Original Contribution

EFFECT OF LARVAL DIET ON FEMALES' ATTRACTION OF *ECTOMYELOIS CERATONIAE* ZELLER (LEPIDOPTERA: PYRALIDAE) IN PHEROMONE TRAPS

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ABSTRACT

Purpose: Feed resources for larval development act on attractive ability of *Ectomyelois ceratoniae* Zeller (Lepidoptera: Pyralidae) females. Its sex pheromone components are synthesized but due low stability not acceptable to recommend for pest control. As alternative method, the reared virgin female moths are suggested for baiting in pheromone traps. To aim this purpose we conducted this research.

Method: The female moths were reared on dietary treatments including fruits of pomegranates and figs and semi-artificial diet in the laboratory. The traps were used for nine days on sunset in the pomegranate and fig orchards. By next morning, the captured moths by the traps were collected and counted.

Results: The results confirmed that different treatments attracted different number of moths significantly. In pomegranate and fig orchards, means of captured moths by the traps baited with the reared females on pomegranate and fig fruits were more than other treatments, respectively. In both orchards, the reared females on semi-artificial diet captured less compare to two treatments. The interactions between treatments and orchards were significant different.

Conclusion: We reported the efficiency of feeding supply during the larval period for sex pheromone production and their ability to attract moths of *E. ceratoniae* in the orchards.

Key words: pomegranate, fig, host plant, carb moth, semi-artificial diet, sex pheromone

INTRODUCTION

Pomegranate (*Punica granatum* L., Punicaceae) is native to Iran and some surrounding areas. Iran is one of the best-known countries with a large production of pomegranate. Pomegranate export and consumption of fresh fruits and processed products such as juice, puree, etc. play a direct effect on economic growth of country. Low numbers of pests are found on pomegranate trees in comparison with other fruit trees (1, 2). Among them, the pomegranate fruit moth (or the carob moth) *Ectomyelois Ceratoniae* Zeller (Lepidopter: Pyralidae) as a major pest of pomegranate orchards is efficiently controlled by sex pheromone traps (3, 4).

Insect sex pheromones as a well-known part of integrated pest management (IPM) have been contributed since 1970s (5, 6). Calling behavior using Lepidopteran sex pheromones greatly use to monitor the seasonal density fluctuations, timing of insecticide spray and

presence of invasive moth species like *E. ceratoniae*. (7, 8, 9). A variety of large to small molecules like aliphatic molecules to cyclic monoterpenoids are detected in insect sex pheromones (5).

The traps baited with female sex lures detect a pest species by attracting the male. Then male caught in the sticky surface in the trap (10). The traps with synthetic or natural sex pheromone lures require virgin females, which could be reared in laboratory or collected in the infected orchards. The traps baited by natural sex pheromone of virgin female attract a mate rather than synthetic sex pheromones (7, 11).

Mass trapping baited by sex pheromones integrate with other control methods of pests successfully by very strong attractants for species-specific male moths (5, 12, 13, 14). Researchers have synthesized and identify sex pheromones from different species of moths such as *Amyelois transitiella* (Pyralidae, (15)), *Andraca bipunctata* (Bombycidae, (16)), and *Grapholita molesta* (Tortricidae, (17)).

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In Pyralidae family, chemical structures of sex pheromones are too close together and their purification is difficult (18). The major component of sex pheromone in *E. ceratoniae* was identified as (Z, E)-9, 11, 13-tetradecatrienal (18). Low durability and stability (approximately 4 hours) of synthetic sex pheromone of *E. ceratoniae* is due to its specific structure in normal conditions. So to track the pyralid moths during their activities in orchards, the virgin female moths use to produce natural sex pheromone as bait in the traps. Young virgin females, who emerge from the last larval instar, are known as valuable sources of natural sex pheromones. Because of some difficulties such as storage fresh fruits and their spoil and rancidity, it is preferred to rear the virgin females of the carob moth on artificial diets and then release as emitting sources of natural sex pheromones on traps.

