Thaiszia - J. Bot., Košice, 21: 185-205, 2011
http://www.bz.upjs.sk/thaiszia

THAISZIA
JOURNAL OF
BOTANY

Predatory and parasitic insects in greenhouses of Botanical Garden of P.J.Šafárik University in Košice, Slovakia

MARTIN SUVÁK

Botanical Garden of P.J. Šafárik University in Košice, Mánesova 23, 043 52 Košice, martin.suvak@upjs.sk

Suvák M. (2011): Predatory and parasitic insects in greenhouses of Botanical Garden of P.J.Šafárik University in Košice, Slovakia. – Thaiszia – J. Bot. 21: 185-205. – ISSN 1210-0420.

Abstract: The paper deals with predatory and parasitoid insect taxa registered in Botanical Garden of P.J. Šafárik University in Košice in greenhouses after excluding the use of broad-spectrum pesticides since April 2006. Special attention is paid to species occurring spontaneously, i.e. those ones which invade greenhouses from outdoors or are accidentally introduced by humans. The intentionally released biological control agents are also mentioned. This preliminary survey presents some observations on natural pest control without, or with only occasional, direct human interventions against the most important pests of plants in greenhouses. On the other hand, natural enemies of beneficial species also occurred here, including several cases of hyperparasitic relations. These preliminary results indicate some successive changes in predatory and parasitic insect species composition in complex environment of heated greenhouses with a mix of tropical, subtropical and temperate flora during 6 years. Some species are interesting also from faunistic viewpoint.

Keywords: biological control, botanical gardens, greenhouses, predators, parasitoids, artificial ecosystems

Introduction

Botanical Garden of Pavol Jozef Šafárik University in Košice (hereinafter BG PJŠU) was founded in 1950. Its first greenhouses were built in 1955 and from that time hundreds of tropical and subtropical plant species were planted here

(MOCHNACKÝ 2001). Problems with pests and diseases of these plants were managed mostly with the use of broad-range pesticides. As a result, the environment inside greenhouses was very adverse for natural biological control. But in the last 10 years, the principles of integrated pest management started to be implemented here with using antagonistic relations known between wide spectrum of species occurring in nature (BELLOWS & FISHER 1999). Amounts of applied pesticides were continually reduced and, since April 2006, biological control methods have been used in several selected greenhouses along with complete abandonment of classical pesticides to the date. Some commercially available biological control agents were intentionally released here but overall improvement of environmental conditions was connected also with spontaneous occurrence of many other arthropod species. Next to the new pests and indifferent species, some beneficial predatory and parasitic/parasitoid organisms also occurred here.

The spectrum of pest species known in greenhouses of BG PJŠU is relatively wide (SUVÁK, unpublished data), the most important ones are as follows: mites (especially spider mites *Tetranychus urticae* Koch 1836 (Trombidiformes: Tetranychidae), sometimes also *Polyphagotarsonemus latus* (Banks 1904) (Trombidiformes: Tarsonemidae)), whiteflies (Hemiptera: Aleyrodidae, especially *Trialeurodes vaporariorum* Westwood 1856 and *Bemisia tabaci* (Gennadius,1889)), several species of aphids (Hemiptera: Aphididae), especially *Aphis gossypii* Glover, 1877, *Aulacorthum solani* (Kaltenbach, 1843), *Brachycaudus helichrysi* (Kaltenbach, 1843), *Macrosiphum euphorbiae* (Thomas, 1878), *Macrosiphoniella sanborni* (Gillette, 1908), *Myzus persicae* (Sulzer, 1776) and *Myzus ornatus* Laing, 1932 (but sometimes also other aphid species), mealy bugs (Hemiptera: Pseudococcidae, mostly *Planococcus citri* (Risso 1813) above ground and representatives of the genus *Rhizoecus* Kunckel d'Herculais, 1878 on roots), soft scales (Hemiptera: Coccidae, especially *Coccus hesperidum* Linnaeus, 1758 and *Saissetia coffeae* (Walker, 1852)), thrips (Thysanoptera: Thripidae, mostly *Echinothrips americanus* Morgan, 1913 with its first Slovak record just in greenhouses of BG PJŠU (VARGA & FEDOR 2008) and *Frankliniella occidentalis* (Pergande, 1895)). The most important non-arthropod pests are slugs (Gastropoda). A lot of less important pest or indiferent arthropod species can be often visible here too, e.g. flies (Diptera: Sciaridae, Chironomidae, Ephydridae, Drosophilidae, Psychodidae), barkflies (Psocoptera: Ectopsocidae), springtails (Collembola), millipedes (Diplopoda), various Chelicerata, woodlice (Oniscidea), and others. Without pesticide suppression, also natural enemies of the mentiond animals started to occurr here successively.

