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Levent Efil
Department of Plant Protection, Faculty of Agriculture, Bingöl University, 12000 Bingöl/Turkey

Okan Özgür
Biological Control Research Station, Adana/Turkey, 01321

Figen Efil
General Directorate of Food and Control, Ministry of Food, Agriculture and Livestock, 06060 Ankara/Turkey

Correspondence:
Levent Efil
Department of Plant Protection, Faculty of Agriculture, Bingöl University, 12000 Bingöl/Turkey

A new pest, *Duponchelia fovealis* Zeller, on strawberries in Turkey – damage, distribution and parazitoid

Levent EFİL, Okan ÖZGÜR, Figen EFİL

Abstract
Our study was conducted in the Turkish provinces of Adana and Mersin during 2011 and 2012, and represents the first study to report the presence, damage, distribution and parasitoid of *Duponchelia fovealis* Zeller as a pest of strawberries in Turkey. *D. fovealis* was determined to overwinter in larval stages and to morph into adult moths in mid-March. Larvae hatched from eggs deposited on mulching material and near plant roots in soil, causing damage due to feeding activity on plant stems, young leaves, and fruit. At the maximum, larval abundance was 58.33 individuals per ten plants. Despite an abundant number of larvae, fruits were not directly impacted by feeding activities; however, damaged fruit rotted. All of the areas surveyed were found to be infested by *D. fovealis* larvae. As a natural enemy of the pest, *Campoletis rapax* (Gravenhorst, 1829) was found to be the parasitoid present in larvae plus pupae. *D. fovealis* hosted *C. rapax* and *C. rapax* was recorded as the first species to parasitize in the literature and its presence is a first record for Turkish fauna. The parasitization level increased as the season ended, reaching a value of 26.68%. The pest was determined to be dispersed throughout strawberry growing areas. Since damage may increase in the future, the pest must be closely monitored.

Keywords: *Duponchelia fovealis*, *Campoletis rapax*, strawberry, distribution.

1. Introduction
Duponchelia fovealis Zeller is a polyphagous pest [1], first identified in Italy in 1988 and then in continental Europe. In 2006, it was reported to be present on ornamental plants [2], and in 2010 to cause extensive damage to strawberries [1]. *D. fovealis* was identified in the Netherlands in 1992 [3] and quickly spread to a large area causing serious damage to ornamental plants [4]. Its presence was [5]reported in 1998 [5], then, in the Crocova Region of Poland in 2006 [6], and in Warsaw in 2012. *D. fovealis* was first documented in France in 2010 and is reported to have caused heavy damage to strawberry fields [7]. The latest infection reported was in Bulgaria [8]. When *D. fovealis* was identified in Canada in 2005, an eradication program was developed [9]. Likewise, when first detected in the United States (US) in 2004, an eradication program began. However, *D. fovealis* reappeared in 2010 and was given quarantinable pest status [10]. Although initially considered an exotic pest, later predictions indicated that *D. fovealis* was a high risk to US crops [11].
As a result of rapid spreading and damage status, previous studies have suggested that *D. fovealis* may have the potential to be an invasive pest species. In Turkey, its presence has been mentioned as one of the species of the family Pyralidae [12], with its damage status first reported for peanuts [13]. The objective of our study was to determine the pest status of *D. fovealis* within strawberry production areas of the eastern Mediterranean region of Turkey.

2. Materials and Methods
Our study was performed in greenhouses and in open fields within the Turkish provinces of Adana and Mersin; location for the majority of strawberry production during 2011 and 2012. Mersin have majority strawberry production areas in Turkey, so study was performed large areas in Mersin. There are small strawberry production areas in Adana, study was performed in these small areas.

2.1. Pest behaviors and damage status

Our study began in November (2011) by determining overwintering stages and sites for the pest. Following harvest, strawberry fields were periodically visited in order to examine the various biological stages of pests on strawberry plants, additional types of plants, and masses of field-removed strawberry plants surrounding fields and greenhouses.

