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**Monitoring of an Iranian population of
Grapholita funebrana TREITSCHKE, 1835
(Lepidoptera: Tortricidae) using sex pheromone traps:
An applicable procedure for sustainable management**

**Mehrnoosh NEGAHBAN, Amin SEDARATIAN-JAHROMI,
Mojtaba GHANEE-JAHROMI & Mostafa HAGHANI**

Abstract

Plum fruit moth (PFM), *Grapholita funebrana* TREITSCHKE, 1835, is a destructive pest of Rosaceae species in different parts around the world including Iran. In the current study, population fluctuations of this pest at two major production area of Kohgiluyeh and Boyer-Ahmad province (Dehbar-Aftab and Karyak regions), Iran, was monitored using pheromone traps. Our results revealed that population fluctuations of the PFM have two peaks in Dehbar-Aftab and Karyak regions and hence, this pest has two generations at both site studies. In the first generation, first adult males in Dehbar-Aftab region were captured on April 5. At Karyak region, this event was observed 3 days later (April 8). The peak of captured adults for Dehbar-Aftab and Karyak regions was recorded on April 21 (33.33 male per trap) and April 24 (55.5 male per trap), respectively. Population fluctuations of the second generation of PFM were also revealed that the first male in Dehbar-Aftab and Karyak regions was observed on May 18 and May 19, respectively. Furthermore, the highest population at Dehbar-Aftab and Karyak regions was 27.83 and 30.75 (male per trap) on May 27 and May 29, respectively. In the second generation, population of the PFM in Dehbar-Aftab reaches its peak sooner than Karyak. Duration of time interval between two peaks of the first and second generations was lasted 37 and 36 days at Dehbar-Aftab

and Karyak regions, respectively. Although the observed difference was less noticeable, but the higher elevation above sea level at Dehbar-Aftab region could decrease the effective temperature for growth and development of the PFM and subsequently the time interval between two peaks was prolonged.

Key words: Plum fruit moth, *Grapholita funebrana*, Population fluctuations, Pheromone tarp, Kohgiluyeh and Boyer-Ahmad

Zusammenfassung

Der Pflaumenwickler *Grapholita funebrana* TREITSCHKE, 1835 ist ein weit verbreiteter Pflanzenschädling an Rosaceae Arten. Die Populationsfluktuation wurde in zwei Provinzen des Iran (Dehbar-Aftab and Karyak regions) mittels Pheromonfallen untersucht, wobei zwei Generationen festgestellt wurden. In höheren Lagen der Dehbar-Aftab Region wirkte sich die abnehmende Temperatur auf die Entwicklung des Pflaumenwicklers aus und verlängerte deutlich das Flugintervall zwischen den beiden Generationen.

Introduction

Plum fruit moth (PFM), *Grapholita funebrana* Treitschke, 1835, is a destructive species of Tortricidae family (Lepidoptera). This insect is one of the serious pests of Rosaceae species in different parts around the world (VERNON 1971; MOLINARI 1994; KOMAI 1999; BARCENAS et al. 2005). The PFM is one the invasive pests which was introduced to Iran during 1940 and restricts production of Plum orchards. The larvae of PFM feed on the fruits of *Prunus* spp., specially *Prunus domestica* (L.). Damage is due to the trophic activity of larvae in fruit. Infested fruits exhibit color changes, penetration holes made by neonate larvae, gumming at the penetration holes, exit holes made by mature larvae leaving fruits, and finally early ripening and fall (ALFORD 1988).

In Plum, the larva usually tends to move near the fruits' stone to eat. The early and intermediate instars have translucent white bodies with grayish prothoracic and anal plates. The final instars become deep pink in color and no gray pigment is on the anal plates (HOLB 2006; TIMM et al. 2008). At the end of growing season, the larva exits the fruit and overwinters in a spun hibernaculum. At this time, larval color is pale reddish yellow and a reddish dorsal line is visible.