Material and methods

Regular monitoring of plant health, pests and their natural enemies was carried out within heated greenhouses of BG PJŠU continually since 2006 (though some records were also older). Both the populations of commercially available biological control agents released in greenhouses and the populations of other species of natural enemies of pests were monitored. The attention was

focused on insect species which expressed themselves as effective regulators of the mentioned groups of pests. But other predators and parasitoids (including hyperparasitoid species) from greenhouses were also recorded. Several complementary methods were used: visual observation, macrophotography, sticky traps, sampling of plant parts and insect individuals and rearing parasitoid species from host samples. Subsequent determination according to specialized keys took place in laboratory conditions. The more or less specialized determination literature was used for Coleoptera (BALTHAZAR 1957), Diptera (DOSKOČIL 1977, GREGOR et al. 2002), Hymenoptera (BAJÁRI & MÓCZÁR 1969, BOUČEK 1957, DALLA TORRE & KIEFFER 1910, GRAHAM 1969, MACEK 1995, PUJADE-VILLAR et al. 2007, TRJAPITZIN 1978a, 1978b), Hemiptera (HOBERLANDT 1959), Neuroptera (BARTOŠ 1959) and Orthoptera (KOČÁREK et al. 2005). In some cases the help of specialists mentioned in Acknowledgements was greatly appreciated.

Results and discussion

In comparison with previous periods, classical pesticides were almost totally avoided from the observation areas in 2006 - 2011. Next to the intentionally released species, a lot of predatory and parasitic insect taxa were registered within greenhouses (though some individual records were known here even before 2006). Many of them occurred in this area only occasionally, mainly as seasonal invaders from outside areas. In the next survey, only the selected taxa with higher abundance (at least seasonally), or otherwise interesting taxa, are mentioned (Tab. 1). The most important biological control agents belonged to 4 insect orders: Coleoptera, Diptera, Hemiptera and Hymenoptera. Some predators from the orders Neuroptera and Orthoptera were also registered. However, also natural enemies of pests were suppressed in higher trophic levels of food chain.

Coleoptera

Ladybirds (Coccinellidae) are very effective predators of many plant sap sucking hemipteran insects like aphids, mealybugs, scales, whiteflies etc. For that reason, some ladybird species are successfully used in biological control of many serious pests of cultivated plants in the world. In BG PJŠU, two species were released by growers: *Adalia bipunctata* (Fig. 1c,d) (sometimes also some individuals got into greenhouses from outside) against aphids and *Cryptolaemus montrouzieri* (Fig. 1a,b), specialized Australian ladybird agaist mealybugs (especially *Planococcus citri*). From time to time, several other ladybird species suppressing plant pests occurred in greenhouses of BG PJŠU. In higher numbers, *Harmonia axyridis* (Fig. 1e,f) was found locally within aphid populations (one case in the greenhouse with citrus plants in summer 2011) and tiny ladybird *Clitostethus arcuatus* (Fig. 1g) was observed eating eggs of whiteflies (more observations in several years, often on *Cyphomandra betacea* (Solanaceae) leaves infested with whiteflies).

Tab. 1. List of predatory and parasitic insect species registered in BG PJŠU

Taxa of predatory and parasitic insects	Prey or host	Date of introduction (with number of individuals) or *date of first record of spontaneous occurrence	Characteristics from biol.control viewpoint**			
			1	2	3	4
Coleoptera						
Coccinellidae						
Adalia bipunctata (Linnaeus, 1758)	aphids	27.4.2006 (1000)	pr	d, l	d, l	+
Clitostethus arcuatus (Rossi, 1794)	whiteflies	*9.3.2007	pr	l	l	+
Cryptolaemus montrouzieri Mulsant, 1853	mealybugs	5.5.2006 (125), 18.5.2007 (500), 15.2.2008 (125), 2.4.2009 (50), 12.2.2010 (25), 31.3.2010 (25), 16.6.2010 (75), 13.4.2011 (75)	pr	d	d	+
Harmonia axyridis (Pallas, 1773)	aphids	*2.6.2009	pr	l	h-l	+, -
Staphylinidae						
Holobus flavicornis (Lacordaire in Boisduval & Lacordaire, 1835)	mites	*31.8.2010	pr	l	m	+
Carabidae						
Carabus coriaceus Linnaeus, 1758	ground invertebrates	*cca 2004	pr	m	m	+
Diptera						
Cecidomyiidae						
Aphidoletes aphidimyza (Rondani, 1847)	aphids	*27.2.2008	pr	m	h-m	+
Feltiella acarisuga (Vallot, 1827)	mites	*27.2.2008	pr	l	m	+
Dolichopodidae						
Dolichopus signifer Haliday, 1838	small invertebrates	*6.7.2011	pr	l	l	+
Dolichopus nr. exscisus	small invertebrates	*28.1.2011	pr	l	l	+
Chrysotus nr. suavis	small invertebrates	*11.8.2011	pr	l	l	+
Medetera veles Loew, 1861	small invertebrates	*25.8.2006	pr	h-m	h-m	+
Medetera sp.	small invertebrates	*18.2.2005	pr	m	m	+
Rhaphium sp.	small invertebrates	*23.5.2007	pr	l	l	+
Muscidae						
Coenosia atra Meigen, 1830	flying insects	*10.7.2006	pr	l	l	+

Tab. 1. – cont.

