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Tachinid (Diptera: Tachinidae) Parasitoids of Overwintered *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae) Pupae in Hazelnut Plantations in Samsun Province, Turkey

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ABSTRACT

The fall webworm, *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae), is an exotic, defoliating larval pest in Europe and Asia. More than 4,000 overwintered pupae of *H. cunea* were collected from hazelnut plantations in Samsun province, Turkey in 2008 and 2009. Two tachinid species, *Compsilura concinnata* and *Nemoraea pellucida*, were reared in both 2008 and 2009. Species richness at sites ranged from 1 to 2 species. Parasitism was 2.4 times higher in 2009 than in 2008. The highest total parasitism for any site was 23.6% in 2009. *Nemoraea pellucida* parasitised 2.4% of all pupae collected, was responsible for 94.6% of all tachinid parasitism, and had the highest parasitism rate of 19.4% for any site. *Compsilura concinnata* parasitised 0.14% of all pupae and was responsible for 5.4% of tachinid parasitism.

Key words: Hyphantria cunea, Tachinidae, biological control, parasitoid, hazelnut.

INTRODUCTION

Hyphantria cunea (Drury) (Lepidoptera: Arctiidae) is a Nearctic defoliating larval pest. Waren and Tadic (1970) reported that it is among the most polyphagous of insects and that across its entire range in North America, Europe and Asia, the number of host plants exceeds 630. In addition to polyphagy, the polyvoltinism and ecological flexibility of *H. cunea* are serious obstacles to its control (Varjas and Sehnal, 1973). This pest is also known to cause health problems; some persons in the Samsun province of Turkey exposed to larvae, and especially webs, have suffered from allergic skin reactions.

Hyphantria cunea has now been reported from at least 20 countries across Europe, including Hungary (Gyorfi, 1954), France (D'Aguilar and Riom, 1979), Greece

(Mouloudis *et al.*, 1980), Italy (Deseo *et al.*, 1986) and a number of other nations (Tschorsnig *et al.*, 2005); 2 in Eurasia, Turkey (Iren, 1977) and Russia (Sharov and Izhevskiy, 1987); and 10 in Asia, Japan (Niimura, 1949), South Korea (Kim *et al.*, 1968), China (Shi, 1981), Azerbaijan (Nurieva, 2002), Iran (Rezaei *et al.*, 2003), Mongolia and Uzbekistan (Grichanov and Ovsyannikova, 2003), Georgia (Japoshvili *et al.*, 2006) and Kazakistan and Kyrgyzstan (Anonymous, 2007).

Farmers and government agencies have frequently used insecticides to control *H. cunea*. In Hungary, DDT suspensions and dusts, and later organophosphates, were used (Szalay-Marzso, 1972). Diflubenzuron was used in the former USSR (Sazanov *et al*., 1984), and also in Turkey in a government subsidised program (Anonymous, 1996). In laboratory experiments, Fenvalerate, Cypermethrin and Permethrin caused 100% larval mortality (Sikura *et al*., 1988). However, pesticides directly and indirectly harm humans and the environment (Carson, 1962; Mueller-Beilschmidt, 1990; Shafer *et al*., 2005; Rauh *et al*., 2006).

A range of ecological studies, including Jermy (1957), Warren and Tadic (1967), Szalay-Marzso (1972), Bas (1982), Deseo *et al*. (1986), Sharov and Izhevskiy (1987), Isik and Yanilmaz (1992), Tuncer (1992), Yaman *et al*. (2002), Rezaei *et al*. (2003), Japoshvili *et al*. (2006) and Yang *et al*. (2008) have focused on its parasitoids and entomopathogens.

A major outbreak of *H. cunea* occurred in Samsun province, Turkey in 1984-1985 and it caused serious defoliation in hazelnut (*Corylus avellana* L.) plantations. Locally serious outbreaks continue, including the period from 2007 to 2011 on the Carsamba plain where *H*. *cunea* has been an important pest since 1982 (Isik and Yanilmaz, 1992; Tuncer, 1992; Sullivan *et al.*, 2010). Areas in western Georgia recently experienced severe outbreaks (Japoshvili *et al*., 2006), and this pest has the potential to infest several hundred thousand hectares of unaffected plantations between Samsun province and the Georgian border.