The carob moth is reported as a polyphagous pest with a variety of host plants. Complex sex pheromone-host plant odors are coded in the insect male antennal lobe and the olfactory center of its brain (19, 20, 21). Overlapping sex pheromone components and host plant association (20, 21, 22) led us to investigate effect of larval diet for attraction females of *E. ceratoniae* who reared on different diets in laboratory. Then we scrutinized efficiency of virgin females baited in hanging traps in pomegranate and fig orchards. We aimed to answer research questions by following: "Do larval food influence on the amount and type of pheromone produced by moth female?". If yes, "May the female moths reared on the other laboratory plant hosts be used in the pomegranate orchards?" and "Do the reared females in the laboratory attract less number of males rather than the collected females in nature?"

MATERIALS AND METHODS

1. Insect sampling and rearing

During winter, the research pomegranate orchard (N 31° 54' 54.84'', E 54° 16' 38.19'') in Center of Agriculture and Natural Resources of Yazd (Yazd-Iran) were daily visited and then infested pomegranate fruits by carob moth larvae and pupae were collected. The infested pomegranate fruits were transferred to laboratory then carefully split and larvae at different instars and pupae isolated. Larvae completed their development inside plastic container (18×13×1.5 cm) on seeds and small pieces of pomegranate fruit. The pupas were separately transferred into different container. Average number of collected larvae or pupa varied depending on number of collected pomegranate fruits and

intensity of moth infection. The rearing containers were kept under controlled condition (30± 2 °C, 75 ± 5% RH, and 16:8 L:D photoperiod) in the rearing room. The containers were daily surveyed and fresh pomegranate slices added to feed larvae during their development.

As second treatment like moth sampling of pomegranate, infested fig fruits by *E. ceratoniae* were collected from a fig orchard 200 meters away from the studied pomegranate orchard (Yazd, Iran). As third treatment, the carob moth larvae were also reared on artificial diet containing wheat flour 72%, honey 12%, glycerin 10%, yeast (green life, Belgium) 1% and distilled water 5%.

After first step of rearing, the emergent young female and male moths were collected from each treatment separately and were shifted to the mating cages. After mating, the females were transferred into the rearing containers and then eggs were obtained from females. The eggs were incubated and after hatching, carob moth larvae were transferred to the treatments in the described rearing conditions previously. Before eclosion, female pupae were individually placed in cylindrical plastic transparent cages, which its tops were covered with moist gauze. Then cylindrical plastic transparent cages were held at the described conditions to allow the pupae to mature. Upon emergence, virgin females were provided with treatments separately and placed in rearing containers.

2. Field Experiments

The traps were made of U-PVC pipes (length 25cm and diameter 11cm). Interior surface of U-PVC pipe was coated with a sticky transparent paper. A pair of virgin females was transferred to perforated cylinders (4×6 cm) at both top and down sides. This cylinder as a source of natural sex pheromone was kept hanging inside U-PVC pipe upwards. The traps were inserted between rows of trees; 1.5 meters above the ground in the studied orchards. At least 30 meters distance was estimated between the traps. By next day, the numbers of captured moths in the traps were counted. The field experiments were carried out for a period of nine days with three replications. Treatments were included the virgin females as source of natural sex pheromone who were reared on pomegranate fruits, fig fruits and artificial diet separately.

3. Data Analysis

Mean numbers of captured moths per day in different treatments baited in the traps were analyzed using MINITAB software (general

linear model). Experimental treatments were classified by Tukey test ($\alpha=5\%$). Statistical t-Student tests have been used to evaluate obtained results and to test whether differences among means of captured moths in the traps were significant. Results were verified using t-Student statistical tests.

RESULTS

1. Total number of captured moths

The results showed that the traps captured 1563 male moths during a period of nine days. Morphologic characters and shape of moth genitalia confirmed that all trapped moths were *E. ceratoniae* from Pyralidae family.

Our results showed that out of total captured moths by the traps, 841 and 722 moths were

captured in pomegranate and fig orchards, respectively. Analysis of variance confirmed that there were no significant differentiations between them ($F:(1.17)=0.00, P>0.01$).

2. Mean of daily captured moths in pomegranate orchard

Analysis of variance of the captured moths per day showed that there were no significant differences between replications ($F:(2.8)=6.16, P>0.01$). However, significant differences were observed between treatments ($F:(2.8)=71.63, P<0.01$). Means of the captured moths in the traps baited by reared females on pomegranate fruits were higher than those reared on fig fruits and semi-artificial diet do (**Figure 1**).

Figure 1. Mean of daily captured moths in pomegranate orchard.

