Response of aphidophagous hoverflies (Diptera, Syrphidae) to herbicide in winter wheat

Hussein Sadeghi Namaghi

Sadeghi, H. (2007): Response of aphidophagous hoverflies (Diptera, Syrphidae) to herbicide in winter wheat. – Volucella 8, 125-134. Stuttgart.

The primary approach used for reducing weeds in wheat fields is the application of broadleaf-selective herbicides, which could have important implications for the arthropod community in this crop. The objective of this study was to identify the influence of herbicides on the abundance of aphidophagous hoverflies as well as aphids in wheat fields. To do this, a 20-ha wheat field was divided into six equal-sized plots. A broadleaf- selective herbicide was applied to three of these, and the other three plots were not treated with herbicide. All other agricultural practices were the same during the season. Weekly sampling of the aphids and hoverflies for eight weeks showed a greater number of both immature and adult syrphids in the untreated plots. As expected, there were more aphids in the herbicide treatment than in the control. It is not clear, however, whether these can be explained by differences in the density and diversity of weeds.

Key words: herbicide, hoverflies, aphids, wheat, Syrphidae.

Zusammenfassung

Zur Bekämpfung von Unkräutern in Weizenfeldern werden überwiegend Herbizide gegen zweikeimblättrige Pflanzen eingesetzt, die große Auswirkungen auf die Arthropodengemeinschaft haben können. Ziel dieser Arbeit war, den Einfluss der Herbizide sowohl auf die Häufigkeit aphidophager Schwebfliegen als auch auf die der Blattläuse in Weizenfeldern zu untersuchen. Dazu wurde ein 20 Hektar großes Weizenfeld in sechs gleich große Probeflächen unterteilt, von denen drei mit Herbiziden behandelt wurden, während drei unbehandelt blieben. Alle anderen ackerbaulichen Maßnahmen waren dieselben. Acht Wochen lang wurden wöchentlich Blattläuse und Schwebfliegen erfasst. In den unbehandelten Flächen waren sowohl Imagines als auch Larven von Schwebfliegen häufiger als in den behandelten. Wie erwartet, war in den mit Herbizid behandelten Flächen die Blattlausdichte größer. Allerdings ist ungeklärt, ob dies nicht durch Unterschiede in der Dichte und Vielfalt des Unkrauts zu erklären ist.

Introduction

Several factors influence crop production. Among them, weeds are an important constraint in most crops across the world. As a result, a huge research effort has been carried out to improve weed control. Marshall et al. (2003) note that in recent years more money has been spent by growers on weed control than other crop inputs. For example, in 2000 the global pesticide market was valued $29 billion, of which 48% was spent on herbicides. Improved crop management techniques including herbicides have resulted in good control of weeds and steadily increasing crop yields, but reducing the abundance of many weed species may affect associated insects and other taxa. In the UK, the decline of the grey partridge (*Perdix perdix*) has been linked to the increased use of herbicide which reduces preferred food through direct toxicity to arthropods as well as their host plants (Freeman & Boutin 1995). Although herbicides were not expected to harm insects significantly, at least some have been shown to affect them in several ways. Reviewing the literature on the side-effects of 2-4-D, for example, Cox (1999) notes that oat fields treated with 2-4-D amine had more aphids than expected due to a reduction in ladybird numbers (Coccinellidae). In a laboratory study 2-4-D reduced successful egg hatch of the beneficial ichneumonid, *Pimpla turionella* (Hymenoptera). She also gave some examples of the effects of herbicides on insects damages to crops: in a field study the number of corn-leaf aphids was twice as great on treated corn plants compared with untreated ones, and stem corn-borers were also more abundant. Reviewing the literature, Marshall et al. (2003) conclude that "weeds have a role within agroecosystems in supporting biodiversity more generally".