Despite earlier research, there is still limited knowledge in Turkey of the ecological factors contributing to outbreaks in some years and suppressing populations in other years. To better understand the ecology of *H. cunea*, the aims of this study were to determine whether tachinids overwinter in *H. cunea* pupae in the study area, and if so, the species involved, percentage parasitism and sex ratio. That knowledge is important to understanding the contribution of tachinids to biological control of the pest and provides important baseline information for future studies.

MATERIALS AND METHODS

In late March and early April of 2008 and 2009, a total of 40 sites were checked for the presence of pupae in the Carsamba (N 41º 11´ 56´´, E 36º 43´ 30´´), Terme (N 41º 12´ 32´´, E 36º 58´ 20´´) and Salipazari (N 41º 04´ 51´´, E 36º 49´35´´) districts of Samsun province. For consistency of collection effort across sites, a total of 4 person hours of search effort was performed at each site. In the field, healthy pupae were separated from those that were diseased, damaged or had exit holes. Eleven of the

13 sites used in 2008 were abandoned in 2009 because no healthy pupae could be found. The 2 sites from 2008 with healthy pupae and 25 new sites made up the 27 sites for 2009. Pupae were collected along plantation borders from living and dead trees, especially willows; wood piles; and fence posts (Sullivan *et al*., 2010).

In the laboratory, each pupa was placed in a separate plastic vial, measuring 5.0 cm x 2.5 cm, with a wad of moistened tissue paper to maintain humidity. The vials were sealed with tightly-woven mesh, and kept in a dark, slightly-ventilated laboratory cupboard at ambient temperatures from 13 ºC to 21 ºC to simulate the natural environment of pupae. Emerged tachinids were briefly refrigerated to slow movement, euthanised in a killing bottle and pinned. They were identified by Prof. Dr. Kenan Kara, one of the authors, using the keys in Tschorsnig and Herting (1994), Tschorsnig and Richter (1998) and Cerretti *et al.* (2010). Levels of parasitism and sex ratio were also determined.

RESULTS

A total of 4,297 overwintered *H. cunea* pupae were collected in 2008 (3,183) and 2009 (1,114). Over the two years, the number of pupae collected at a site ranged from 2 to 561. The average number of pupae per site was 245 in 2008 and in 2009, it was 41. Tachinids were reared from 10 of 13 sites (77%) in 2008 and from 10 of 27 sites (37%) in 2009. That meant that tachinids were collected from 20 of 40 sites (50%) over the 2 years. Two tachinid species, *Nemoraea pellucida* (Meigen) (Diptera: Tachinidae: Tachininae) (Figs. 1-3) and *Compsilura concinnata* (Meigen) (Diptera: Tachinidae: Exoristinae) (Figs. 4-6) were reared. In 2008 and 2009, the species richness at individual sites ranged from 1 to 2 species. In 2008, 35% of all tachinids were reared from one site (Dalbahçe-Carsamba), and in 2009, 43% of all tachinids were reared from a different site (Erenköy Merkez-Terme).

For 2008 and 2009, total parasitism was 1.9% and 4.5%, respectively. That meant that parasitism was 2.4 times higher in 2009 than in 2008. Parasitism by *N. pellucida* was 1.85% and 4.04% in 2008 and 2009, respectively, and by *C. concinnata* was 0.03% and 0.45 % in 2008 and 2009, respectively. The highest parasitism rate for any site (Erenköy Merkez) was 23.6% [*N. pellucida* (19.4%), *C. concinnata* (4.2%)] in 2009. A total of 104 *N. pellucida* adults (53% ♀) emerged in 2008 (31 ♀, 28 ♂) and 2009 (24 ♀, 21 ♂). It parasitised 2.4% of all pupae and was responsible for 94.6% of all tachinid parasitism in the 2 year study. In total, 6 specimens of *C. concinnata* (66.7% ♀) were reared in 2008 (1 ♀) and 2009 (3 ♀, 2 ♂). It parasitised 0.14% of all pupae and was responsible for 5.4% of tachinid parasitism in the 2 year study.