Treatment 1, 2, and 3 are the traps with female moths that were reared on fig fruits, pomegranate fruits, and semi-artificial diet under laboratory condition, respectively. Statistical differences have been done between treatments and marked by different letters ($p<0.05$).

Furthermore, no significant differences were found between mean number of captured moths in traps baited by reared females on fig fruits, and semi-artificial diet (**Figure 1**).

3. Mean of daily captured moth in fig orchard

Variance of the mean of daily captured moths in fig orchard showed no significant differences between replications ($F(2.8)=0.87, P>0.01$) and between treatments ($F(2.8)=1.01, P>0.01$). In fig orchard, the means of captured moths by the reared females on fig fruits were higher than by the reared females on pomegranate fruits but there were no significant differences between them. Moreover, the mean of captured moths by the reared females on fig fruits was significantly higher than in comparison to those reared on the semi-artificial diet (**Figure 2**).

Figure 3 shows the mean of the captured moths in the traps with the same baits in the studied orchards. As can be seen from the

figure, the host plant influence on the amount of produced pheromone by treatments. For example, on the first day, the reared females on pomegranate fruits captured maximum numbers of male moths in the both orchard, while the females who were reared on the semi-artificial diet captured minimum numbers of moths in the traps hanging in the orchards.

Figure 3 illustrates mean of captured moths by the reared females on pomegranate fruits in both orchards which was higher in pomegranate orchard (lines A, D in Figure 3) than fig one. The maximum number of moths was captured between third and fourth days after hanging the traps in pomegranate and fig orchards. Sharply after hanging the traps baited with reared females on pomegranate fruits captured more moths in fig orchards versus same traps in pomegranate one (Figure 3). In pomegranate orchard between first and second day, the reared females on pomegranate fruits started capturing the more

moths compare to those in fig orchard. However, both curves showed a

synchronization and coordination for capturing of moths after the pick (day 3 and 4).

Figure 2. Mean of daily captured moths in fig orchard.

Treatment 1, 2, and 3 are the traps with female moths that were reared on fig fruits, pomegranate fruits, and semi-artificial diet under laboratory condition, respectively. Statistical differences have been done between treatments and marked by different letters ($p < 0.05$).

Figure 3. Mean of daily captured moths in fig orchard.

A, B, C: The traps with the reared females on *pomegranate fruits*, *fig fruits* and *semi-artificial diet* in the **pomegranate orchard**, respectively.

D, E, F: The traps with the reared females on *pomegranate fruits*, *fig fruits* and *semi-artificial diet* in the **fig orchard**, respectively.

In fig orchard, numbers of captured moths in the traps baited by the reared females on fig fruits were sharply more versus those were captured in pomegranate orchard (lines E and B in Figure 3). In addition, on same host orchard means of captured moths were higher than pomegranate orchard. Both curves showed a positive correlation until reaching to maximum pick of mean (between sixth and seventh days, **Figure 3**) then reduction in moth capturing was observed in both orchards.

In general, the traps baited with reared females on semi-artificial diet captured less numbers of moths in both orchards compare to other

treatments (lines C and F, Figure 3). Nevertheless, the effectiveness of these traps in fig orchard were higher than pomegranate one. Maximum capturing was observed between day 5 and 6 in fig orchard.

4. Interaction between orchard and treatment

As shown in Figure 4, the interaction between the orchard and treatment showed a significant variation ($F(2.17) = 7.68$, $P < 0.01$). Mean of captured moths by females who reared on pomegranate fruits in same orchard were more significant than means of this treatment in the fig orchard. No significant differences were

observed between traps baited with reared females on pomegranate fruits as well as those reared on fig fruits in fig orchard. However, reared females on fig fruits captured more moths in same orchard versus pomegranate

orchard. Mean number of captured moths on semi-artificial diet showed no significant difference (**Figure 4**). The results were confirmed using t-Student tests ($\alpha=5\%$).

Figure 4. Mean of daily captured moths between pomegranate and fig orchards. Statistical differences have been done between treatments and marked by different letters ($p<0.05$).

DISCUSSION

Lepidoptera is the most well-known insects who emit sex pheromones to attract males over long distance (23). Sex pheromones in mating are known as undeniable compounds in survival of generation, and increasing insect population. A successful mating disruption by species-specific sex pheromones is applied to control moth populations in orchards (24). By releasing high quantities of female sex pheromones, mating disruption occurs and affecting in search behavior of males to find the females for mating (24, 25). As a part of IPM programs, mating disruption can be associated with other methods of pest controls in orchards (24).