Taxa of predatory and parasitic insects	Prey or host	Date of introduction (with number of individuals) or *date of first record of spontaneous occurrence	Characteristics from biol.control viewpoint**			
			1	2	3	4
Coenosia attenuata Stein, 1903	flying insects	*11.2.2005	pr	h	h-l	+, (-)
Coenosia humilis Meigen, 1826	flying insects	*25.2.2008	pr	l	l	+
Coenosia rufipalpis Meigen, 1826	flying insects	*27.3.2009	pr	l	l	+
Coenosia testacea (Robineau-Desvoidy, 1830)	flying insects	*21.2.2008	pr	l	l	+
Coenosia tigrina (Fabricius, 1775)	flying insects	*23.5.2007	pr	l	l	+, -
Coenosia sp.	flying insects	*19.2.2009	pr	l	l	+
Lispocephala brachialis (Rondani, 1877)	small invertebrates	*8.3.2007	pr	l	l	+
Syrphidae						
Baccha elongata (Fabricius, 1775)	aphids	*27.3.2009	pr	l	l	+
Episyrphus balteatus (De Geer, 1776)	aphids	*8.2.2008	pr	m	m	+
Eupeodes corollae (Fabricius, 1794)	aphids	*11.8.2011	pr	l	l	+
Platycheirus albimanus (Fabricius, 1781)	aphids	*27.9.2011	pr	l	l-m	+
Scaeva pyrastri (Linnaeus, 1758)	aphids	*16.8.2011	pr	l	l	+
Sphaerophoria scripta (Linnaeus, 1758)	aphids	*27.9.2011	pr	l	l	+
Hemiptera						
Anthocoridae						
Orius laevigatus (Fieber, 1860)	thrips	27.4.2006 (500), 3.8.2007 (500), 15.2.2008 (1000)	pr	d	d	+
Miridae						
Dicyphus errans (Wolff, 1804)	aphids	*22.3.2007	pr	l-m	l-m	+ (-)
Macrolophus caliginosus Wagner, 1951	whiteflies	5.5.2006 (1000)	pr	d	d	+
Myrmecoris gracilis (J. Sahlberg, 1848)	aphids	*22.3.2007	pr	l	l	+
Nabidae						
Nabis rugosus (Linnaeus, 1758)	small insects	*26.7.2006	pr	l	l	+

Tab. 1. – cont.

Taxa of predatory and parasitic insects	Prey or host	Date of introduction (with number of released individuals) or *date of first record of spontaneous occurrence	Characteristics from biol.control viewpoint** 1	2	3	4
Hymenoptera						
Cynipoidea						
Figitidae						
Alloxysta victrix (Westwood, 1833)	parasitised aphids	*29.11.2006	hy	h	h-l	-
Alloxysta sp.	parasitised aphids	*6.7.2011	hy	l	l	-
Leptopilina heterotoma (Thomson, 1862)	fruit flies	*4.8.2009	pa	l-m	m	0
Phaenoglyphis villosa (Hartig, 1841)	parasitised aphids	*31.10.2011	hy	m	l-m	-
Chalcidoidea						
Aphelinidae						
Encarsia citrina (Craw, 1891)	scales	*4.6.2010	pa	h	h-m	+
Encarsia formosa Gahan, 1924	whiteflies	27.4.2006 (15000), 5.5.2006 (15000), 18.5.2006 (15000), 24.5.2006 (15000), 9.6.2006 (15000), 15.6.2006 (15000), 18.5.2007 (7500), 25.5.2007 (7500), 15.6.2007 (15000), 14.3.2008 (3000), 20.3.2008 (3000), 31.3.2008 (3000), 2.4.2009 (15000), 12.2.2010 (3000), 24.2.2010 (3000), 2.3.2010 (3000), 16.6.2010 (1500), 23.6.2010 (1500), 30.6.2010 (1500), 10.2.2011 (3000), 17.2.2011 (3000), 25.2.2011 (3000), 6.5.2011 (1500), 18.5.2011 (1500), 25.5.2011 (1500)	pa	d	d	+
Eretmocerus eremicus Rose & Zolnerowich, 1997	whiteflies	18.5.2007 (7500), 25.5.2007 (7500), 16.6.2010 (1500), 23.6.2010 (1500), 30.6.2010 (1500), 6.5.2011 (1500), 18.5.2011 (1500), 25.5.2011 (1500)	pa	d	d	+
Coccophagus lycimnia (Walker, 1839)	soft scales	*27.9.2011	pa	l	l	+
Encyrtidae						
Anagyrus pseudococci (Girault, 1915)	mealybugs	3.6.2010 (100), 13.4.2011 (1500)	pa	d	d	+

Tab. 1. – cont.

