude 33° 55' E. The age of pistachio trees was almost the same and the average age was 17 years.

For this purpose, five pistachio gardens were selected with Akbari cultivar and their geographical characteristics are as follows:

site 1: N (33° 50' 02") and E (51° 57' 09")
site 2: N (33° 53' 50") and E (51° 44' 23")
site 3: N (33° 50' 55") and E (51° 47' 04")
site 4: N (33° 55' 32") and E (51° 41' 41")
site 5: N (33° 53' 47") and E (51° 46' 48")

Weather data including average, the highest, and the lowest daily temperatures, relative humidity and wind speed were obtained from a nearby meteorological station.

2.2 PHEROMONE TRAP CATCHES

First, according to the reports of previous years, for the purpose of studying the population fluctuations, delta pheromone traps were installed on March 5, 2016, and the sampling was repeated the following year. Sex pheromone used in the experiment was provided by the Pherobank Company, Netherlands, with a concentration of one milligram of pheromone per capsule. According to previous researches, the pistachio twig borer, *K. pistaciella* is not susceptible to certain colours. Therefore, delta traps were selected from two yellow and white colours.

Twenty delta-type traps per hectare (approximately 20 meters apart) were installed in five pistachio gardens before leaf and fruit buds were opened and every three days, number of captured male insects were counted. Traps were re-baited at one-month intervals. Traps were located on the highest part of the plant at a height of one meter, approximately, and at a detected distance in the field. The captured male moths were collected and counted every three days. Traps were re-baited at one-month intervals. Pheromone traps were installed at an altitude of one meter, approximately, and on the northern side of the trees, in the exterior of the twigs to be less exposed to the wind and direct sunlight. The captured male moths were collected and counted every three days in the early hours of the day.

3 RESULTS

3.1 POPULATION FLUCTUATIONS OF ADULTS

The results of the sampling of adult insects using the pheromone trap and by counting the captured adult insects in the traps in the two years are presented in Figs 1 and 2. On the basis of population fluctuations, in the first year, the emergence period of adult insects of *K. pistaciella*, was observed for 42 days from March 29 to May 4, a false peak was occurred on the 8th of April and the true peak was observed on April 20th. In the second year, a 27 days period was observed from April 8 to May 4, and a true peak was observed on April 23rd and there was no false peak.

3.2 THE RELATIONSHIP BETWEEN TEMPERATURES, HUMIDITY AND WIND SPEED WITH POPULATION FLUCTUATIONS OF ADULTS

The difference in population changes over two consecutive years is due to instability and the difference in climate conditions and environmental factors, especially the temperature, relative humidity and wind speed of the studied gardens, as shown in Figs 1 and 2.

The correlation coefficient between number of moth's catches of *K. pistaciella* and weather parameters revealed that mean temperature (R^2 = 0.031 for 2015-16) and (R^2 = 0.143 for 2016-17) exhibited no association in the first year and a weak positive association in the second year of study.

4 DISCUSSION

Pistachio twig borer, *K. pistaciella,* male insects started to be attracted by pheromone traps in on March 22 in the first year and in the second year from April 8th.

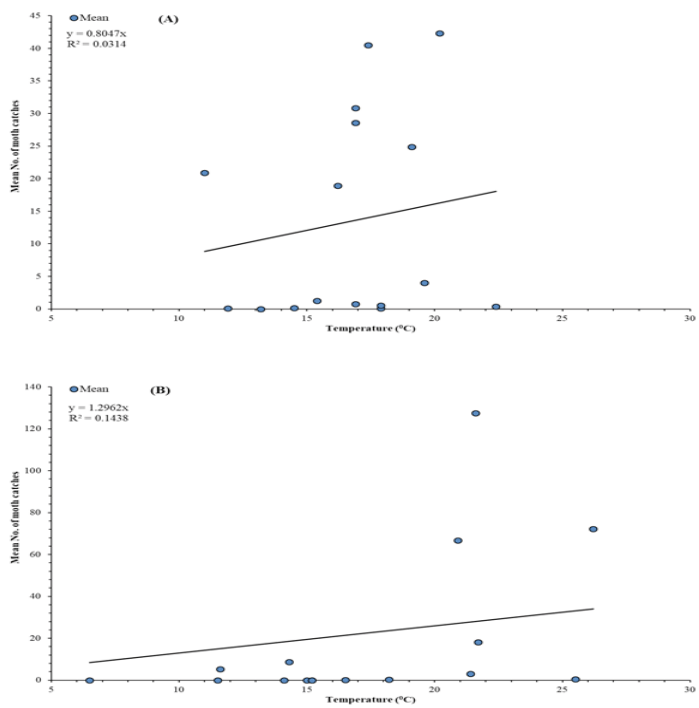

Figure 3: Scatter plot showing a positive correlation between average daily temperature (°C) and mean number of the pistachio twig borer, *K. pistaciella* adults captured in pheromone traps in in studied orchards in A) 2015-2016 and B) 2016-2017

This trend was continued in the first and second year to the fourth of May. The flight period lasted for 42 days in the first year and 24 days in the second year. It seems that these differences in population fluctuations over the two years are due to different temperature and humidity conditions. In the first year, relative humidity varied from 31-75 % and in the second year from 20-89 % and the mean temperature in the first year varied from 11-22 °C, and in the second year it varied from 11-26 °C.