Effects of plant volatiles on insect sex pheromone were studied on several phytophagous moth species including *Helicoverpa zea* (26) and *Cydia pomonella* (26, 27), *Spodoptera exigua* (28), *Ostrinia nubilalis* (29), *Eupoecilia ambiguella* (30), *Grapholita molesta* (31), and *Lobesia botrana* (32). It is reported that exposed males of *Spodoptera littoralis* to the plant volatiles (including geraniol or linalool) increase their response to sex pheromone (33).

Sex pheromone traps effectively capture lepidopteron pests especially *E. ceratoniae* which is known as major pest of pomegranate orchards in Iran. Traps baited with females might be as alternative to capture more moths versus synthetic pheromones, which have low durability in the nature. Our results demonstrated that the reared females on pomegranate fruits attracted the male moths in

pomegranate orchard effectively in comparison to the reared females on fig fruits or semi-artificial diet. This finding could be as special influence of host plant (pomegranate) on pheromone production and there is a probability to develop specific compounds that attract the males to the reared females on pomegranate solely. It can be said that the pheromone constituents in both female populations (reared on pomegranate and fig fruits) effect on male capturing by traps. This result was in consisting with the finding of (29) on *O. nubilalis* (Lepidoptera: Crambidae). Some pests (especially moths) as alternative to their sex pheromone analogues, or pre-sex pheromone compounds (34) could utilize host plant allelochemicals. In some cases, presence of plant allelochemicals could significantly increase the production and release of insect sex pheromones (35, 36). Plant volatile may be used by insects to enhance sex pheromones (37) as well as to regulate or mediate sexual communication as sexual kairomones in mating (34, 38, 39, 40).

In both orchards, maximum number of moth capturing by the traps baited with females who were reared on pomegranate fruits happened in day 3 and 4. That time could be interpreted as the best time to outbreak second or third generation of *E. ceratoniae* in pomegranate orchard, which would be as destructive stage of this pest. Therefore, there is a possibility for applying sex pheromone traps during the pick of moth activity to predict egg hatching and release dates of *Trichogramma*. Considering to *E. ceratoniae* sex ratio that is predicted an

equal number of female-producing and male-producing within populations as 1:1. So by estimation the number of males, the total numbers of population would be estimated and then the number of captured moths by traps may be applied as pest damage indicator.

In the current study, females who were reared on the fig fruits or semi-artificial diet as pheromone source attracted less number of male moths in the orchards. Hence, the food source during larval period probably plays an important role in production, biosynthesis, constituents and diffusion of sex pheromone (11, 29).

The findings provide an obvious understanding of correlation between host plants and pheromone phenotype, which may influence on some relations including moth emergent and host plant phenology; amount of mortality of pheromone strains on the moths which are active on different host plants and finally host plant choosing by female moths for feeding and oviposition strategies (41).

In *E. ceratoniae*, polyphagy has been known although it is enigma whether this pest is intrinsic-polyphagous (feed on different host plants) or pseudo-polyphagous (different biotypes of pest that feed on a range of host plants). Prior studies (unpublished) showed traps baited with natural pheromone captured no male moths and no larval infections were observed in fig orchard in early season (before August). Nevertheless, in the middle of season, oviposition and larval emergence were observed in the fig orchard. Unlike that study, in our research, the traps baited by the reared females on pomegranate or fig fruits in the laboratory, captured the males in both orchards. Probably absence of moth at the beginning of the season on fig fruits is related to quality of fig fruits and interaction effects of orchard, which are needed future researches.

CONCLUSION

The host-plant chemical cues and the moth sex pheromone often play important influence on the sexual behavior of herbivorous insects. This research was conducted to appreciate the effects of host plants on female attracting. In summary, we found that food source during larval period effect on amount of pheromone and attracting of female moths that were used as natural sources of sex pheromone. Our results confirmed the maximum number of captured moths in each host plant by the traps baited with the reared females on the fruits. Hence, it is valuable to utilize the females who were reared on same host plants in laboratory. Finally, we found that attractive ability of the

reared females on diets in laboratory were stronger than the collected female moths in the orchards. Comprehensive studies are needed to understand the actual relation between host plant cues and role of phytochemical compounds to produce or release insect sex pheromones.

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