Taxa of predatory and parasitic insects	Prey or host	Date of introduction (with number of individuals) or *date of first record of spontaneous occurrence	Characteristics from biol.control viewpoint**			
			1	2	3	4
Coccidoxenoides perminutus Girault, 1915	mealybugs	*28.5.2007	pa	m	l-m	+
Encyrtus aurantii (Geoffroy, 1785)	soft scales	*4.6.2008	pa	h	h	+
Encyrtus infelix (Embleton, 1902)	soft scales	3.6.2010 (100)	pa	d	d	+
Leptomastix dactylopii Howard, 1885	mealybugs	*24.5.2007; 3.8.2007 (1000), 31.3.2010 (200), 3.6.2010 (100)	pa	d, m	d, m-l	+
Metaphycus helvolus (Compere, 1926)	soft scales	*3.6.2010 (50)	pa	d, l	d, l-m	+
Eulophidae						
Eulophus pennicornis Nees, 1834	moths	*21.7.2011	pa	l	l	+
Pteromalidae						
Asaphes vulgaris Walker, 1834	parasitised aphids	*14.10.2011	hy	m	m	-
Pachyneuron aphidis (Bouché, 1834)	parasitised aphids	*6.7.2011	hy	m	l-m	-
Pachyneuron formosum Walker, 1833	syrphid flies	*23.11.2011	hy	l	l	-
Ichneumonoidea						
Braconidae						
Aphidius colemani Viereck, 1912	aphids	5.5.2006 (2500), 24.5.2006 (1000), 18.5.2007 (500), 15.2.2008 (1000), 27.2.2009 (1500)	pa	d, h	d, l-h	+
Aphidius ervi Haliday, 1834	aphids	15.2.2008 (1000)	pa	d, l	d, m	+
Praon sp.	aphids	*16.11.2006	pa	m	l-h	+
Ichneumonidae						
Diplazon laetatorius (Fabricius, 1781)	syrphid flies	*11.8.2011	pa	m	l	-
Diplazon tetragonus (Thunberg, 1822)	syrphid flies	*7.10.2011	pa	l	l	-
Formicoidea						
Formicidae						
Camponotus fallax (Nylander, 1856)	small invertebrates	*21.7.2006	pr	l	l	+, -
Dolichoderus quadripunctatus (Linnaeus, 1771)	small invertebrates	*cca 2007	pr	l	l	+, -
Hypoponera schauinslandi (Emery, 1899)	ground invertebrates	*9.9.2004	pr	h	h	+

Tab. 1. – cont.

Taxa of predatory and parasitic insects	Prey or host	Date of introduction (with number of individuals) or *date of first record of spontaneous occurrence	Characteristics from biol.control viewpoint**			
			1	2	3	4
Lasius brunneus (Latreille, 1798)	small invertebrates	*12.1.2007	pr	m	l-h	+, -
Lasius emarginatus (Olivier, 1791)	small invertebrates	*11.2.2005	pr	h	l-h	+, -
Lasius flavus (Fabricius, 1781)	small invertebrates	*20.11.2009	pr	l	l	+, -
Lasius niger (Linnaeus, 1758)	small invertebrates	*21.9.2006	pr	m	l-h	+, -
Myrmica rubra (Linnaeus, 1758)	small invertebrates	*cca 2008	pr	l	m	+, -
Temnothorax crassispinus (Karavaiev, 1926)	small invertebrates	*22.3.2007	pr	l	l-h	+, -
Tetramorium caespitum (Linnaeus, 1758)	small invertebrates	*27.12.2007	pr	m	m-h	+, -
Proctotrupoidea						
Diapriidae						
Synacra paupera Macek, 1995	sciarid flies	*1.12.2006	pa	m	l-h	+
Vespoidea						
Vespidae						
Polistes gallicus (Linnaeus, 1767)	invertebrates	*12.1.2007	pr	l	l	+, 0
Vespa crabro Linnaeus, 1758	invertebrates	*2011	pr	l	l	+, 0
Vespula germanica (Fabricius, 1793)	invertebrates	*cca 2008	pr	l	l-m	+, 0
Orthoptera						
Rhaphidophoridae						
Diestrammena asynamora (Adelung, 1902)	invertebrates	*cca 2006	pr	m	m	?
Neuroptera						
Chrysopidae						
Chrysopa sp.	aphids	*cca 2008	pr	l	l-m	+
Hemerobiidae						
Hemerobius sp.	aphids	*27.9.2011	pr	l	l-m	+

** 1 – predator, at least in some stages of life cycle, or polyphagous with occasional predatory activity (pr), parasitoid (pa), hyperparasitoid (hy)
2 – frequency of occurrence (records of species in time and space): dependent on supply (d); without introduction usually high (h), medium (m), low (l)
3 – density of occurrence (individuals in a site): dependent on supply (d); without introduction usually high (h), medium (m), low (l)
4 – relation to pest control: negative (-), positive (+), indifferent (0), questionable (?)