To monitor adult flight time, pheromone traps were installed. Two traps were installed in 2011 - one in Adana and the other in Silifke, Mersin. Five pheromone traps were installed in Silifke during 2012. Due to a shipment delay in 2011, traps were installed in April. In 2012, all traps were installed in January. Pheromone capsules were changed every four weeks while bottom bowls were changed as necessary. Mature flights were monitored for 12 months. Once the first adult was captured in traps in 2011 and 2012, we began collecting data in three greenhouses located in Adana and four fields located in Silifke. In each greenhouse and field, and in three different locations, ten strawberry plants occupying a single row were examined at the roots, near the root area, on stems, on fruits, and on the entire portion of the above-ground plant. Therefore, egg deposition locations, larvae damaged plant parts, damage types, larvae infestation per plant, and pupa forming sites were recorded.

2.2. Parasitization rates

Each week during the study, field collected larvae were brought to the laboratory in plastic vials and placed in a culturing room with a relative humidity of 65 ± 5, a 16:6 h light regime, and a temperature of 27 ± 1 ^{0}C. Each larva was cultured in 6 cm petri dishes containing a dump drying-filter paper disk. Larvae were fed daily with fresh begonia leaves. Pupa forming and parasitoid emerged *D. fovealis* larvae were recorded according to the date and collection region.

2.3. The distribution area

We surveyed 15 fields located within the province of Adana and 73 fields located within the province of Mersin during 2011 and 2012. During surveys, a field was designated as infested when a single larva was detected.

3. Results

3.1. Pest behaviors and damage status

During the months of January and February, the larvae of *D. fovealis* were found. However, no eggs and/or pupae were detected. Most overwintering larvae were found near the root region of strawberry plants left in the field (Figure 1) and in field-removed plant masses located near fields (Figure 2). In 2011, pheromone traps were installed. Due to a shipment delay, the first adults were captured on 18 April 2011. As recorded in July 2011, the highest number of moth flights was 122 individuals. Adult flights decreased when the strawberry season ended; no flight was recorded after 10 November 2011 (Figure 3).

In Adana, pheromone traps were installed during January 2012. The first adult flight was detected in greenhouses on 20 March 2012 and in fields on 29 March 2012. Mature flights reached the highest number (45 individuals) on 12 April 2012 and no flights were detected after 14 June2012 until 25 September 2012. In open fields, adult flights reached the highest number (64 individuals) on 5 May 2012 and no adult flights were recorded after 16 July 2012 until 25 September 2012 (Figure 4).

In Silifke, a total of five pheromone traps were installed - one in a greenhouse and the other four in open fields. The first adult flight was detected on 14 March 2012 in the greenhouse pheromone trap as well as the number one open field trap located 500 m from greenhouses. Other traps captured the first adults on 28 March 2012. The highest numbers of adults (105) were captured by a trap located in the greenhouse on 13 June 2012, while open field traps captured 101 individuals on 23 May 2012. Seventy-three individuals were captured on 11 May 2012, 113 individuals were captured on 4 May 2012, and 101 individuals were captured on 23 May 2012 (Figure 5). Adults deposit eggs on dried leaves near the stem and on the surface of mulching plastics (Figure 6). Once hatched from eggs, larvae begin to feed on fresh tissues located on the inner side of the plant near the soil root region. Larvae were then observed feeding on the outer portion of leaves where they connected to the stem. Older instar stages fed on the tips of the inner young leaves of seedlings causing them to dry (Figure 7). Late instars preferred ripened fruit over un-ripened fruit. Late instar larvae were found to feed on the ripened fruit's upper surfaces, making 1-2 mm deep cavities and leaving their dark feces near their feeding area. We observed that larvae partially fed on the fruit; leaving the majority undamaged (Figure 8), and caused the damaged fruit to rot (Figure 9). In Adana, no damaged fruit was recorded during 2011, while 28 damaged fruits were determined during 2012. In Silifke, 115 damaged fruits were determined in 2012. During the study, 720 plant samples were examined in Adana and 840 plant samples were examined in Silifke. When damaged plants were evaluated based on total fruit number, damaged fruit was a small proportion.