One of the commonest approaches used for reducing weeds in wheat fields in Iran is the application of a broadleaf-selective herbicide, usually 2-4-D or Granstar DF 75%. According to Baqestani & Zand (2003), over a period of 10 years (1980-1990) herbicide-treated areas in Iran increased from 500,000 ha up to 2 million ha. Despite this increased usage of herbicides in Iran, there has been no attempt to investigate the ecological effects of these chemicals, especially the interaction between chemical control of weeds and beneficial predatory insects.

Syrphids have been demonstrated to have considerable potential as biological control agents of aphids. For example, Chambers et al. (1983, 1985) showed that aphidophagous hoverflies have the potential of slowing aphid multiplication, limiting maximum population size and halting aphid population growth. While the larvae of many species are aphid feeders, the adults feed on nectar and pollen from flowering plants. Dixon (1959) studying the oviposition behaviour of Syrphidae, notes that the likelihood of a female syrphid visiting an area of plants is probably dependent upon the number, colour and type of flowering plants in the area. Once attracted into an area, the search for a potentially successful oviposition site depends upon the capacity of a female to find an area with aphid-infested plants. The olfactory stimuli provided by aphids elicit alighting and oviposition responses in gravid females of syrphid species. Most investigations of predator and parasitoid foraging behaviour have been concerned with the interaction with prey and host, and have overlooked the important interaction with non-prey food (Jervis & Kidd 1996). It is therefore important for effective pest management of aphids to understand the effects of reducing floral resources to aphidophagous hoverflies, and consequently to aphids.

Materials and Methods

Study site: This study was conducted at the Research and Educational Farm of the Agricultural College of Ferdowsi University, Mashhad, an area of about 200 ha located 5 km east of Mashhad (N.E.Iran). The experiment was carried out with two treatments in a 20-ha winter-wheat field. This field was surrounded by a road on one side and areas of bare ground on the other sides. The experimental field was divided into six equal-sized plots, three of them were treated with Granstar, a broadleaf-selective herbicide (applied at a rate of 15 g/ha), hereafter is referred to as herbicide treatment and the other three plots were not treated with herbicide, referred to as the control treatment. All other agricultural practices during the season were the same in all treatments. A week before herbicide application, weed determination was done at species level when possible. The main weed species in sampled wheat field were: *Stellaria media* (L.) Vill., *Rapistrum rugosum* (L.) All, *Polygonum aviculare* L., *Descurainia sophia* (L.) Prantl, *Convolvulus arvensis* L., *Sinapis arvensis* L., *Chenopodium album* L., *Cardaria draba* (L.) Desv., *Acroptilon repens* (L.) Dc., *Sonchus oleraceus* L., *Centaura* spec., *Alhagi camelorum* Fisch., *Daturea stramonium* L., *Portulaca oleracea* L., *Phalaris minor* Retz., *Secale cereale* L., *Avena fatua* L., *Cynodon dactylon* (L.) Pres., *Setaria* spp., *Cyperus rotundus* L. Overall, weed cover in untreated plots was less than 1% and the crop was dominating the canopy.

Study organisms: The hoverflies (Diptera, Syrphidae) are a well-known very large family of true flies (Thompson & Rotheray 2000). One monophyletic clade (Rotheray & Gilbert 1989) consists of homopteran predators as larvae, with most members concentrating on aphid prey (Rotheray 1989, Rojo et al. 2003). The adults are very active insects. They occur commonly throughout the spring, summer and autumn. The adults spend most of their time visiting many flowers, especially Asteraceae, Rosaceae and Umbelliferae in large numbers. By visiting fruit blossoms, some are important pollinators of fruit trees.

Sampling methods: Sampling started one week after herbicide application. Samples were taken at approximately weekly intervals and continued for 8 weeks. For each sample, 50 randomly chosen tillers were carefully cut down and examined for aphids and immature stages of aphidophagous hoverflies (i.e. larvae and pupae). To estimate the population density of adult syrphids, on the day of weekly sampling when walking in a straight line inside each plot, the number of observed adult syrphids during a 20-minute period was recorded. All samples were taken between 9-12 a.m. on sunny, clear days.

Identification: Aphids were identified using Hodjat & Azmayeshfard (1987) and Blackman & Eastop (2000). The names of identified aphid species in this study are given below. In the case of syrphids, all syrphids were recorded to species or genus. Where identification to species in the field was not possible the insect was caught, preserved in 75% ethanol and brought to the laboratory for identification (Sadeghi 2002, Thompson & Rotheray 2000, Stubbs & Falk 1996, Shtakelberg 1988). Names of the Syrphidae follow Peck (1988), those of the aphids follow Eastop & Hille Ris Lambers (1975), and those of the plants follow Rashed Mohassel et al. (2002) and Mabberley (1997).

Statistical analysis: To normalize the data, square-root transformation was applied prior to analysis by RMANOVA. To determine the influence of the herbicide, time, and the herbicide by time interaction on the abundance of hoverflies and aphids, the data were analysed with a 2-Way Repeated Measures Analysis of Variance on two factors: herbicide and control were considered as treatments and time (sampling date) which were repeated 7 times. The means differences were compared using Student Newman-Keuls (SNK) test.

Results

The hoverflies abundance and composition

Absolute number of syrphids recorded in each treatment and plot in standard census walk and examining standard samples is given in table 1. The number of adult syrphids observed in the control and herbicide treatments were significantly different (table 2) over the entire sampling period of seven weeks. Repeated measures analysis of variance indicated a significant interaction between treatment and the date of sampling ($p<0.01$). On nearly all sampling dates, the number of adult hoverflies observed in control plots were more than those on the herbicide plots (fig. 1). With some exceptions (e.g., 2nd & 4th sampling dates), the number of flies in both treatments steadily increased over the experimental period. The peak of adult hoverflies occurred on 24 May, with 92 and 142 individuals per sample in herbicide and control treatments respectively. After the 24th May, the number of flies decreased, probably as the amount of nectar and pollen diminished. The hoverflies found in the study site were: *Sphaerophoria scripta* (L.), *Episyrphus balteatus* (DeGeer), *Eupeodes corollae* (Fab.), *Syrphus ribesii* (L.), *Eupeodes nuba* (Wied.), *Syrphus vitripennis* (Meigen), *Paragus bicolor* (Fab.), *Sphaerophoria rueppellii* (Wied.) and *Paragus tibialis* (Fall.). Among them, the most abundant species were *Sphaerophoria scripta* (31%), *Episyrphus balteatus* (21%) and *Eupeodes corollae* (23%).

The abundance of immature (larvae and pupae) syrphids on wheat at the study site throughout the sampling period are shown in fig. 2. As seen in this figure, the number of larvae and pupae of syrphids in the control treatment (except on 26th April) was more than those in the herbicide treatment. A total of 163 and 81 immature syrphids were collected over entire sampling period in the control and herbicide treatments (these were not significantly different as determined by the repeated measures analysis of variance,

Sampling date	Herbicide treatment			Control treatment			
	Plot 1	Plot 2	Plot 3	Plot 1	Plot 2	Plot 3	
19 April	2	0	2	2	10	16	A
26 April	2	5	8	28	32	24	
3 May	9	7	8	30	33	27	
10 May	5	6	8	18	12	17	
17 May	4	5	4	20	24	17	
24 May	31	20	38	86	102	121	
31 May	76	92	102	152	142	131	
19 April	1	0	0	1	1	0	B
26 April	4	1	7	3	1	2	
3 May	4	10	7	12	8	6	
10 May	3	8	5	11	18	7	
17 May	7	3	5	14	25	8	
24 May	1	4	7	3	11	9	
31 May	0	2	6	6	3	8	

Table 1: Absolute number of syrphids (A: adults; B: immatures) recorded in each treatment and plot in standard samples once per week from 19 April to 31 May 2004.

Source of Variance	DF†	MS††		
		Adult Syrphids	Imm. Syrphids	Aphids
Subject	2	0.629	0.217	1.65
Treatment	1	83.142***	4.902^{ns}	29.26^{ns}
Treatment × subject	2	0.192	1.073	17.47
Date	6	45.652**	4.729**	105.09**
Date × subject	12	0.305	0.748	4.60
Treatment × date	6	2.028**	0.738^{ns}	8.96^{ns}
Residual	12	0.571	0.312	6.04
Total	41	9.302	1.293	21.45

Table 2: The Two Way Repeated Measures Analysis of Variance on two factors: treatments (herbicide, control) and time (sampling date) which were repeated 7 times in 2004.
** = p< 0.5, *** = p < 0.01, ns = non significant. † = degrees of freedom. †† = mean square.

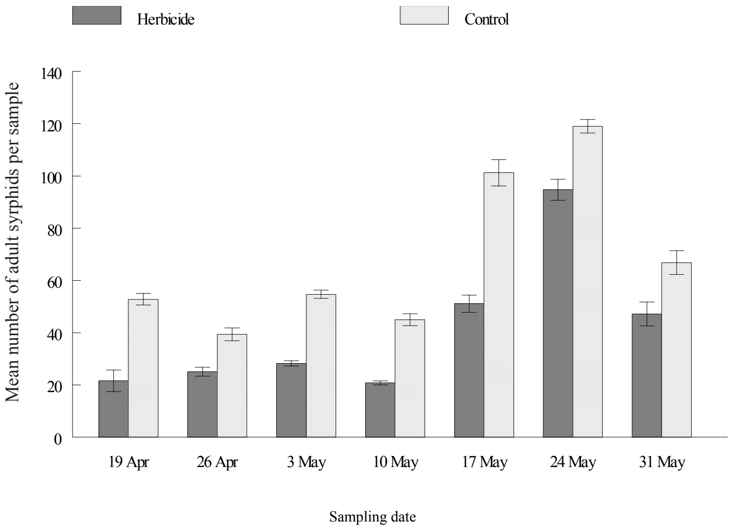

Fig.1: Number of adult Syrphidae (mean ± se)*) in sampled wheat field in Mashhad (NE Iran), 2004. Each sample consisted of 20 mins observation along a transect within the plot. Data were square-root transformed prior to analysis by ANOVA. – *) = multiplied by 10.

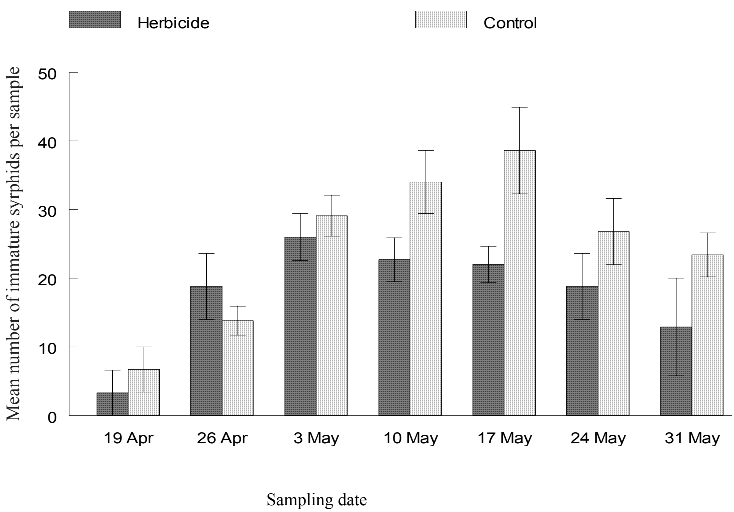

Fig.2: Abundance (mean ± se)*) of immature syrphids (i.e. larvae & pupae) in wheat fields in Mashhad (NE Iran), 2004. Each sample consisted of 50 randomly chosen tillers. Data were square-root transformed prior to analysis by ANOVA. – *) = multiplied by 10.

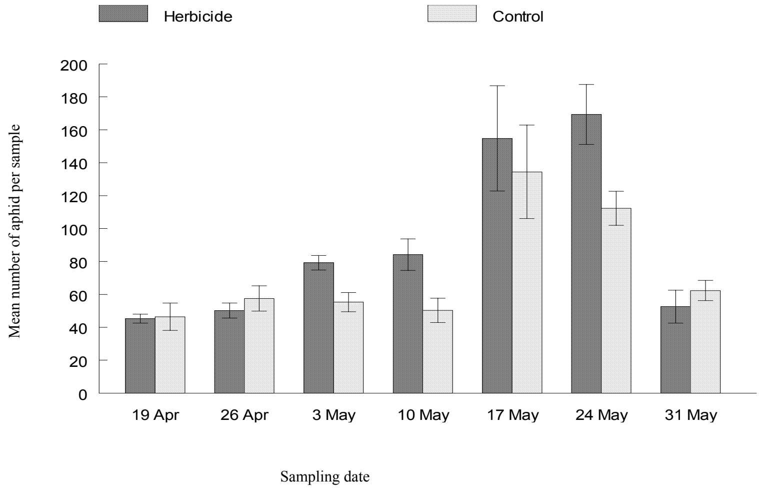

Fig. 3: Abundance (mean ± se)*⁾ of aphids in wheat that was treated/untreated with herbicide in Mashhad, (NE Iran), 2004. Each sample consisted of 50 randomly chosen tillers. Data were square-root transformed prior to analysis by ANOVA. – *⁾ = (mean± se) multiplied by 10.

table 1). Larvae and pupae of all syrphid species considered collectively. Overall, very few pupae were found compared with the number of larvae. The total population of syrphid larvae and pupae relative to the number of aphids present was very low.

The aphid abundance and composition

Aphid availability and the mean number per sample in wheat field are shown in fig. 3. The aphid population in both treatments gradually increased prior to late May, but from that date the number of aphids decreased, probably due to approaching the harvest time and adverse quality of host plants. Overall, the number of counted aphid per sample in herbicide treatment was not significantly greater than that in the control ($p = 0.325$). Also, the interaction between the treatments, and the sampling dates was not significant ($p = 0.264$). Among the aphid species found in the study site, *Sitobion avenae* (Fab.) (51%) was the most abundant aphid, followed by *Metapolophium dirrhodum* (Walker) (21%) and *Schizaphis graminum* (Rondani) (13%). Populations of other species – *Diuraphis noxia* (Mordvilko), *Rhopalosiphum padi* (L.), *Rhopalosiphum maidis* (Fitch), and *Sipha maydis* (Passerini) – were very low (15%).

Discussion

It is not clear whether the differences in hoverfly abundance between treatments can be explained by the differences in density or diversity of weed species. This study did not analysis for a correlation between weed species and their population with the Syrphidae and aphids, so we can not show the differences between treated plots and weedy check. However, we observed that the used herbicide had no effect on grass weeds, and also little effect on some weed species such as *Convolvulus arvensis*, *Cardaria draba*, *Acroptilon repens* and *Alhagi camelorum*.

However, if the presence of weeds within cereals enhances biological control of aphids by larvae of aphidophagous hoverflies, it would be expected that there would be more hoverflies of all developmental stages and fewer aphids in untreated plots compared with herbicide-treated plots. Although there were more syrphids in the control plots, there was no apparent effect of the herbicide on the abundance of aphids on wheat plants. We must bear in mind that more syrphids in the control treatment do not necessarily translate into a biologically significant improved level of aphid control which allows us to eliminate the need for the application of pesticides.

Increased numbers of adult syrphids in herbicide treatments especially towards end of season might be due to the fact that towards late May, some weeds flowered within the herbicide-treated plots and this may have contributed to the attractiveness of this treatment to the adult syrphids, increasing their numbers in the herbicide treatments. Another possible explanation is the higher population density of aphids in the herbicide treatment, which we expect to elicit alighting and oviposition responses in gravid syrphid females.

The presence of weeds in a crop may influence the abundance of adult syrphids in two ways: by altering the optical attractiveness of the crop to ovipositing females; and by providing alternative oviposition sites. However, some authors (e.g. Chandler 1968) have shown that the presence of flowers has no effect on the oviposition activity of Syrphidae. Powell et al. (1984) studying the influence of weeds on insect communities in winter wheat, found that the number of cereal aphids was unaffected in a herbicide treatment. Fuente et al. (2003) found also that the application of herbicide in wheat fields had a lower impact on insect distribution than other agronomic variables. These conflicting results may be explained by the fact that some hoverflies have been shown to be selective in the flowers they visit (Colley & Luna 2000).

This study can not conclude that application of herbicide in wheat fields has no significant influence on the abundance of aphidophagous hoverflies and consequently on aphid populations. More detailed work on this matter is required.

Hoverflies have been shown to be selective in the flowers they visit (Colley & Luna 2000). Among the weeds present in the control treatment, the following species were visited frequently by adult syrphids: *Stellaria media*, *Rapistrum rugosum*, *Convolvulus arvensis*, *Sonchus oleraceus*, and *Polygonum aviculare*.

This study did not evaluate the impact of weed competition on crops, or the relative attractiveness of these weeds to hoverflies. However, some of these weeds might be considered as attractive to insects and hence worth being cautious about their complete removal from crops, especially in cases such as *Stellaria media* that harbours over 70 insect species and is not a strong competitor with crops (Marshall et al. 2003). Using beneficial "insectary plants" in agroecosystems is considered to be a strategy to enhance the effectiveness of natural enemies for biological pest control (e.g. Colley & Luna 2000). However, it should be noticed that some flowering plants might be attractive to both pests and beneficial insects. Thus understanding the relationship between weeds and insects needs more detailed studies.

Acknowledgement

I wish to express my gratitude to Dr Francis Gilbert (Nottingham,UK) for his valuable comments on the manuscript. Special thanks go to Dr Mahdi Nasiri for help with analysing data. I also thank the authorities of Research Farm of Agricultural College of Ferdowsi University for providing research facilities and the students who helped with field sampling. This study was financially supported by Ferdowsi University of Mashhad who is gratefully thanked.

References

Baqestani, M.A.; Zand, S.(2003): Weeds in wheat fields: challenges and perspective. – Journal of Nehadeh 18, 11-17. [in Persian]

Blackman, R.L.; Eastop,V.F. (2000): Aphids on the World's Crops: an identification and information guide, 2nd ed. 466 p. Chichester (John Wiley and Sons).

Chambers, R.J.; Sunderland, K.D.; Wyatt, I..J.; Vickerman, G.P. (1983): The effects of predators exclusion and caging on cereal aphids in winter wheat. – Journal of Applied Ecology 20, 209-224.

Chambers, R.J.; Sunderland, K.D.; Stacey, D.L.; Wyatt, I.J. (1985): Control of cereal aphids in winter wheat by natural enemies: aphid-specific predators, parasitoids and pathogenic fungi. – Annals of Applied Biology 108, 219-231.

Chandler, A.E.F. (1968): Some factors influencing the occurance and site of oviposition by aphidophagous Syrphidae (Diptera). – Annals of Applied Biology 61, 435-446.

Colley, M.R.; Luna, J.M. (2000): The relative attractiveness of potential beneficial insectary plants to aphidophagous hoverflies (Diptera: Syrphidae). – Environmental Entomology 29, 1054-1059.

Cox, C. (1999): 2-4-D: Ecological Effects. – Journal of Pesticide Reform 19(3), 14-18.

Dixon, T.J. (1959): Studies on oviposition behaviour of Syrphidae (Diptera). – Transactions of the Royal Entomological Society London 111, 57-81.

Eastop, V.F.; Hille Ris Lambers, D. (1975): Survey of the World's Aphids. 573 p. The Hague, The Netherlands (W. Junk).

Freeman, K.; Boutin, C. (1995): Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscape: A review with special reference to North America. – Agriculture, Ecosystem & Environment 52, 67-91.

Fuente, E.B.; Suárez, S.A.; Ghersa, C.M. (2003): Weed and Insect Communities in Wheat Crops with Different Management Practices. – Agronomy Journal 95, 1542-1549.

Hodjat, S.H.; Azmayeshfard, P. (1987): Aphids on grasses in Iran. – Iranian Journal of Applied Entomology & Phytopathology 54, 83-109.

Jervis, M.A.; Kidd, N.A. C. (1996): Phytophagy. – In: Jervis, M.A.; Kidd, N. (eds.): Insect natural enemies: practical approaches to their study and evaluation, p. 375-394. London (Chapman and Hall).

Mabberley, D.J.(1997): The Plant book. 2nd ed. 588 p. Cambridge (Cambridge University Press).

Marshall, E.J.P.; Brown, V.K.; Boatman, N.D.; Lutman, P.J.W.; Square, G.R.; Ward, L.K. (2003): The role of weeds in supporting biological diversity within crop fields. – European Weed Research Society, Weed Research 43, 77-89.

Peck, L.V. (1988): Syrphidae - Conopidae. – In: Soós, A.; Papp, L. (eds.): Catalogue of Palaearctic Diptera 8, 11-230. Amsterdam (Elsevier).

Powell, W.; Dean, G.J.; Dewar, A.(1985): The influence of weeds on polyphagous arthropod predators in winter wheat. – Crop Protection 4(3), 298-312.

Rashed Mohassel, M.H.; Najafi, H.; Akbarzadeh, M.(2002): Weed Biology and Control. 404 p. Mashhad, Iran (Ferdowsi University Press). [in Persian]

Rojo, S.; Gilbert, F.; Marcos-Garcia, M.A.; Nieto, J.M.; Mier, M.P. (2003): A World review of predatory hoverflies (Diptera, Syrphidae) and their prey. 319 p. Alicante (Centro Iberoamericana de Biodiversidad).

Rotheray, G.E. (1989): Aphid predators. 81p. Naturalists Handbook 11. Slough (Richmond Pub.)

Rotheray, G.E.; Gilbert, F. (1989): The phylogeny and systematics of European predacious Syrphidae (Diptera) based on larval and puparial stages. – Zoological Journal of the Linnean Society 95, 29-70.

Sadeghi, H. (2002): A part of the hoverflies (Diptera: Syrphidae) fauna of Mashhad region and a key to the genera. – Journal of Agriculture and natural resources 9(3), 119-127. [in Persian]

Shtakelberg, A.A. (1988): Family Syrphidae. – In: Bei-Bienko, G. Ya. (ed.): Keys to the insects of the European part of the USSR. Vol. V (part II). Washington D.C. (Smithsonian Institution Libraries and The national Science Foundation)

Stubbs, A.E.; Falk, S.J.(1996): British Hoverflies: an illustrated Identification Guide. 469 p. London (British Entomological & History Society).

Thompson, F.C.; Rotheray, G. (2000): Family Syrphidae. – In: Papp, L.; Darvas, B. (eds.): Contributions towards a manual of Palearctic Diptera 3, 81-139. Budapest (Academic Press).

Author's adress:

Dr Hussein Sadeghi Namaghi, Dept. Plant Protection, College of Agriculture, Ferdowsi, University of Mashhad, Iran. E-mail: Husseinsadeghi@Yahoo.co.uk