Chemical control is the main method for combating the PFM populations in different parts around the world including Iran and unfortunately, these applications are mostly calendar base (RIOLO et al. 2010). The deleterious impacts of these chemicals on non-target organisms including beneficial insects (especially natural enemies and pollinators), their human health risks, environmental pollutions, pest resistance and resurgence are among the major problems of calendar application (FIT 2000; FATHIPOUR & SEDARATIAN 2013). However, an attitude change to manage the PFM while limiting the use of chemical pesticides is urgently

needed. Accordingly, noticeable efforts have been devoted to manage populations of the PFM using IPM programs.

In IPM programs, regular visits were performed by pest managers, called monitoring activity. These activities provide the critical information for appropriate decision making. However, as central idea in IPM programs, a treatment is only used when pest numbers justify it, not as a calendar measure (FATHIPOUR & SEDARATIAN 2013). Keeping this in view, in IPM programs, chemicals are applied only after monitoring systems detect the presence of pests in that specific region, the pest numbers have exceeded the economic/action threshold (ET/AT) and adequate control cannot be achieved with non-chemical methods. Therefore, it was discussed that monitoring activities could decrease spraying costs by withholding a spray until a given threshold is reached (NYAMBO 1982).

Different methods used for monitoring insect pest populations are the fundamental tool for the implementation of a successful pest management program (KOGAN & HERZOG 1980). An applicable sampling program includes determination of the appropriate time for sampling, selection of sampling unit, identification of spatial distribution of sampling units and sample size (SOUTHWOOD & HENDERSON 2000; SEDARATIAN et al. 2008, 2010). However, for lepidopteran pests, pheromone traps have a reliable accuracy and extensively are used in monitoring programs. Pheromone traps have high efficiency, are simple to construct, inexpensive, and portable (requiring no power). Furthermore, only the specific species is attracted and hence, counting is easy and quick. In addition to above-mentioned explanations, spring emergence of adult moths using these traps was detected 2 or 3 weeks earlier than light ones and therefore, give more precision to forecasts.

However, a review of literature revealed that there is no available information regarding population fluctuation of the PFM in different plum orchards of Iran. Accordingly, the present study was designed to monitor population fluctuations of this tortricid moth in plum orchards of Kohgiluyeh and Boyer-Ahmad province, South-west Iran. Such information could be useful for implementation of an integrated management program of PFM in Plum orchards.

Materials and methods

Experimental Sites

The experiments were performed in major production regions of Plum in Yasouj, Iran from April to June 2014. Accordingly, to monitor population fluctuations of the PFM, two site studies were determined in Karyak (30° 49' N, 51° 25' E, elevation above sea level =1774 m) and Dehbar-Aftab (30° 46' N, 51° 30' E, elevation above sea level=2060 m) villages. These regions are the most important area for production of Plum in Kohgiluyeh and Boyer-Ahmad province, Iran. To monitor population fluctuations of PFM in Karyak, a Plum orchard of 2 ha was selected. In Dehbar-Aftab village, the area of selected orchard for sampling was 3 ha. Cultural practices in selected orchards were performed by using standard recommendation for Yasouj region.

Experimental Protocols

Primary sampling was performed from overwintering shelters of the PFM such as soil and under tree barks (every 4 days). After pupation, sex pheromone traps were established. Two sex pheromone traps (Delta type produced by Zist Bani Paya Co, Iran) was applied per each ha. Accordingly, 4 and 6 sex pheromone traps was used to monitor the population fluctuations of PFM in Karyak and Dehbar-Aftab regions, respectively. These traps were checked daily and the number of captured moth was recorded. Every day, the captured moth was removed from sticky plates. In addition, these plates were replaced every 15 days. In each trap, synthetic pheromone lure of the PFM was placed (Green Universe Agriculture, Spain). These lures were also replaced every 4 weeks. The mentioned traps were founded at the 1.5 to 2 m above ground level (apical one-third of Plum tree). Furthermore, a distance of 100 m was considered among traps.