Fig. 1. Selected predatory beetles (Coleoptera) in greenhouses of BG PJŠU: a) *Cryptolaemus montrouzieri* (imago), b) *C. montrouzieri* (larva), c) *Adalia bipunctata* (imago), d) *A. bipunctata* (larva), e) *Harmonia axyridis* (imago), f) *H. axyridis* (larva), g) *Clitostethus arcuatus*, h) *Holobus flavicornis*. Scale bar: 1 mm.

Some other beetle families were also represented in greenhouses by predatory species but observations were relatively rare. Tiny rove beetles (Staphylinidae) of the species *Holobus flavicornis* (Fig. 1h) were found feeding on phytophagous mites (*Tetranychus urticae*) on *Erythrina* sp. (Fabaceae). Regularly, the dead individuals of big carabid beetles *Carabus coriaceus* were found on the ground area of greenhouses. They probably feeded also on slugs but direct observations were missing due to night activity of the mentioned species.

Diptera

Though no dipteran species of commercially available biological control agents were intentionally released in greenhouses of BG PJŠU, several very effective pest regulators occurred here in spite of it. Predatory larvae of *Aphidoletes aphidimyza* (Fig. 2a) (Cecidomyiidae) and *Episyrphus balteatus* (Fig. 2c,d) with other Syrphidae were often found feeding on aphids. Sometimes also larvae of *Feltiella acarisuga* (Fig. 2b) (Cecidomyiidae) fed on spider mites.

Representatives of Dolichopodidae (Fig. 2f-h) and Muscidae:Coenosiinae (Fig. 3a-h) are usually carnivorous both as imagoes on vegetation and as larvae in soil. Especially abundant are *Coenosia attenuata* (Muscidae) and *Medetera veles* (Dolichopodidae). *C. attenuata* is an effective predator of flying insects with interesting behaviour and wide spectrum of prey species (SUVÁK 2008a), this fly was recorded in Slovakia for the first time just in greenhouses of BG PJŠU (SUVÁK 2008b). Next to the so far registered *Coenosia* species (Tab. 1, Fig. 3), it is possible that some other species known from immediate vicinity of greenhouses could get indoors, e.g. *C. agromyzina*, sometimes very abundant outside. Finding of *M. veles* here was also the first Slovak record of this species (POLLET 2009). Several other Dolichopodidae species were observed in greenhouses feeding on small insects and mites on natural (leaves, tree bark) and artificial surfaces (glass, pots, tin plates).

Hemiptera

Two species of predatory bugs from the family Anthocoridae (*Orius laevigatus*, Fig. 4b) and Miridae (*Macrolophus caliginosus*, Fig. 4a) were intentionally released within greenhouses. *O. laevigatus* was used against thrips. There were observed predatory activities against adults and preimaginal stages of *Echinothrips americanus* mainly on *Acalypha hispida* plants but these predatory bugs usually were not able to stay in greenhouses too long after releasing in space. *M. caliginosus* was locally applied against whiteflies. In comparison with the previous species, this predatory bug was observed on the monitored plant (*Cyphomandra betacea*) long time after releasing, it suggested the formation of stable population there but after all also this bug species disappeared from greenhouses.

Several other predatory bug species from the family Miridae (*Dicyphus errans*, Fig. 4d, and *Myrmecoris gracilis*, Fig. 4c) and Nabidae (*Nabis rugosus*) were also observed in greenhouses, especially on plants infested with aphids, but their occurrences were only occasional.

Fig. 2. Selected dipteran predators in greenhouses of BG PJŠU: a) larvae of *Aphidoletes aphidimyza*, b) larva of *Feltiella acarisuga* c) *Episyrphus balteatus* (imago), d) *E. balteatus* (larva), e) *Scaeva pyrastri*, f) *Medetera* sp., g) *Medetera veles*, h) *Dolichopus signifer*. Scale bar: 1 mm.

Fig. 3. Representatives of predatory flies from the family Muscidae, the subfamily Coenosiinae in greenhouses of BG PJŠU: a) *Coenosia atra*, b) *Coenosia attenuata*, c) *Coenosia humilis*, d) *Coenosia rufipalpis*, e) *Coenosia testacea*, f) *Coenosia tigrina*, g) *Coenosia* sp., h) *Lispocephala brachialis*. Scale bar: 1 mm.