In Adana province, larvae numbers were first counted on 10 May 2011 as 2.66 individuals per ten plants in greenhouse one, three individuals per ten plants in greenhouse two, and two individuals per ten plants in greenhouse three. On 22 May 2011, the number of larvae was determined to be 2.66 individuals per ten plants and 6.33 individuals per ten plants in greenhouses one and two, respectively; and 5.33 individuals per ten plants in greenhouse three on 30 May 2011. No larvae were detected after 11 July 2011 (Table 1).

In Adana on 5 May 2012, the first encountered larvae numbers were, as follows: 1.66 individuals per ten greenhouse plants in greenhouse one, one individual per ten plants in greenhouse two, and 2.33 individuals per ten plants in greenhouse three. In greenhouses one, two, and three on 25 May 2012, the highest numbers of larvae were 20.66 individuals per ten plants, 23.66 individuals per ten plants, and 18.33 individuals per ten plants, respectively (Table 1).

During 2012, studies were conducted in four open fields located in Silifke in Mersin province. The first larvae numbers recorded (on 11 May 2012) were 0.66 individuals per ten plants in field one, 0.66 individuals per ten plants in field two, 0.33 individuals per ten plants in field three, and 0.33 individuals per ten plants in field-four. The highest number of larvae determined on 28 June 2012 in fields one, two, three, and four were 58.33 individuals per ten plants, 27.66 individuals per ten plants, 10.66 individuals per ten plants, and 31 individuals per ten plants, respectively. After 13 July 2012, no larvae were encountered (Table 1).

3.2. Parasitization and ratios

Only one species was determined to be a larva plus pupae parasitoid; *Campoletis rapax*, isolated from *D. fovealis* larva plus pupae (Figure 10). Known hosts are as follows: *Anarta myrtilli, Autographa gamma, Epinotia sordidana, Lacanobia*

*oleracea, Lymantria dispar, Lymantria monacha, Ostrinia nubilalis, Panolis flamme*a, and the Hyperparasitoid: *Itoplectis maculator* (Ichneumonidae: Pimplinae). The adult food source *is Pimpinella rotundifolia*; and the associated plants are *Heracleum sphondylium* and *Peucedanum oreoselinum.* The general distribution of the pest is as follows: Austria, Azerbaijan, Bulgaria, Czechoslovakia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Netherlands, Norway, Poland, Romania, Russia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom. Infection regions include the eastern and western Palearctic and Europe. The species was first recorded in Turkish fauna [14]. In Adana, 249 larvae were cultured in 2011 and 218 larvae were cultured in 2012. The average ratios of parasitized larvae were 5.11% and 7.04% during 2011 and 2012, respectively. In Silifke, 346 larvae were cultured in 2012 and the parasitized larvae ratio was 11.22%. The highest level of parasitization occurred at the end of strawberry season (Table 2).

Fig 1: Overwintering larvae surrounding the root region of the strawberry plants left in the field.

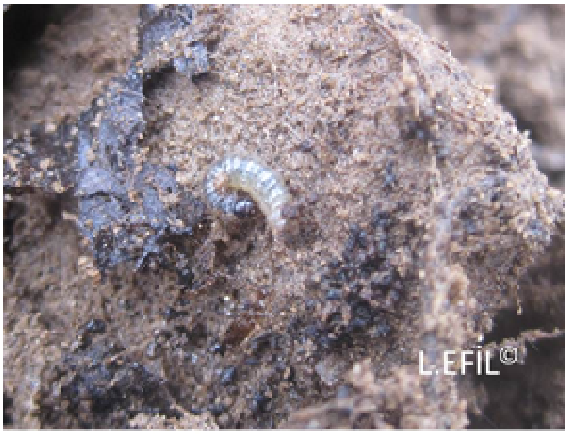

Fig 2: Overwintering larvae in masses of field-removed plants located near fields.

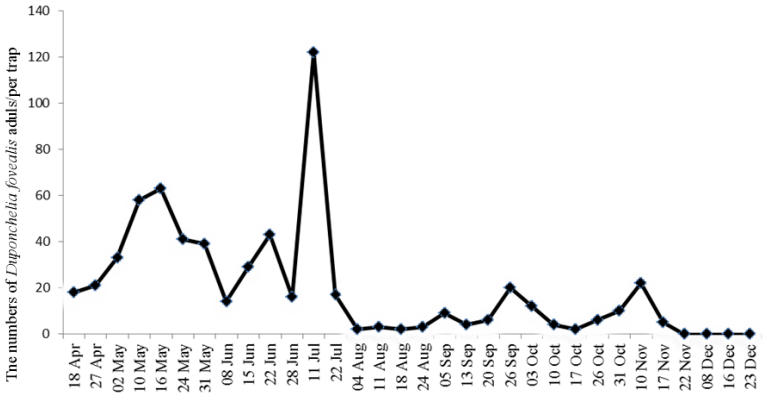

Fig 3: *Duponchelia fovealis* adults on pheromone traps in Adana in 2011

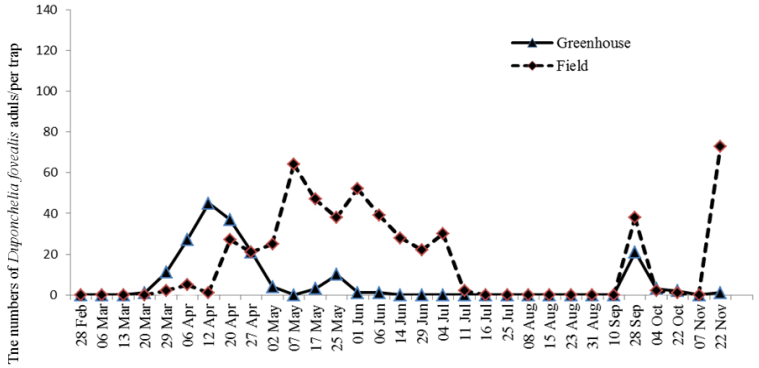

Fig 4: *Duponchelia fovealis* adults on pheromone traps in Adana in 2012

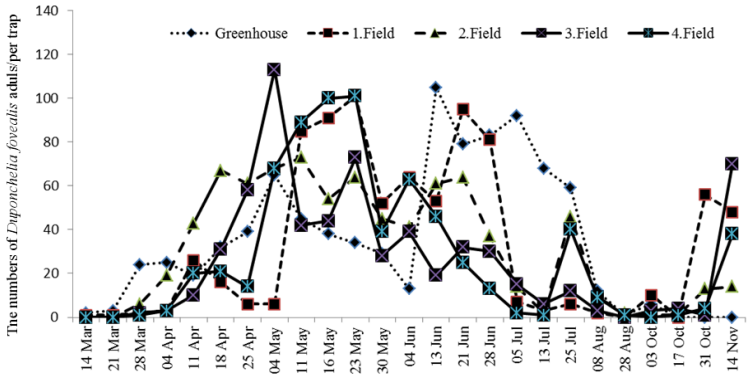

Fig 5: *Duponchelia fovealis* adults on pheromone traps in Mersin (Silifke) in 2012

Fig 6: *Duponchelis fovealis* eggs on dried leaves near the stem.

Fig 7: Larvae on the fresh tissues of the inner sides of the near soil root region.

Fig 8: *Duponchelia fovealis* larvae feeding on strawberry fruits.

Fig 9: *Duponchelia fovealis* larvae caused rotten and damaged fruits.

Fig 10: The parasitoid larvae in *D. fovealis* pupae

Table 1: The development of *Duponchelia fovealis* larvae on strawberries in greenhouse and in fields located in Adana and Mersin (indiviuduals per ten plants).

2011 yılı								
Adana	10.05	15.05	30.05	16.05	22.05	28.05	11.07	
1.G.house	2.66	4.66	4	3.33	4.33	4	0.66	
2.G.house	3	4.33	5.66	5.33	6.33	2.33	1	
3.G.house	2	5	5.33	4	4.33	2.33	1	
2012 yılı								
Adana	05.05	14.05	25.05	01.06	06.06	14.06	29.06	04.07
1.G.house	1.66	3.33	20.66	13	7.66	4	1	0.33
2.G.house	1	4.33	23.66	10.33	10	3.66	1.66	0.66
3.G.house	2.33	2.66	18.33	8.33	9.66	2.66	1.33	0.66
Mersin	11.05	23.05	30.05	13.06	21.06	28.06	05.07	
1.Field	0.66	16.33	19.66	9.66	34.33	58.33	32	
2.Field	0.66	4.33	12.66	6	15.4	27.66	9	
3.Field	0.33	6.66	8.66	5.33	11	19.66	4.66	
4.Field	0.33	14.66	17.33	8.33	14.33	31	5	

Table 2: The percentage of parazitizm for *Duponchelia fovealis* larvae by *Campoletis rapax.*

2011				
Location	date	Collected larvae	parazitoid	% parasitizm
Adana	15.05	37	1	2.7
	28.06	74	4	5.4
	11.07	138	10	7.24
Total		249	15	5.11
2012				
Location	date	Collected larvae	Parazitoid	%parazitizm
Adana	14.05	24	2	8.33
	18.05	36	2	5.55
	25.05	51	3	5.88
	14.06	107	9	8.41
Total		218	16	7.04
Location	date	Collected larvae	Parazitoid	%parazitizm
Mersin	23.05	17	1	5.88
	30.05	58	1	1.72
	13.06	72	5	6.94
	21.06	105	28	26.68
	28.06	94	14	14.89
Total		346	49	11.22

Table 3: A summary of the surveys conducted in Mersin and Adana.

		Percentage of fields infested by *Duponchelia fovealis* (numbers of fields surveyed)	
City	Location	2011	2012
Adana	Merkez	100 (7)	100 (8)
Mersin	Tarsus		100 (2)
	Silifke		100 (35)
	Taşucu		100 (18)
	Anamur		100 (10)
Total		100 (7)	100 (73)

3.3. Distribution areas
Our study revealed that all of the strawberry growing areas in Adana and Mersin were infested with *D. fovealis* (Table 3).

4. Discussion
In this work, we discovered that *D. fovealis* is a strawberry pest in Turkey. *D. fovealis* was determined to overwinter in the larval stage under plant remnants and under strawberry seedlings and to survive in the field until the following year. Removing remnant plants from the field and collecting the excess leaves of seedlings decreases overwintering populations of the pest. The flight of adults began in mid-March. The use of pheromone traps, especially in greenhouses, may decrease pest damage. It was suggested that pheromone traps can be used to control *Tuta absoluta* populations [15].

In open fields, since strawberry growing areas are close to one another, mating disruption during the early season may be an effective mechanism of pest control. Mating disruption method was reported to be successful against *T. absulata* [16]. During our study, the young leaves of seedlings dried due to larval feeding activities while fruits were not significantly affected. However, researchers in France reported that the pest caused serious damage to both strawberry leaves and fruits [7]. The work presented here indicates that all of the strawberry growing areas in Adana and Mersin are infested by the pest. In 2011, peanut areas in Adana province were found to be infested by *D. fovealis* [13]. Regarding the spreading potential, infestation to new areas can be avoided by monitoring the exchange of infested plant materials. When first detected in the US, the US began an eradication program against the pest. However, it rapidly spread to different states and was later designated as a quarantinable pest species [10].

Due to their tendency to hide under mulching plastics and in the soil surrounding roots, control via pesticides does not seem to be effective. Since larvae take shelter under plant debris and in the soil, chemical control was suggested as an ineffective method [4].

Since strawberries ripen and are harvested early, biological control may also be useful pest control. Additionally, the mass rearing and releasing of parasitoids may be integrated into management programs. Mass release of *Campoletis flavicincta* could be used successfully against *Spodoptera littoralis* [17]. The use of *Hypoaspis miles* [18] and *Steinernema feltiae* and *S. carpocapsae* against *D. fovealis* larvae [19] have also been suggested. On the other hand, *Trichogramma* spp. could be successfully used against pest eggs [20].

In our study we determined that *D. fovealis* was present in the strawberry growing areas of Adana and Mersin. The larval infestation of *D. fovealis* has the potential to cause serious problems for the strawberry industry, at least in the eastern Mediterranean region of Turkey. Therefore, in intensive strawberry growing areas control methods should be developed and put into practice.

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