Population fluctuations and data analysis

Population density of the PFM was determined at two sampling regions in two subsequent generations. For each region, the mean density of total traps (captured moth) was calculated using Excel software and the respected graphs were drawn (Microsoft Office, 2007). Three-dimensional contour plot was drawn to display population fluctuations of the PFM over range of temperature and humidity using SigmaPlot software (SigmaPlot for Windows, Ver. 11.0). These figures could show three variables at the same time. Furthermore, to determine correlation between environmental factors (temperature and relative humidity) and population density of the PFM, SPSS software was used (SPSS, Ver. 18.0).

Results and Discussion

Over last years, high considerations were devoted to monitor pest populations using light traps. In the other hand, efficiency of these traps (pheromone and light) was compared by different researchers. Reported results indicated number of captured insects in light traps may index seasonal fluctuations of populations more accurately than pheromone ones, however, sensitivity of pheromone traps to low populations early in the season is more than light traps (ROACH 1975; NOWINSZKY et al. 2010; PUSKAS et al. 2010; NOWINSZKY et al. 2015). However, in IPM programs, pheromone traps have replaced by light ones as monitoring device. These traps have an applicable effectiveness, reliable cost and requiring no power for establishment. Furthermore, since identification of captured insects and counting is quick and easy, decision making is more reliable. In addition to these advantages, emergence of new spring population in pheromone traps was detected 2 or 3 weeks earlier than light ones and give more precision to forecasts (FATHIPOUR & SEDARATIAN 2013).

In the current study, population fluctuations of the PFM in two major regions of Plum production of Iran were evaluated using sex pheromone traps. Our results revealed that population fluctuations of the PFM have two peaks in Dehbar-Aftab and Karyak regions and hence, this pest has two generations at both site studies (Figure 1). However, the PFM is the key pest of Plum in different parts around the world. The performed study by MOLINARI

(1994) in Italy, revealed that this pest has 3 generations per year. In addition, in central and eastern parts of Europe, it has 1 or 2 generations per year (VERNON 1971).

According to figure 1, first adult males in Dehbar-Aftab were captured on April 5. At Karyak region, this event was observed 3 days later (April 8). These curves revealed that population density schedule of the PFM fluctuated throughout the season and showing an asymmetrical pattern. The peak of captured adults for Dehbar-Aftab and Karyak regions was recorded on April 21 (33.33 males per trap) and April 24 (55.5 males per trap), respectively. However, the population density of the PFM has a higher peak at Karyak than Dehbar-Aftab (Fig. 1).

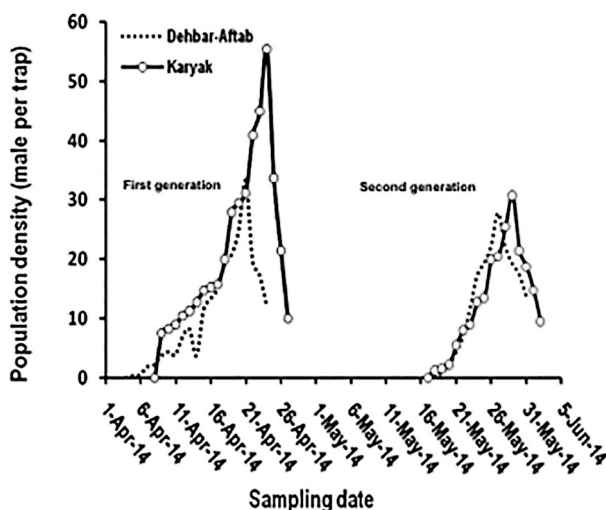


Fig. 1. Population fluctuations of the first and second generations of *Grapholita funebrana* in Dehbar-Aftab and Karyak during 2014

Population fluctuations of the second generation of PFM were also presented in figure 1 at two sampled regions. The first male in Dehbar-Aftab and Karyak was observed on May 18 and May 19, respectively. Furthermore, the highest population at Dehbar-Aftab and Karyak regions was 27.83 and 30.75 (males per trap) on May 27 and May 29, respectively. As the first generation, in this generation, population of PFM in Dehbar-Aftab reaches its peak sooner than Karyak.