Fig. 4. Selected predatory bugs (Heteroptera) as natural enemies of pests in greenhouses of BG PJŠU: a) *Macrolophus caliginosus*, b) *Orius laevigatus*, c) *Myrmecoris gracilis*, d) *Dicyphus errans*. Scale bar: 1 mm.

Hymenoptera

Parasitic hymenopteran insects are considered to be the most important biological control agents. Most pest species are related to their specific hymenopteran parasitoid species and these relations are well known and used. It is the reason of mass rearing of the selected parasitic wasps by specialized producers. Some of these species were bought and released in BG PJŠU: *Encarsia formosa* (Aphelinidae) (Fig. 5a) and *Eretmocerus eremicus* (Aphelinidae) (Fig. 5c) against whiteflies, *Leptomastix dactylopii* (Encyrtidae) (Fig. 6e) (it occurred also spontaneously in advance) and *Anagyrus pseudococci* (Encyrtidae) (Fig. 6a) against mealybugs, *Encyrtus infelix* (Encyrtidae) (Fig. 6d) and *Metaphycus helvolus* (Encyrtidae) (Fig. 6f) against soft scales (mainly *Saissetia coffeae*) and *Aphidius colemani* (Braconidae) (Fig. 7c) and *Aphidius ervi* (Braconidae) against aphids.

Next to them, 3 other important parasitoid species were introduced to greenhouses probably with infested plant material: *Coccidoxenoides perminutus* (Encyrtidae) (Fig. 6b) on young larvae of mealybugs, *Encarsia citrina* (Aphelinidae) (Fig. 5b) parasitising small stages of soft scales (both *Saissetia* and *Coccus hesperidum* scales) and *Encyrtus aurantii* (Encyrtidae) (Fig. 6c) attacking older stages of soft scales (especially *Coccus hesperidum*). Successful examples of regulation of some of these serious sedentary pests on leaves are presented in Figs. 8-10.

Fig. 5. Aphelinidae in greenhouses of BG PJŠU: a) *Encarsia Formosa*, b) *Encarsia citrina*, c) *Eretmocerus eremicus*, d) *Coccophagus lycimnia*. Scale bar: 1 mm.

Some parasitoid species of aphids commonly occurring outdoors were also sometimes registered within greenhouses. They were mainly representatives of the subfamily Aphidiinae (Braconidae), especially *Praon* sp. with its characteristic type of aphid mummy.

Several individuals of *Eulophus pennicornis* (Eulophidae) (Fig. 7a), parasitoid species on Lepidoptera larvae, were seen probably with relation to the caterpillars of *Phlogophora meticulosa* on *Pelargonium* plants or *Pieris brassicae* on decorative *Brassica* plants in the same greenhouse at the same time.

Other less important pest species were also parasitised by specialized hymenopteran parasitoids, e.g. fungus gnats (Diptera: Sciaridae, namely *Bradysia paupera*) by *Synacra paupera* (Diapriidae) (Fig. 7d). Preimaginal stages of fruit flies (Diptera: Drosophilidae) were attacked by *Leptopilina heterotoma* (Figitidae) (Fig. 7b – female laying eggs into larvae of *Drosophila* sp. in a white mass of old fruit of banana species *Musa velutina*).

Predatory hymenopteran taxa in greenhouses were represented especially by ants (Formicidae). Several species of ants were registered in greenhouses of BG PJŠU, most abundant ones were *Lasius niger*, *Lasius emarginatus* and *Hypoponera schauinslandi*. Though ants are usually considered as undesired insects supporting sap-sucking hemipterans (aphids, scales, etc.), predatory activity of some species can be sometimes significant and it was observed also in the case of 3 species mentioned above (e.g. Fig. 7f with larvae of *Lasius emarginatus* feeding on aphids brought to them by workers). Especially non-

native *H. schauinslandi* is a typical predator of subterranean non-vertebrates (e.g. Fig. 7e, where 2 workers attacked a sciarid larva) but many workers of this species were also observed collecting immobile stages of thrips (*E. americanus*) and whiteflies on fallen leaves.

Fig. 6. Representatives of Encyrtidae in greenhouses of BG PJŠU: a) *Anagyrus pseudococci*, b) *Coccidoxenoides perminutus*, c) *Encyrtis aurantii*, d) *Encyrtus infelix*, e) *Leptomastix dactylopii*, f) *Metaphycus helvolus*. Scale bar: 1 mm

Most of other ant species mentioned in Tab. 1 were probably brought into greenhouses with decorative wood pieces for epiphytic plants or with leaf mould from forest park of BG PJŠU. Despite of it, these workers were observed very long time and they were active even in winter, though usually only in very small numbers or individually (*Camponotus fallax*, *Dolichoderus quadripunctatus*, *Temnothorax crassispinus*). Another case was *Lasius brunneus* with 2 separate

nest sites in tropical greenhouses with continual activity of workers observed several years. The unusual behaviour was seen also in workers of *Lasius flavus*, usually subterranean species, on leaves of potted plants with aphids relatively high above ground (cca 0.5 m). *Tetramorium caespitum* and *Myrmica rubra* were found also feeding on sweet liquid produced by sap-sucking Hemiptera on leaves of plants.