Based on the results of the first capture of adult insects, the flight peaks and the end of the capturing in the first year were recorded on March 22, 8-20 April, and May 4, and in the second year of experiment they were recorded on April 8, April 23, and May 4, respectively. The results showed that the incidence of the peak of flight period of male insects in the trap varied in five different orchards. It seems that the different weather conditions of these gardens have caused this in one year and different weather conditions differently for two consecutive years.

Based on the results of Zamani et al. (2012), the first capture of adult insects, the peaks of the flight period and the end of the capturing in 2012 were recorded on April 20, May 9, and May 30, respectively. Funnel traps in comparison with Delta trap had a greater number of insects, and there was no significant difference in trapping and geographic location in attracting insects. According to Yaniki & Yildirim (2016), *K. pistaciella* males first emerged in early to mid- April, and they had a four - five week flight period in orchards of Bozova and Hilvan Counties of the Province of Sanliurfa, Turkey.

The number of insects captured in the flight peak varied in different orchards, with an average of between 4 and 153 in the first year and 27 to 330 individuals in the second year. Studies in Rafsanjan pistachio orchards (Bassirat, 2006) showed that adult emergence occurred from early April to early May and flight peak from 25 to 30 April. There is a difference in the biology of the pest in the two regions of Kashan and Rafsanjan due to differences in weather conditions of the two regions. The presence of atmospheric unstable conditions, especially in the spring, such as the sudden fall of temperature, thunder shower and sporadic rainfall, monsoon rains and even hail and no precipitation, in some years, cause the fluctuations in the population curve of adult insects and false pixels.

In another study in order to control the population of pests, the effect of shape and direction of the installation of pheromone trap in the crown of the tree and the geographical location in attracting the adult pest insects were studied. The experiment was conducted as a factorial experiment in a completely randomized design with two funnel and delta traps, two direction of north and south axis of the tree crown and three geographical regions of the pistachio orchards of Shahin-e-Shahr and Meymeh of Isfahan province. Traps were installed at 50 meters intervals with two replications. The number of captured insects per traps were counted from late March to early June on a weekly basis. Based on the results of the first adult insect capturing, the flight peaks and the end of flight period in 2012 were recorded on April 20, May 9, and May 30, respectively. In addition, funnel trap in compare to the delta trap captured more insects, and there was no significant difference in the attraction of insects to trap installation direction and trap and geographic position (Zamani et al., 2012).

Based on the previous studies conducted by Bassirat during the years of 2002-2008, the peaks numbers were observed in some years during the flight period of adults of *K. pistaciella*, so the results of the research also confirmed previous findings in this context (Bassirat, 2016). Also, based on previous research (Bassirat, 2008), if the percentage of emergence was considered as the basis for the time of the control, the peak of the appearance of insects in four years and in two regions, on average, approximately was coincided with 65 % of the emergence of adult insects. Research has shown that the use of 500 units of pheromones per hectare to disturb mating of *K. pistaciella* adult moths is more effective than chemical control. The research showed that the development of the mating disruption method to control the pistachio twig borer is more preferable in the production of healthy food and environmental protection (Avand-Faghih et al., 2016).

The current studies revealed that the weather parameters such as temperature and relative humidity has great influence on the mean numbers of Pistachio twig borer adults. The peaks of adult moths was occurred with the mean air temperature of 20 to 25ºC. According to previous studies (Bassirat, 2008), the total daily effective temperature for the peak of the appearance of insects with respect to the minimum thermal threshold is 12 ºC. Therefore, due to the effective daily temperature in the area, the time of emergence of insects can be determined and planted to control the pest. The influence of the mean daily temperature on the capture of *K. pistaciella* moths, as revealed by correlation analysis, can be explained by the fact that the temperature was close to 25 °C, which is the ideal temperature for the moths to mate (Fakhri, 2018; Abbaszadeh et al., 2006). As can be seen in Figs. 1 and 2, the mean number of *K. pistaciella* moths captured in the present study was the highest when the temperature was near 25 °C, as it was between April 17 and 23.

5 CONCLUSION

In the present study, we found positive correlations among the number of *K. pistaciella* males captured, temperature, and relative humidity. The Delta pheromone trap was efficient in capturing a large numbers of *K. pistaciella* male adults. The flight peaks and the end of the capturing in the first year were recorded on March 22, 8-20 April, and May 4, and the second year was recorded on April 8, April 23, and May 4, respectively. Also for effective management of the pest, local hanging of pheromone traps is suggested.

6 ACKNOWLEDEMENTS

The work received financial support from Postgraduate Education Bureau of the Shahed University, Iran, which is greatly appreciated.

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