DISCUSSION AND CONCLUSIONS

In the current study, *N. pellucida* and *C. concinnata* are reported as overwintering parasitoids of the exotic, foliar feeding pest *H. cunea* in the Samsun province of Turkey. *Nemoraea pellucida* has been reported from at least 28 countries in Europe

Figs. 1-2. *Nemoraea pellucida* (Meigen) (♂): 1. Adult, 2. Head

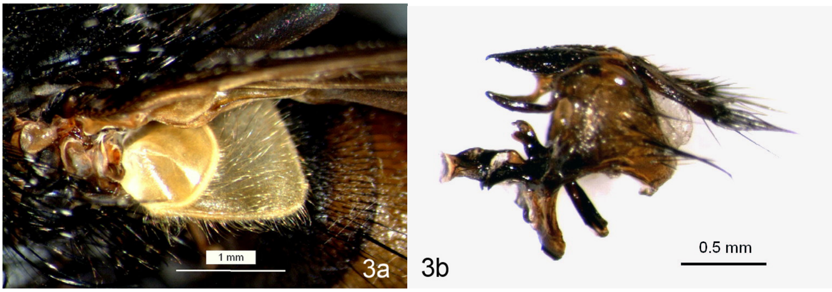

Fig. 3. *Nemoraea pellucida* (♂) a. Calyptrae, b. Genitalia

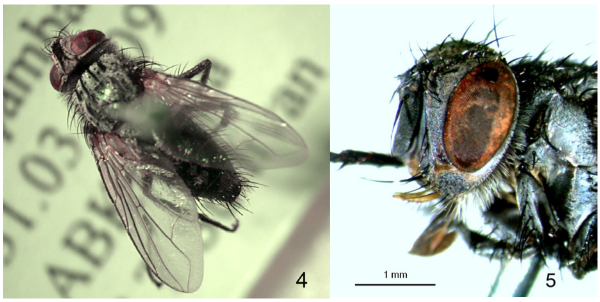

Fig. 4-5. *Compsilura concinnata* (Meigen) 4. (♂), 5. Head (♀)

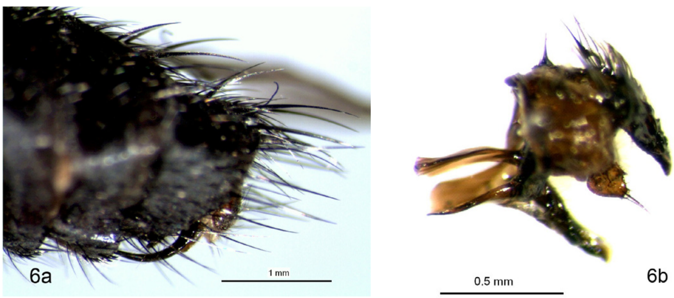

Fig. 6. *Compsilura concinnata*: a. Abdomen (lateral) (♀), b. Genitalia (♂)

(Tschorsnig *et al*., 2004). It parasitises various species of the lepidopteran families Noctuidae and Arctiidae, especially *H. cunea*, and more rarely the Geometridae, Lymantriidae, Sphingidae and Notodontidae (Tschorsnig and Herting, 1994). *Compsilura concinnata* is a widespread Paleartic, Afrotropical, Oriental and Australasian parasitoid (Crosskey, 1973, 1976, 1980; Herting, 1984; Herting and Dely-Draskovits, 1993; Tschorsnig *et al*., 2005; Cerretti, 2010; O'Hara, 2010) that was imported into the USA for the control of the gipsy moth and the browntail moth (Culver, 1919). It has the highest number of known host species, attacking at least 230 hosts in the Palaearctic region (Muckstein *et al.,* 2007). In Turkey, *C. concinnata* has been reported as a parasitoid of 8 lepidopteran families (Kara and Tschorsnig, 2003).

Compsilura concinnata and *N. pellucida* are included in a group of more than 50 species of tachinids reported from *H. cunea* in North America, Europe and Asia by many authors, including Aldrich (1931), Swain (1937), Gyorfi (1954), Jermy (1957), Warren and Tadic (1967), Kim *et al.* (1968), Szalay-Marzso (1972), Arnaud (1978), Poong *et al.* (1981), Bas (1982), Canakcioglu and Selmi (1988), Nanni (1991), Herting and Dely-Draskovits (1993), Richter (1996), Camerini and Groppali (1999), Tschorsnig and Herting (2001), Kara and Tschorsnig (2003), Tschorsnig *et al.* (2005), Watanabe (2005), Shima (2006), Yang *et al.* (2008), O'Hara (2009) and Cerretti and Tschorsnig (2010).

Intersite variation may have influenced the levels of parasitism by *N. pellucida* and *C. concinnata* from site to site and from 2008 to 2009. The differences between sites included altitude; temperature; humidity; the presence or absence of bordering hedges, fencing, dead trees and logs; proximity to creeks and other water bodies, and adjoining forest; and the diversity and amount of herbaceous ground cover. Non-crop vegetation may provide parasitoids with access to alternative hosts, adult food sources such as nectar, and safety from disturbances such as insecticides and crop harvesting (Shellhorn *et al*., 2000; Tscharntke, 2000). Takasu and Lewis (1995) showed that a deficiency of plant sugar sources reduces parasitoid search efficiency. Additionally, Campbell *et al*. (1990), Vet and Dicke (1992), Kalule and Wright (2002) and Steidle and van Loon (2003) reported that parasitoids use chemical cues from their hosts to locate them, directly or indirectly, through their products like silk and faeces.

The oviposition strategies of *C. concinnata* and *N*. *pellucida* are distinctly different. The female of the former injects fully incubated eggs directly into the host haemocoel (Culver, 1919; Ichiki and Shima, 2003; Ichiki and Nakamura, 2007; Koch and Hutchinson, 2011), whereas the latter deposits fully developed eggs near hosts; they develop into planidium type larvae that mount and enter the hosts (Mellini, 1963). In the present study, the much narrower host range of *N. pellucida* may have been a contributing factor in its much higher percentage of total parasitism (95%) than *C. concinnata* (5%). Supporting that contention is the work of D'Aguilar and Riom (1979) in France who reported that *N. pellucida* and *C. concinnata* contributed 84% and 16% of all tachinid parasitism, respectively.

In the current study, all of the 2008 sites were at low altitudes on the Carsamba plain. In 2009, pupae were much more difficult to find and the research area was extended to sites up to approximately 500 m altitude where the pest was seen for the first time in the summer generation. A very high proportion of the tachinids reared in 2009 was from 2 newly-infested, higher altitude sites at Erenkoy (Erenkoy Merkez and Keltepe). It appears that the tachinids, especially, *N. pellucida*, were already in that area and utilising a different host or hosts or they migrated to the higher altitude sites with the pest.

Both species reared in the current study have been reported from *H. cunea* in Turkey. Bas (1982) reported *C. concinnata*, *E*xorista *larvarum* (Linnaeus) and *Pales pavida* (Meigen) from the Marmara region of Turkey. From the Samsun region, Tuncer (1992) reported the same 3 species and *N. pellucida* from summer and overwintered pupae combined. The same author reported tachinid parasitism of 4.2% and 18% in 1990 and 1991, respectively, but the percentage parasitism by the various species and their sex ratios were not reported. *Nemoraea pellucida* was not reported from *H. cunea* by Herting (1960) but was reported by Tschorsnig and Herting (1994). In the intervening period, it developed an affinity for the host in France (D'Aguilar and Riom, 1979), Romania (Ziegler, 1990) and Turkey (Tuncer, 1992).

In conclusion, this study contributes to the body of knowledge of the ecology of the widely distributed pest *H. cunea* and strengthens the case for its biological control. More specifically, there is strong evidence to suggest that *N. pellucida* is the only tachinid that commonly uses this host to overwinter in the area of the present study. The high degree of parasitism by *N. pellucida* at a number of sites suggests that it may be a suitable candidate for inclusion in a regional biological control program for this pest.

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REFERENCES

Aldrich, J. M., 1931, Notes on Francis Walker's types of North American flies of the family Tachinidae. *Proceedings of the United States National Museum,* No. 2910, 80(10): 1-16.

Anonymous, 1996, *Zirai Mucadele Teknik Talimatlari*. T. C. Tarim ve Koyisleri Bakanligi, Koruma ve Kontrol Genel Mudurlugu, Cilt 4, Ankara, 393.

Anonymous, 2007, Global invasive species database. http://www.issg.org/database/welcome/. (12.11.2011).

Arnaud, P. H. Jr., 1978, A host-parasite catalog of North American Tachinidae (Diptera). *United States Department of Agriculture. Miscellaneous Publication,* 1319: 1-860.

Bas, R., 1982, *Turkiye icin yeni bir bitki zararlisi, Hyphantria cunea (Drury) (Lepidoptera, Arctiidae)*. Yayinlanmamis Tez, Istanbul, Turkiye, 65.

Camerini, G., Groppali, R., 1999, Predators and parasitoids of *Hyphantria cunea* in Pavia district (Northern Italy). *Informatore Fitopatologico,* 49(10): 19-28.

Campbell, R. K., Salto, C. E., Summer, L. C., Eikenbarry, R. D., 1990, Tritrophic interactions between grains, aphids and a parasitoid. *Symposia Biologica Hungarica*, 39: 393-401.

Canakcioglu, H., Selmi, E., 1988, Turkiye ormanlarinin faydali bocekleri. Orman Bocek ve Hastaliklariyla Biyolojik Mucadele Semineri, Tebligler, Tarim Orman ve Koyisleri Bakanligi, Orman Genel Mudurlugu, Ankara, 670(27): 85-102.

Carson, R., 1962, *Silent Spring*. Houghton Mifflin, Boston, 368.

Cerretti, P., 2010, *I tachinidi della fauna italiana (Diptera Tachinidae), con chiave interattiva dei generi ovest-paleartici*. Volume I + II (atlante iconografico) + CD-ROM. Cierre Edizioni, Verona, 573 + 339.

Cerretti, P., Tschorsnig, H. P., 2010, Annotated host catalogue for the Tachinidae (Diptera) of Italy. *Stuttgarter Beiträge zur Naturkunde, A (Biologie), Neue Serie*, 3: 305-340.

Cerretti, P., Tschorsnig, H. P., Lopresti, M., 2010, Moschweb, interactive key to the Palaearctic genera of Diptera: Tachinidae. http://www.issg.org/database/welcome/. (10.12.2011).

Crosskey, R. W., 1973, A conspectus of the Tachinidae (Diptera) of Australia, including keys to the supraspecific taxa and taxonomic and host catalogues. *Bulletin of the British Museum Natural History, Entomology Supplement,* 21: 1-221.

Crosskey, R. W., 1976, A taxonomic conspectus of the Tachinidae (Diptera) of the Oriental region. *Bulletin of the British Museum Natural History, Entomology Supplement,* 26: 1-357.

Crosskey, R. W., 1980, *Family Tachinidae*. *In*: Crosskey, R. W. (Ed.). Catalogue of the Diptera of the Afrotropical Region. British Museum (Natural History), London, 822-882.

Culver, J. J., 1919, A study of *Compsilura concinnata*, an imported tachinid parasite of the gipsy moth and the browntail moth. *Bulletin of the U.S. Department of Agriculture*, 766: 27.

D'Aguilar, J., Riom, J., 1979, *Nemoraea pellucida* (Meigen), a new parasite of *Hyphantria cunea* (Drury). *Bulletin de la Societe Entomologique de France*, 84(7-8): 204-206 [Abstract in *The Review of Applied Entomology*, 1980, 68(8): 3854].

Deseo, K. V., Montermini, A., Cortellini, W., 1986, The first outbreak of the fall webworm (*Hyphantria cunea* Drury; Lepid., Arctiidae) in North Italy: Preliminary observations on the development, diapause and derivation. *Journal of Applied Entomology*, 101: 201-206.

Grichanov, I. Y., Ovsyannikova, E. I., 2003, Interactive Agricultural Ecological Atlas of Russia and neighbouring countries. http://www.agroatlas.ru/en/content/pests/Hyphantria_cunea/. (24.03.2011).

Gyorfi, J., 1954, *Hyphantria cunea* (Drury). *Erdeszeti Tudomanyos Intezet Evkonyve*, *Budapest*, 2: 183-198.

Herting, B., 1960, Biologie der westpaläarktischen Raupenfliegen, Dipt., Tachinidae. *Monographien zur Angewandete Entomologie*, 16: 1-188.

Herting, B., 1984, Catalogue of Palearctic Tachinidae (Diptera). *Stuttgarter Beiträge zur Naturkunde*, *Serie A (Biologie)*, 369: 1-228.

Herting, B., Dely-Draskovits, A., 1993, *Family Tachinidae*. *In*: Soós, Á., Papp, L. (Eds.). Catalogue of Palaearctic Diptera. Hungarian Natural History Museum, Budapest, 13: 118-458.

Ichiki, R., Nakamura, S., 2007, Oviposition and immature development of the parasitoid fly *Compsilura concinnata* (Meigen) (Diptera: Tachinidae). *Japan Agricultural Research Quarterly*, 41: 227-232.

Ichiki, R., Shima, H., 2003, Immature life of *Compsilura concinnata* (Meigen) (Diptera: Tachinidae). *Annals of the Entomological Society of America*, 96: 161-167.

Iren, Z., 1977, *Onemli Meyve Zararlilari, Tanimlari, Zararlari, Yasayislari ve Mucadele Metodlari*. Zirai Mucadele ve Zirai Karantina Genel Mudurlugu. Ankara Bolge ve Zirai Mucadele Arastirma Enstitusu Yayinlari, Mesleki Eserler Serisi, Ankara, 36: 165 pp.

Isik, M., Yanilmaz, A. F., 1992, Studies on natural enemies and control measures of the fall webworm (*Hyphantria cunea* Drury. Lep.: Arctiidae) in hazelnut plantation in Samsun. *Karadeniz Tarimsal Arastirma Enstitusu, Samsun, Zirai Mucadele Arastirma Yilligi*, 22-23 (1987-1988): 55-58. (Abstract).

Japoshvili, G., Nikolaishvili, A., Dzneladze, N., Goguadze, L., 2006, The fall webworm (*Hyphantria cunea*) in western Georgia. *Proceedings of the Georgian Academy of Science, Biological Series*, *B,* 4(4): 122-126.

Jermy, T., 1957, Contributions to the knowledge of the tachinids parasitising the larvae of *H. cunea*. *Annals of the Hungarian Plant Protection Institute,* 7(1952-56): 253-262, Budapest [Abstract in *The Review of Applied Entomology*, 1959, 47: 4].

Kalule, T., Wright, D. J., 2002, Tritrophic interactions between cabbage cultivars with different resistance and fertiliser levels, cruciferous aphids and parasitoids under field conditions. *Bulletin of Entomological Research*, 92: 61-69.

Kara, K., Tschorsnig, H. P., 2003, Host catalogue for the Turkish Tachinidae (Diptera). *Journal of Applied Entomology*, 127: 465-476.

Kim, C. W., Noh, Y. T., Kim, J. I., 1968, Study on the natural enemies proper in Korea attacking fall webworm, *Hyphantria cunea* Drury. *Entomological Research Bulletin,* 4: 17-36 [Abstract in *The Review of Applied Entomology*, 1974, 62: 3642].

Koch, R. L., Hutchinson, W. D., 2011, *Compsilura concinnata*, VegEdge: Vegetable IPM resource for the midwest. University of Minnesota. http://www.vegedge.umn.edu/vegpest/beneficials/Comps.htm. (12.12. 2011).

Mellini, E., 1963, Studi sui Ditteri Larvevoridi. XI. *Nemoraea pellucida* (Meig.) su *Spilarctia lubricipeda* L. (Lepidoptera: Arctiidae). *Bollettino dell'Istituto di Entomologia della Università di Bologna*, 26 (1962): 241-273.

Mouloudis, S., Vassilaina-Alexopoulou, P., Papadogeorgopoulos, F., Mourikis, P. A., 1980, The presence of *Hyphantria cunea* (Drury) Lepidoptera: Arctiidae in Greece. *Annales de l'Institut Phytopathologique Benaki*, 12(2): 253-255.

Muckstein, P., Tschorsnig, H. P., Vanhara, J., Michalkova, V., 2007, New host and country records for European Tachinidae (Diptera). *Entomologica Fennica*, 18: 179-183.

Mueller-Beilschmidt, D., 1990, Toxicology and environmental fate of synthetic pesticides. *Journal of Pesticide Reform*, 10(3): 32-37.

Nanni, C., 1991, Activity of indigenous entomophagous species against *Hyphantria cunea*. *Informatore Fitopatologico,* 41: 15-21.

Niimura, T., 1949, *Hyphantria cunea* Dr. or the fall webworm as a newcomer to Japan. *National Science Museum,* Tokyo, Bulletin 25.

Nurieva, I., 2002, Bioecological abilities of parasitoids parasitising *Hyphantria cunea* Drury (Lepidoptera, Arctiidae) in Azerbaijan. *Proceedings of the Fifth Turkish National Congress of Biological Control,* 4-7 September 2002, Erzurum, Turkiye,161-166.

O'Hara, J. E., 2009, Taxonomic and host catalogue of the Tachinidae of America north of Mexico. http://www.nadsdiptera.org/Tach/CatNAmer/Home/CatNAmerhom.htm. (22.10.2011).

O'Hara, J. E., 2010, World genera of the Tachinidae (Diptera) and their regional occurrence. Version 5.0. PDF document, pp. 74. *http://www.nadsdiptera.org/Tach/Genera/Gentach_ver5.pdf. 04.05.2011.*

Poong, L. H., Kim, O. S., Kim, J. T., 1981, Studies on natural enemies parasiting overwintering fall webworm pupae, *Hyphantria cunea* Drury and way of protection for parasitoids. *Korean Journal of Entomology,* 11(2): 11-16.

Rauh, V., Garfinkel, R., Perera, F., Andrews, H., Hoepner, L., Barr, D., Whitehead, R., Tang, D., Whyatt, R., 2006, Impact of prenatal Chlorpyrifos exposure on neurodevelopment in the first 3 years of life among inner-city children. *Pediatrics*, 118(6): 1845-1859.

Rezaei, V., Moharramipour, S., Talebi, A. A., 2003, The first report of *Psychophagus omnivorus* (Walker) and *Chouioia cunea* (Yang) parasitoid wasps of American white webworm *Hyphantria cunea* Drury (Lep.: Arctiidae) from Iran. *Applied Entomology and Phytopathology*, 70(2): 137-138.

Richter, V. A., 1996, On the fauna of tachinids (Diptera, Tachinidae) of the Crimea. *Entomologicheskoe Obozrenie*, 75: 908-929.

Sazonov, A. P., Karetnikova, I. N., Novozhilov, K. V., 1984, *The sterilant effect of diflubenzuron using Hyphantria cunea as an example. In:* Novozhilov, K. V. (Ed.). Regulyatory rosta i razvitiya nasekomykh v bor'be s sel'skokhozyaistvennymi vreditelyami. Vsesoyuznyi Nauchno-issledovatel'skii Institut, Leningrad, USSR. *Zashchita Rastenii*, 54-58.

Shafer, T. J., Meyer, D. A., Crofton, K. M., 2005, Developmental neurotoxicity of Pyrethroid insecticides: Critical review and future research needs. *Environmental Health Perspectives*, 113(2): 123-136.

Sharov, A. A., Izhevskiy, S. S., 1987, The parasitoid complex of the American white butterfly *Hyphantria cunea* (Drury) (Lepidoptera, Arctiidae) in the south of the European part of the USSR. *Entomologicheskoe Obozrenie*, 66(2): 290-298 [Abstract in *Entomological Review*, 7(1): 48-56].

Shellhorn, N. A., Harmon, J. P., Andow, D. A., 2000, *Using cultural practices to enhance insect pest control by natural enemies. In*: Rechcigl, J. E., Rechcigl, N. A. (Eds.). Insect Pest Management: Techniques for Environmental Protection, CRC Press, Boca Raton, FL, USA, 147-170.

Shi, Y. S., 1981, *Exorista japonica* - a natural enemy of the fall webworm *Hyphantria cunea* Drury. *Acta Entomologica Sinica*, 24: 342.

Shima, H., 2006, A host-parasite catalog of Tachinidae (Diptera) of Japan. *Makunagi/Acta Dipterologica Supplement,* 2: 1-171.

Sikura, A. I., Fedosov, S. A., Vovk, T. I., 1988, Synthetic pyrethroids in the control of *Hyphantria cunea*. *Zashchita Rastenii*, 5: 40.

Steedle, J. L. M., van Loon, J. J. A., 2003, Dietary specialization and infochemical cues in carnivorous arthropods: testing a concept. *Entomologica Experimentalis et Applicata*, 108: 133-148.

Sullivan, G. T., Karaca, I., Ozman-Sullivan, S. K., Kolarov, J., 2010, Ichneumonid (Hymenoptera) parasitoids of overwintering *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae) pupae in hazelnut plantations of the central Black Sea region of Turkey. *Zootaxa*, 2608: 63-68.

Swain, R. B., 1937, The parasites of the fall webworm *Hyphantria cunea* Dr. (Lep.: Arctiidae). *Entomological News,* 48(9): 244-248.

Szalay-Marzso, L., 1972, Biology and control of the Fall webworm (*Hyphantria cunea* Drury) in the Middle- and East European Countries. *Organisation Europeenne et Mediterranneene Pour la Protection des Plantes*, 3: 25-35 [Abstract in *The Review of Applied Entomolog*y, 1973, 61(3): 702].

Takasu, K., Lewis, W. J., 1995, Importance of adult food sources to host searching of the larval parasitoid Microplitis croceipes. *Biological Control*, 5: 25-30.

Tscharntke, T., 2000, *Parasitoid populations in the agricultural landscape. In:* Hochberg, B. E., Ives, A. R. (Eds.). Parasitoid Population Biology. Princeton University Press, Princeton, 235-253.

Tschorsnig, H. P., Herting, B., 1994, Die Raupenfliegen (Diptera: Tachinidae) Mitteleuropas: Bestimmungstabellen und angaben zur verbreitung und ökologie der einzelnen arten. *Stuttgarter Beiträge zur Naturkunde (A)*, 506: 1-170. Online authorized version of English translation by Rayner, R., Raper, C.: Tschorsnig H. P., Herting, B., 2001: The Tachinids (Diptera: Tachinidae) of Central Europe: Identification keys for the species and data on distribution and ecology. http://tachinidae.org.uk/site/downloads.php. (24.06.2010).

Tschorsnig, H. P., Herting, B., 2001, The Tachinids (Diptera: Tachinidae) of Central Europe: Identification Keys for the Species and Data on Distribution and Ecology. http://tachinidae.org.uk/site/downloads.php. (23.10.2010).

Tschorsnig, H. P., Richter, V. A., Cerretti, P., Zeegers, T., Bergström, C., Vaňhara, J., Van de Weyer, G., Bystrowski, C., Raper, C., Ziegler, J., Hubenov, Z., 2005, *Tachinidae*. *In*: Fauna Europaea Service, 1.2 (www document). *http://www.faunaeur.org*. (17.05.2011).

Tuncer, C., 1992, *Amerikan Beyaz Kelebegi (Hyphantria cunea Drury, Lepidoptera: Arctiidae)'nin Samsun ve cevresindeki biyolojisi ve ozellikle konukcu bitkilerin degisik acilardan etkileri uzerinde arastirmalar*. Doktora Tezi, Ankara Universitesi, Fen Bilimleri Enstitusu, Ankara, 149.

Varjas, L., Sehnal, F., 1973, Use of a juvenile hormone analogue against the fall webworm, *Hyphantria cunea*. *Entomologia Experimentalis et Applicata,* 16(1): 115-122.

Vet, L. E. M., Dicke, M., 1992, Ecology of infochemical use by natural enemies in a tritrophic context. *Annual Review of Entomology*, 37: 141-172.

Warren, L. O., Tadic, M., 1967, The fall webworm, *Hyphantria cunea*, its distribution and natural enemies. A world list (Lepidoptera: Arctiidae*). Journal of the Kansas Entomological Society,* 40(2): 194-202.

Warren, L. O., Tadic, M., 1970, The fall webworm, *Hyphantria cunea* (Drury). *Arkansas Agricultural Experiment Station Bulletin*, 759: 1-106.

Watanabe, M., 2005, Parasitism and over-wintering status of tachinids (Diptera) on larvae of the fall webworm, *Hyphantria cunea* Drury (Lepidoptera: Arctiidae), in the Kanto Region of Japan. *Applied Entomology and Zoology*, 40(2): 293-301.

Yaman, M., Nalcacioglu, R., Demirbag, Z., 2002, Studies on bacterial flora in the population of the fall webworm, *Hyphantria cunea* Drury. (Lep., Arctiidae*). Journal of Applied Entomology*, 126(9): 470-474.

Yang, Z. Q., Wang, X. Y., Wei, J. R., Qu, H. R., Qiao, X. R., 2008, Survey of the native insect natural enemies of *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae) in China. *Bulletin of Entomological Research*, 98(3): 293-302.

Ziegler, J., 1990, Zur Kenntnis der Wirtsbeziehungen paläarktischer Raupenfliegen (Dipt., Tachinidae). 7. Beitrag. *Entomologische Nachrichten und Berichte*, 34: 140-141.

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