Wasps (Vespidae) sometimes fly into greenhouses but no predatory activity has been seen so far, only licking exsudates of Hemiptera on leaves. Interesting case was a queen of *Pollistes gallicus* active in winter season, but more frequent were workers of *Vespa crabro* and *Vespula germanica* here in summer.

Fig. 7. Other selected parasitoid and predatory hymenopteran species in greenhouses of BG PJŠU: a) *Eulophus pennicornis* (Eulophidae), b) *Leptopilina heterotoma* (Figitidae), c) *Aphidius colemani* (Braconidae), d) *Synacra paupera* (Diapriidae), e) *Hypoponera schauinslandi* (Formicidae), f) *Lasius emarginatus* (larvae) (Formicidae). Scale bar: 1 mm.

Fig. 8. Development of infestation of *Saissetia coffeae* on a single leaf of *Asplenium nidus*. (Polypodiales: Aspleniaceae) The same part of a leaf photographed on 30.4.2010, 8.6.2010, 2.9.2010 and 4.3.2011 (from left to right).

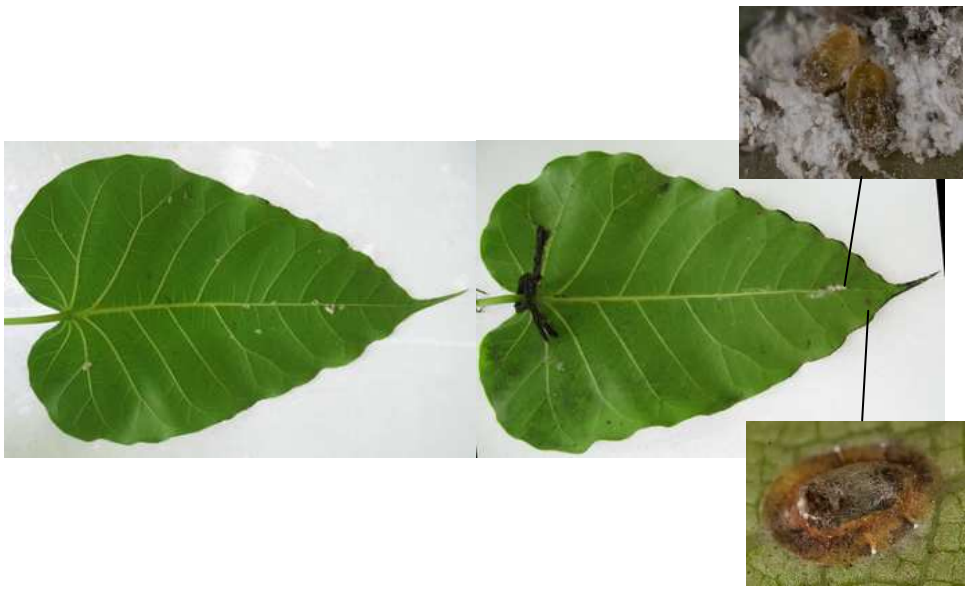

Fig. 9. Development of infestation caused by mealybugs *Planococcus citri* and soft scales *Coccus hesperidum* on a single leaf of *Ficus* sp. (Rosales: Moraceae). The same leaf photographed on 17.3.2011 and 10.8.2011 (from left to right). Details of mealybugs parasitized probably by *Anagyrus pseudococci* (top right) and a soft scale after parasitation by *Encyrtus aurantii* (bottom left) are magnified.

Fig. 10. Development of infestation of *Coccus hesperidum* on a single leaf of *Annona* sp. (Magnoliales: Annonaceae). Young stages of *C. hesperidum* were parasitised by *Encarsia citrina*, the older ones by *Encyrtus aurantii*. The same leaf photographed on 6.5.2010, 8.6.2010, 2.9.2010 and 4.3.2011 (from left to right).

Hyperparasitic species and parasitoids attacking species of biological control agents should be mentioned separately. In contrary with previously mentioned species, their role in biological control is usually negative. There were registered Figitidae hyperparasitoids on aphids – *Alloxysta victrix* (Fig. 11a), at least 1 other *Alloxysta* sp. and *Phaenoglyphis villosa* (Fig. 11b) - new record of this species for Slovakia not published to the date. Aphid hyperparasitoids from the family Pteromalidae were represented by *Asaphes vulgaris* (Fig. 11e) and *Pachyneuron aphidis* (Fig. 11c). All these taxa reduced the populations of primary aphid parasitoids, especially of *Aphidius* and *Praon* species from the family Braconidae. Preimaginal stages of Syrphidae on leaves were attacked by *Pachyneuron formosum* (Pteromalidae) and by 2 Ichneumonidae parasitoid species (*Diplazon laetatorius*, Fig. 11f, and *D. tetragonus*).

Orthoptera

Typical synanthropic greenhouse species *Diestrammena asynamora* is relatively abundant in BG PJŠU. But due to mostly night activity of this species, no direct observations on predatory behaviour were done. Though several individuals were captured on sticky traps on trunks of plants infested by sap-sucking Hemiptera.

Neuroptera

From time to time, characteristic eggs (*Chrysopa* sp.) on plant parts or individual larvae (*Chrysopa* sp., *Hemerobius* sp.) feeding on aphids were found but no imagoes were collected so far.

Fig. 11. Aphid hyperparasitoids (a, b, c, e) and parasitoids of aphidophagous Syrphidae (d, f) registered in greenhouses of BG PJŠU: a) *Alloxysta victrix* (Figitidae) b) *Phaenoglyphis villosa* (Figitidae), c) *Pachyneuron aphidis* (Pteromalidae), d) *Pachyneuron formosum* (Pteromalidae), e) *Asaphes vulgaris* (Pteromalidae), f) *Diplazon laetatorius* (Ichneumonidae). Scale bar: 1 mm.

Conclusions

BG PJŠU is the only botanical garden in Slovakia with the wide use of biological control of pests. Highly concentrated plant diversity in greenhouses is related to the wide spectrum of animal species, including complex problems with various pests. Avoiding pesticides was connected with the change in relevance of individual groups of pests. E.g. serious problems with whiteflies despite high amounts of pesticides in the past was easily solved with *Encarsia formosa* and

other species later. On the other hand, mealebugs and soft scales became more important pest groups today. Not all greenhouses could be implemented in biological control program because the damage caused by pests on some succulent plants could be visible for years and this could not be tolerated. But in most other expositions the relatively slower actions of biological control agents against pests is acceptable.

The other problem with practical biological control in Slovakia is a poor availability of the required biological control agents in comparison with the situation in other botanical gardens in the world (SUVÁK 2004). Some of the required species of commercially available biological control products (common in West Europe) are often impossible to obtain in time, if ever. For those reasons some elements of classical biological control methods with environmental modifications (banker plant system) were applied in greenhouses of BG PJŠU in comparison with more usual augmentative-inundative approach (GURR & WRATTEN 2000). Next to the discussed insect species, there are also other important predators with biological control potential (especially spiders and predatory mites – they will be dealt with in other prepared paper). Several tropical and subtropical greenhouses without using classical pesticides for more than 6 years are confirming examples of possibility of VAN LENTEREN (2000) idea of environmentally friendly cultivation of greenhouse plants. But the complexity of environment in botanical gardens raises the need for more data on occurring animal species and their relations in artificial communities for growers to be more effective in such type of pest management.

The presented list of predatory and parasitic insect taxa in BG PJŠU is by far not complete. But it clearly illustrate very interesting environment in greenhouses of this botanical garden. Next to the practical viewpoint of pest control, it is a unique area to study multiple ecological relationships in environment with unusual combination of wide spectrum of plant and animal species.

Acknowledgements

I would like to express my sincere thanks to each of the entomologists listed here in alphabetical order: Igor Grichanov (Russia), Frank Koehler (Germany), Ján Macek (Czech Republic), Marc Pollet (Belgium) and Roger Thomason (Great Britain) for helping me with determination of some of the discussed species and also for providing me with additional information on them.

References

BAJÁRI E. & MÓCZÁR L. (1969): Furkeszdarazs-alkatuak 4. Ichneumonoidea 4. Fauna Hungariae. 96:1-122.

BALTHASAR V. (1957): Řád Brouci – Coleoptera. Pp. 419-703 In: Kratochvíl J. (Ed.): Klíč Zvířeny ČSR II, Praha, 746 pp.

BARTOŠ E. (1959): Řád síťokřídlí - Neuroptera. Pp. 559-568 In: Kratochvíl J. (Ed.): Klíč Zvířeny ČSR III, Praha, 869 pp.

BOUČEK Z. (1957): 9. nadčeleď Chalcidky – Chalcidoidea. Pp. 204-288 In: Kratochvíl J. (Ed.): Klíč Zvířeny ČSR II, Praha, 746 pp.

BELLOWS T. S. & FISHER T. W. (Eds.) (1999): Handbook of Biological Control: Principles and Applications of Biological Control, Academic Press, San Diego, 1046 pp.
DALLA TORRE K. W. & KIEFFER J. J. (1910): Cynipidae. Das Tierreich, 24. Friedlander & Sohn, