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Population dynamics and parasitoid complex of *Archips rosana* (L.) (Lepidoptera: Tortricidae) in Western Turkey

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Dinámica poblacional y complejo parasitoide de *Archips rosana* (L.) (Lepidoptera: Tortricidae) en Turquía occidental

RESUMEN. El arrollador de frutales, *Archips rosana* (L.) (Lepidoptera: Tortricidae), es una plaga que causa graves pérdidas de cultivos en los manzanos de todo el mundo. En este estudio se investigó la dinámica poblacional de *A. rosana* y sus parasitoides asociados en dos provincias del oeste de Turquía (Denizli y Usak) en 2018 y 2019. Se recolectaron un total de 318 masas de huevos, 300 larvas y 129 pupas de las áreas de estudio. Aunque no se detectaron parasitoides en masas de huevos, diez especies de parasitoides pertenecientes a Braconidae, Chalcididae e Ichneumonidae (Hymenoptera) y Tachinidae (Diptera), se criaron a partir de las muestras de larvas y pupas. *Phytodietus astutus* (Gravenhorst) (Ichneumonidae) fue la especie parasitoide más abundante, con una abundancia relativa del 35,1%, seguida de *Itoplectus maculator* (Fabricius) (Ichneumonidae) representada por el 27% de los parasitoides recuperados. Además, *P. astutus* y *Scambus inanis* (Schrank) (Ichneumonidae) criados a partir de las muestras son los primeros registros de Turquía, mientras que *Cotesia glomerata* (L.) (Braconidae), *Exochus* sp. (Ichneumonidae) y *Nemorilla maculosa* (Meigen) (Tachinidae) son los primeros registros de *A. rosana*. Utilizando trampas de feromonas en los manzanos, el primer adulto de *A. rosana* fue capturado el 24 de mayo en Civril (Denizli) y el 30 de mayo en Sivasli (Usak) en 2019.

PALABRAS CLAVE. Arrollador de frutales. Ichneumonidae. Nuevo registro. *Phytodietus*.

ABSTRACT. The rose tortrix moth, *Archips rosana* (L.) (Lepidoptera: Tortricidae), is a pest that causes serious crop losses in apple orchards throughout the world. In this study, the population dynamics of *A. rosana* and its associated parasitoids were investigated in two provinces of Western Turkey (Denizli and Usak) in 2018 and 2019. A total of 318 egg masses, 300 larvae, and 129 pupae were collected from the survey areas. Although no parasitoids were detected in egg masses, ten parasitoid species belonging to Braconidae, Chalcididae, and Ichneumonidae (Hymenoptera), and Tachinidae (Diptera), were reared from the samples of larvae and pupae. *Phytodietus astutus* (Gravenhorst) (Ichneumonidae) was the most abundant parasitoid species, with a relative abundance of 35.1%, followed by *Itoplectus maculator* (Fabricius) (Ichneumonidae) represented by 27% of the recovered parasitoids. Moreover, *P. astutus* and *Scambus inanis* (Schrank) (Ichneumonidae) reared from the samples are the first records from Turkey, while *Cotesia glomerata* (L.) (Braconidae), *Exochus* sp.(Ichneumonidae), and *Nemorilla maculosa* (Meigen) (Tachinidae) are the first records from *A. rosana*. Using pheromone traps in the apple orchards, the first adult of *A. rosana* was caught on May 24 in Civril (Denizli) and on May 30 in Sivasli (Usak) in 2019.

KEYWORDS. Ichneumonidae. New record. *Phytodietus*. Tortrix moth.

INTRODUCTION

Apple, *Malus domestica* (Borkh) (Rosales: Rosaceae), is one of the most widely cultivated fruits in the world, constituting 12% of total world fruit production. According to the United States Department of Agriculture (USDA), in the 2019-2020 season, 75.8 million tons of apples were produced in a cultivated area of 5.3 million hectares (USDA, 2020). The origin of apple is Turkistan, the Caucasus, and Anatolia. Hence, it is not surprising that Turkey is an important production center for apple, with its 3.6 million tons accounting for 4.2% of the world's annual production. Globally, Turkey ranks third in apple production, following China and USA (FAOSTAT, 2020).

Archips rosana (L.) (Lepidoptera: Tortricidae) is a pest that causes significant losses in apple orchards if management efforts are not employed. It has been reported to damage the foliage and fruit of ornamental, forest, and fruit trees, especially apples, pears, quince, plums, walnuts, peaches, and cherries trees (Aysu, 1955; Kovancı et al., 2003; Piekarska-Boniecka et al., 2019). Females generally lay their eggs on the bark of the trunk and thick branches, where they overwinter, hatching the following spring. First instars feed in leaf shelters, causing leaves to drop, and later instars feed on the fruits (Erden, 1988; Polat & Tozlu, 2010; Canbay & Tozlu, 2013). The species is univoltine throughout its range.

Pesticides used to control pests and diseases in agriculture not only have an impact on target organisms, but also cause significant damage to non-target organisms such as natural enemies. In addition, pesticide misuse frequently drives the development of resistance to these chemical substances, requiring a gradual increase in the amount of the pesticides being used. According to the Republic of Turkey Ministry of Agriculture and Forestry, the amount of pesticides used in Turkey has increased by 59% to 60,000 tons over the last decade. Given that only 0.1% of pesticides used reaches target pests, the destructive effect of these chemicals on the environment is significant and widespread (Pimentel, 1995; Gill & Garg, 2014). To reduce pesticide usage, it is important to understand the composition and abundance of natural enemies of the target pest.

There are many natural enemies that limit reproduction of *A. rosana* under natural conditions. Over 100 parasitoid species are known to attack this species, 44 of which have been recorded in Turkey (Doğanlar, 1987; Özdemir & Özdemir, 2002; Polat & Tozlu, 2010; Aydoğdu, 2014).

The present study was conducted to determine the field biology of *A. rosana* and its parasitoids and quantify rates of parasitism of this species in apple orchards in western Turkey.

MATERIAL AND METHODS

Determination of the parasitoids

Surveys were conducted in apple orchards in six different locations in the provinces of Usak and Denizli, Turkey in 2018 and 2019 (Table I). All apple orchards are conventionally farmed, and pesticides are used to manage diseases and pests. Survey sites are at similar altitudes, between 800-950 m, and continental climatic conditions. Samples of eggs, larvae, and pupae were collected bimonthly from each location between February and June in both years.

Egg masses found during field surveys conducted in February and March were removed from bark using a knife, and placed in glass tubes (11 x 1.6 cm). The tubes were covered with muslin cloth and kept at room temperature until emergence of larvae or parasitoids. In order to determine larval and pupal parasitoids of the *A. rosana*, at least 50 samples of larvae were collected from each district in April and May of both years, following the protocol of Razmi et al. (2011). Larvae were reared in plastic boxes (10 x 10 x 3.5 cm) maintained at room temperature. The larvae were fed with fresh apple leaves. Emerging parasitoids were pinned and labeled using a binocular microscope and sent to experts for identification. Braconid (Hymenoptera: Braconidae) species were sent to Ahmet Beyarslan (Bitlis Eren University, Turkey), tachinid (Diptera: Tachinidae) species to Kenan Kara (Gaziosmanpaşa University, Tokat, Turkey), and ichneumonid (Hymenoptera: Ichneumonidae) species to Sasha Varga (I.I. Schmalhausen Institute of Zoology of National Academy of Sciences of Ukraine). Additionally, the identification of *A. rosana* was confirmed by Mustafa Özdemir (Directorate of Plant Protection Central Research Institute, Ankara, Turkey). Voucher specimens of all parasitoids are deposited in the Insect Museum of the Plant Protection Department, Faculty of Agriculture and Natural Sciences, Usak University, Usak, Turkey.

Population monitoring

Population monitoring of the pest was conducted in a 1.1 ha apple orchard in Usak, Sivasli (38.502095 N, 29.667049 E) and in a 1.4 ha orchard in Denizli, Civril (38.306233 N, 29.775270 E) in 2019. In each location, one delta trap with a sticky board baited with pheromone (PH-104- 1RR, Russel IPM) was deployed on the south

side of the trees about 1.5 m above the ground level in mid-May. The traps were checked twice a week until the first adults were trapped, and from then on once a week, with the number of adults recorded. The pheromone capsule was changed every five weeks, as recommended by Russel IPM.

To determine the first emerging date of larvae from egg masses, four trees with egg masses detected in Sivasli and Civril in 2019 were marked and checked weekly. The sum of effective temperatures for first hatching egg and first adult appearance of *A. rosana* was calculated using the following formula:

$$C = (T_1 - t^0) + (T_2 - t^0) + (T_n - t^0)$$

where "C" refers to sum of effective temperatures, "$T_1 \ldots T_n$" refers to mean daily temperature and "t^0" refers to physiological threshold. Average temperature and relative humidity values regarding survey areas were obtained from the Turkish State Meteorological Service.

Data analysis

All statistical analyses were performed using the SPSS 16.0 software package. The groups were composed of parasitism rates of samples collected from Banaz, Civril and Sivasli districts in both years. The difference between the groups was examined using one-way (ANOVA) variance analysis and independent samples t-test. The parasitism rates, expressed as a proportion, were performed using arcsine transformation before the statistical analyses. The parasitism rate was calculated as the ratio of the number of a parasitoid species to the total number of larvae and pupae collected in the localities, whereas the relative abundance was determined as the ratio of the number of a parasitoid species to the total number of parasitoids.

RESULTS AND DISCUSSION

A total of 429 samples were collected during the study: 207 (150 larvae, 57 pupae) in 2018 and 222 (150 larvae, 72 pupae) in 2019. Ten parasitoid species, belonging to Ichneumonidae, Braconidae, and Chalcididae (Hymenoptera), and Tachinidae (Diptera), were detected (Table II, Table III). Ichneumonidae was the most commonly encountered family with five parasitoid species, followed by Braconidae (three species), Chalcididae (one species), and Tachinidae (one species). Twelve individual parasitoids were reared from the samples in 2018 and 25 in 2019. Parasitism rates in 2018 and 2019 were 5.8% and 11.3%, respectively. Overall, ichneumonid parasitoids accounted for 6.3% of total of parasitism rate (8.6%) and were the most effective species in the parasitization of the pest. This finding is consistent with those of Piekarska-Boniecka (2004), Kot (2007), and Piekarska-Boniecka et al. (2019), all of which found Ichneumonidae to be the most effective parasitoid. In Edirne province, northwestern Turkey, the parasitoid complex of *A. rosana* was studied by Aydoğdu (2014), and 23 parasitoid species were found. Because that study was conducted in an organic orchard, the number of parasitoid species observed was considerably higher than in our research. *Phytodietus astutus* (Gravenhorst) (Ichneumonidae) was the most abundant parasitoid species, with a relative abundance of 41.7% in 2018, while in 2019, *Itoplectis maculator* (Fabricius) (Ichneumonidae) was the most abundant (36%), followed by *P. astutus* (32%). Similarly, *I. maculator* was reported to be the most abundant species in studies conducted by Polat & Tozlu (2010) and Aydoğdu (2014).

Although *Cotesia glomerata* (L.) (Braconidae), *I. maculator*, and *P. astutus* were collected in both years, *Paroplitis* sp. (Braconidae), *Exochus* sp. (Ichneumonidae), *Scambus inanis* (Schrank) (Ichneumonidae), *Nemorilla maculosa* (Meigen) (Tachinidae) were found only in 2018, and *Habrobracon hebetor* (Say) (Braconidae), *Brachymeria tibialis* (Walker) (Chalcididae), and *Scambus elegans* (Woldstedt) only in 2019. The highest parasitism rate in 2018 and 2019 was observed in the Banaz district (10.5%) and Sivasli (16.7%), respectively. However, it was determined that there was no significant difference between parasitism rates in 2018 and 2019 (t_{419} = -1.925; p = 0.053). Moreover, parasitism rates calculated in the localities in 2019 were compared, and no significant difference was found ($f_{2,219}$ = 2.741 p = 0.067). No parasitoid species were detected in the samples collected from Civril in 2018. In addition, Civril was the district in which the number of parasitoids was lowest in 2019. Overuse of pesticides in the region is the most likely explanation for this finding. *P. astutus* and *S. inanis*, which are solitary ectoparasitoids, were newly recorded for Turkey on *A. rosana*. In earlier studies conducted in Turkey, different species of *Phytodietus* and *Scambus* were identified, *i.e., S. calobatus, S. buolianae, S. brevicornis*, and *P. polyzonias* (Özdemir & Özdemir, 2002; Aydoğdu, 2014). The braconid species recovered from this research are gregarious parasitoids,

Locality	Latitude (N)	Longitude (E)	Area (ha)	Elevation (m)
Denizli/Civril (1)	38.306233	29.775270	1.4	834
Denizli/Civril (2)	38.293470	29.783395	2.5	828
Usak/Banaz (1)	38.741676	29.781390	1.3	922
Usak/Banaz (2)	38.746348	29.779173	3.1	918
Usak/Sivasli (1)	38.507163	29.685794	0.1	942
Usak/Sivasli (2)	38.502095	29.667049	1.1	918

Table I. Details of survey sites where the samples were collected in 2018 - 2019 (1) = 2018; (2) = 2019

	Location	Parasitoid species										Total
		Cotesia glomerata (L)	*Habrobracon hebetor* (L)	*Paroplitis* sp. (L)	*Brachymeria tibialis* (P)	*Exochus* sp. (LP)	*Itoplectis maculator* (LP)	*Phytodietus astutus* (LP)	*Scambus elegans* (P)	*Scambus inanis* (P)	*Nemorilla maculosa* (LP)	
N	Banaz	0	0	1	0	1	0	2	0	1	2	7
RA (%)		0	0	14.3	0	14.3	0	28.6	0	14.3	28.6	-
PR (%)		0	0	1.5	0	1.5	0	3.1	0	1.5	3.1	10.7
N	Civril	0	0	0	0	0	0	0	0	0	0	0
RA (%)		0	0	0	0	0	0	0	0	0	0	-
PR (%)		0	0	0	0	0	0	0	0	0	0	0
N	Sivasli	1	0	0	0	0	1	3	0	0	0	5
RA (%)		20	0	0	0	0	20	60	0	0	0	-
PR (%)		1.4	0	0	0	0	1.4	4.1	0	0	0	6.9

Table II. Abundance and parasitism rates of parasitoids obtained from larvae and pupae of *Archips rosana* in Banaz, Civril and Sivasli districts in 2018. L: Larval parasitoid; P: Pupal parasitoid; LP: Larva-pupa parasitoid; N: Number of individuals; RA: Relative abundance; PR: parasitism rate

whereas the others are solitary endoparasitoid. Moreover, it was reported that *B. tibialis* is primary a pupal endoparasitoid, but it might rarely be a secondary parasitoid (Askew, 2001; Barbuceanu & Andriescu, 2012).

No parasitoids were reared from the total of 318 egg masses collected in 2018 and 2019. By contrast, Ercan et al. (2015) reported two *Trichogramma* species (*T. dendrolimi* (Matsumura) and *T. euproctidis* (Girault)) as egg parasitoids of *A. rosana* in the Central Anatolia Region of Turkey. In a similar study, Wei et al. (1998) found no parasitoids in egg masses. In addition, none of the other studies conducted in Turkey recovered egg parasitoids from *A. rosana*.

In Civril, the first emergence of *A. rosana* larvae from egg masses was observed on March 21, when the maximum temperature was 19.1 °C, the first larvae were recorded on April 2 (15.1 °C) in Sivasli. Egg hatching commenced on the date when the sum of effective temperature (above 8 °C) reached 36 °C in Sivasli, 34 ° C in Civril. In a study conducted in Poland, Pluciennik & Tworkowska (2004) found this temperature to be about 60 °C in 1993, 1995, and 1996, 50 °C in 1994, and about 30 °C in 1997. Similarly, AliNiazee (1977) also indicated that the sum of effective temperatures necessary for the onset of egg hatching was 40 °C. Ulu (1983) and Doğanlar (2008) reported hatching dates of *A. rosana* eggs on February 15 and March 29, respectively. Polat & Tozlu (2010) determined the first date of hatching to be May 12 in eastern Turkey. The differences among dates are almost certainly the result of temperature differences of the regions, and varying from year to year.

The delta traps used to monitor the adult population of *A. rosana* were hung on trees on May 10 in Civril and on May 12 in Sivasli. The first moths were captured on May 24 in Civril, when average temperature and relative humidity were 19.4 °C, 65% respectively, whereas in Sivasli, they were captured on May 30 (21.9 °C and 39.3%). The moth flight lasted for about 30 days until the end of June in both localities (Figs. 1, 2). Pluciennik & Tworkowska (2004) found that the flight period of this species varies between 30 and 53 days.

In research conducted in eastern Turkey, Canbay & Tozlu (2013) found that the adult flight period began on June 16 and lasted 34 days. In dates of first catch, the

	Location	Parasitoid species										Total
		Cotesia glomerata (L)	*Habrobracon hebetor* (L)	*Paroplitis* sp. (L)	*Brachymeria tibialis* (P)	*Exochus* sp. (LP)	*Itoplectis maculator* (LP)	*Phytodietus astutus* (LP)	*Scambus elegans* (P)	*Scambus inanis* (P)	*Nemorilla maculosa* (LP)	
N	Banaz	0	0	0	1	0	2	5	1	0	0	9
RA (%)		0	0	0	11.1	0	22.2	55.5	11.1	0	0	-
PR (%)		0	0	0	1.4	0	2.9	7.1	1.4	0	0	12.8
N	Civril	1	0	0	0	0	2	0	1	0	0	4
RA (%)		25	0	0	0	0	50	0	25	0	0	-
PR (%)		1.3	0	0	0	0	2.5	0	1.3	0	0	5.1
N	Sivasli	0	4	0	0	0	5	3	0	0	0	12
RA (%)		0	33.3	0	0	0	41.7	25	0	0	0	-
PR (%)		0	5.6	0	0	0	6.9	4.2	0	0	0	16.7

Table III. Abundance and parasitism rates of parasitoids obtained from larvae and pupae of *Archips rosana* in Banaz, Civril and Sivasli districts in 2019. L: Larval parasitoid; P: Pupal parasitoid; LP: Larva-pupa parasitoid; N: Number of individuals; RA: Relative abundance; PR: parasitism rate

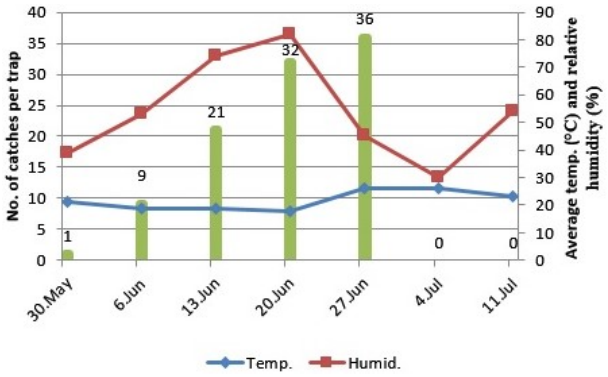

Fig. 1. Number of *Archips rosana* individuals captured weekly in Sivasli.

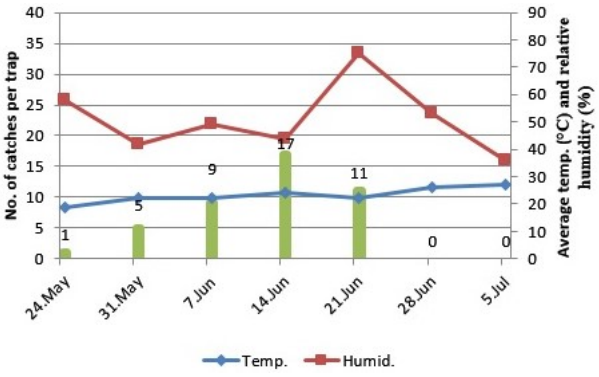

Fig. 2. Number of *Archips rosana* individuals captured weekly in Civril.

sum of effective temperatures in Civril and Sivasli as of January 1st was found to be 477 and 535 degree-days, respectively. In parallel with this study, Doğanlar (2008) established that the sum of effective temperatures necessary to initiate moth emergence is 512 degree-days. The highest number of individual moths in the traps of Sivasli and Civril were 36 on June 27 and 17 on June 14, respectively. Afterwards, the number of catches declined sharply. Similarly, the highest numbers of catches were reported to occur from the middle to the end of June in studies by Kovancı et al. (2003) and Pluciennik & Tworkowska (2004). The total number

of *A. rosana* individuals caught in the traps was 43 in Civril and 99 in Sivasli, with the number of catches in Sivasli significantly higher than in Civril (t_{38} = - 2.124; p = 0.042). The higher trap catches in Sivasli is likely a reflection of the fact that the orchard there is relatively subjected to less pesticide.

In conclusion, *P. astutus,* which is newly recorded for Turkish fauna, is responsible for nearly half of the total parasitism. Therefore, further studies focused specifically on this parasitoid should be conducted to determine its biology and population dynamics. Also, some protective practices, including pesticide use reduction, should be implemented to improve the efficacy of the parasitoids.

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