Although a reliable threshold in monitoring programs of insect pest populations could be achieved by egg count, but biasing data (e.g. egg desiccation, egg infertility, egg parasitism and etc.) together with skill needed for field scouting, resulted weak correlations between recorded egg number and larval damage (VAN HAMBURG 1981). Furthermore, it has been proved that fruit inspection in the field is a valuable tool when developed against a number of fruit eating insects (ZALOM et al. 1986). Accordingly, regarding short time between plant scouting for larval injury and fruit damage, correlation between both of these variables

could increase. However, TORRES-VILAA et al. (2003) stated that decision making based on fruit-count may also be easily learned and performed by growers.

According to figure 1, duration of time interval between two peaks of the first and second generations was lasted 37 and 36 days at Dehbar-Aftab and Karyak, respectively. These observations revealed that the PFM could complete its life span in the same time interval at two mentioned regions. However, observed differences could be explained regarding higher elevation of the Dehbar-Aftab. Although the observed difference was less noticeable, but the higher elevation above sea level at Dehbar-Aftab could decrease the effective temperature for growth and development of the PFM and subsequently, the time interval between two peaks was prolonged.

Figures 2 and 3 present a three-dimensional contour plot of the predicted population density of the PFM over a wide range of environmental factors. Accordingly, temperature and humidity could affect population density of the PFM. Furthermore, to quantify relationship between temperature/humidity and population density of the PFM, a correlation analysis was performed and respected results were presented in table 1.

According to correlation analysis, relationship between humidity and population density of the PFM was statistically significant (Table 1). Furthermore, this significant correlation was negative in all cases and therefore, converse relationship was determined between these variables. In the case of temperature, with one exception (first generation in Dehbar-Aftab), the observed relationship was significant and a positive correlation was detected (Table 1). These results revealed that temperature had a direct effect on the population fluctuations of PFM. However, temperature has a obvious effect on population of insect pests (JERVIS & COPLAND 1996) and in previous studies direct effects of temperature on population density of other arthropods was reported (RAHMANI et al. 2010).

In the current research, population fluctuations of the PFM were monitored by sex pheromone tarps. However, we must now determine whether these pheromone traps are going to be of practical values in management programs of the PFM. Therefore, there is first a need to standardize trap application (trap design, pheromone dosage and its release rate, establishment of the traps and etc.). As the next step, ability of these tarps for insect capture should be compared with other measures of the PFM populations (light traps and actual counts of damaged fruits). However, some studies in the USA revealed that recorded data in pheromone traps have been used in prediction models and could provide useful information for controlling insect pest infestations (NYAMBO 1982).

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Authors' addresses:

M.Sc. Mehrmoosh NEGAHBAN

Assist. Prof. Amin SEDARATIAN-JAHROMI*

Assist. Prof. Mojtaba GHANE-JAHROMI

Associate. Prof. Mostafa HAGHANI

Agricultural Entomology, Department of Plant Protection,
Faculty of Agriculture, Yasouj University, Yasouj, Iran

*Corresponding author: Sedaratian@yu.ac.ir & Sedaratian@gmail.com

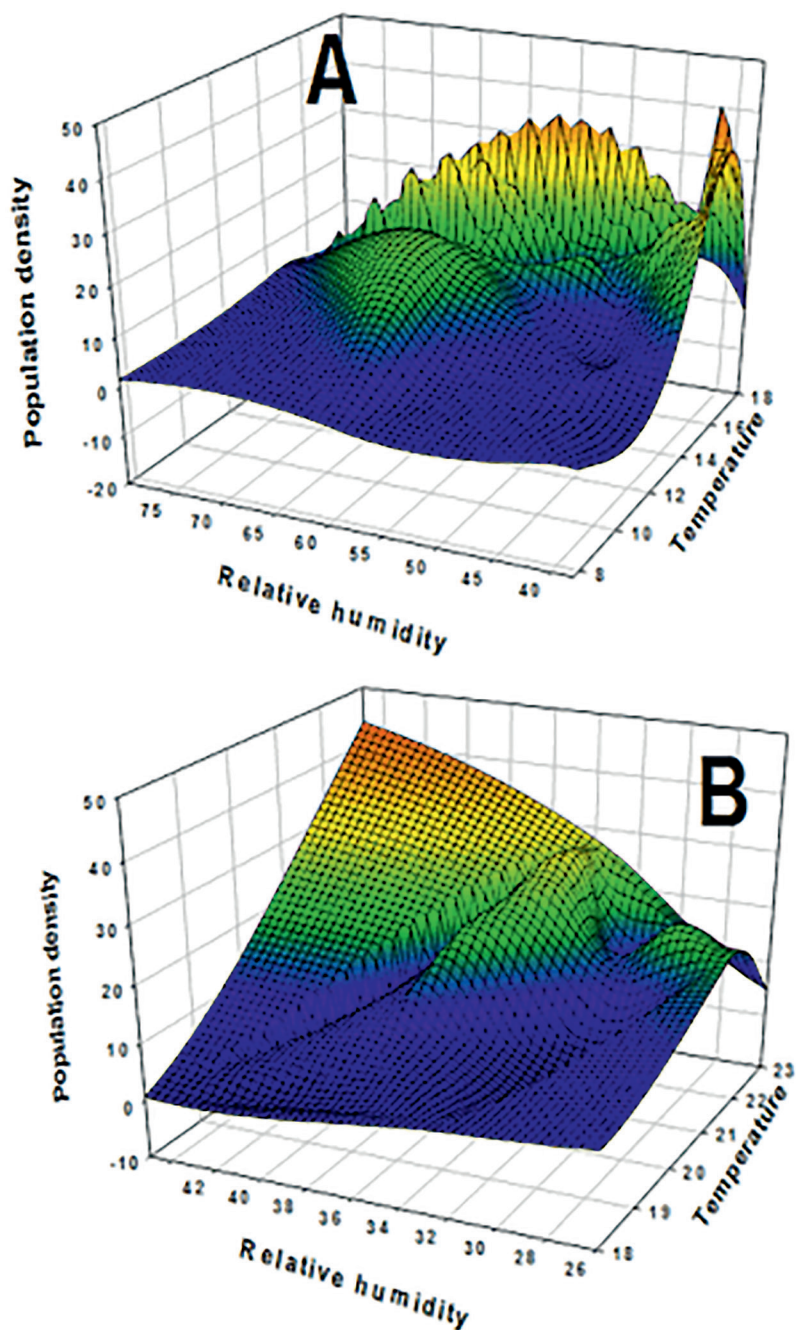


Fig. 2. Three-dimensional contour plot showing the temperature and humidity effects on population density of the first (A) and (B) second generations of *Grapholita funebrana* in Dehbar-Aftab during 2014

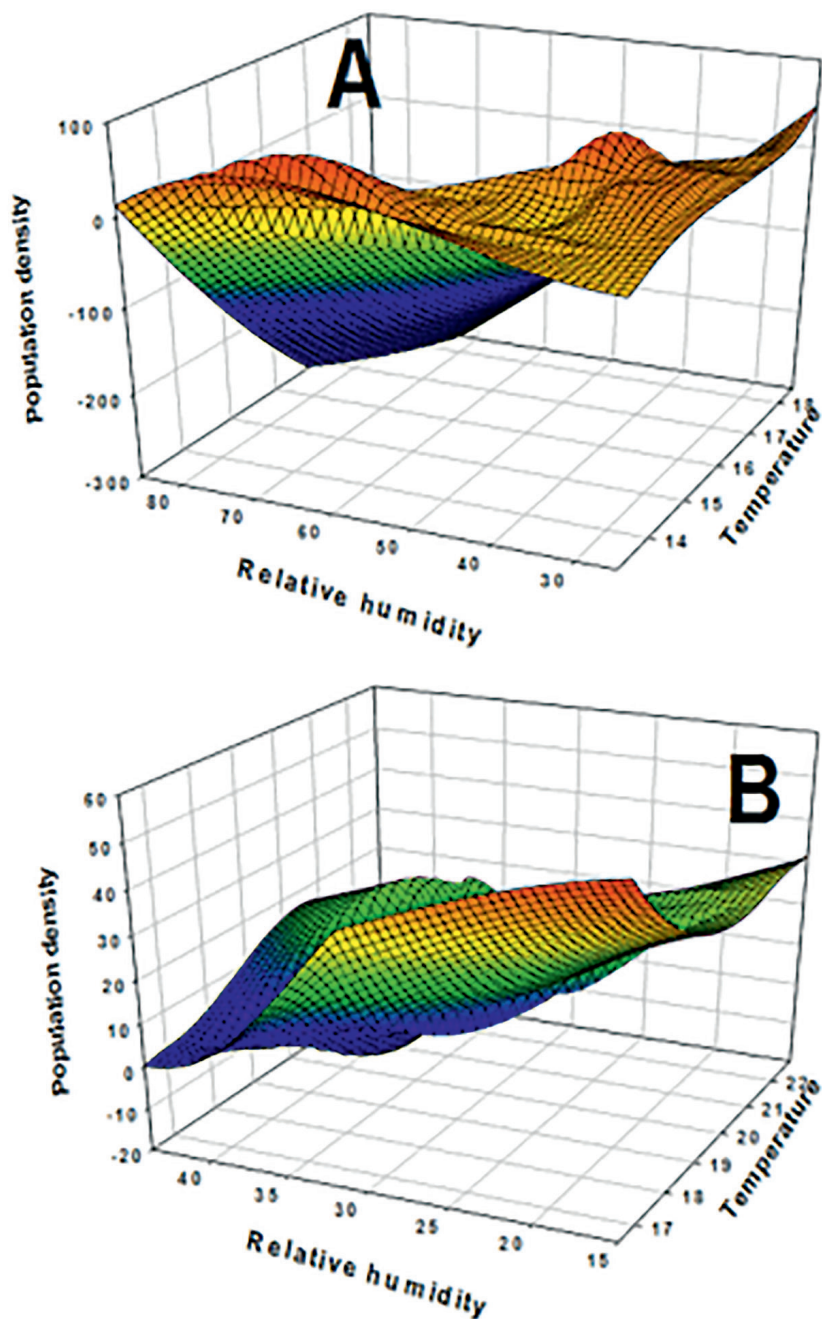


Fig. 3. Three-dimensional contour plot showing the temperature and humidity effects on population density of the first (A) and (B) second generations of *Grapholita funebrana* in Karyak during 2014

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Maximilian SCHWARZ, Konsulent f. Wissenschaft der Oberösterreichischen Landesregierung, Eibenweg 6,
A-4052 Anselden, Austria; maximilian.schwarz@liwest.at.

Redaktion: Fritz GUSENLEITNER, Biologiezentrum Linz, f.gusenleitner@landesmuseum.at;
Roland GERSTMEIER, Lehrstuhl f. Zoologie, TU München, gerstmei@wzw.tum.de;
Thomas WITT, Tengstraße 33, D-80796 München, thomas@witt-thomas.com
Berthold CLEWING, Akademischer Verlag München, avm@druckmedien.de;
Harald SULAK, Museum Witt München, h.sulak@atelier-sulak.de;

Mitarbeiter: Karin TRAXLER, Biologiezentrum Linz, bio.redaktion@landesmuseum.at;
Heike REICHERT, Museum Witt München, heike_reichert66@web.de;
Erich DILLER, Zool. Staatssammlung München, Erich.Diller@zsm.mwn.de.

Adresse: Entomofauna, Redaktion und Schriftentausch Thomas WITT, c/o Museum Witt München,
Tengstr. 33, 80796 München, Deutschland, thomas@witt-thomas.com;
Entomofauna, Redaktion c/o Fritz GUSENLEITNER, Lungitzerstr. 51, 4222 St. Georgen/Gusen,
Austria, f.gusenleitner@landesmuseum.at.

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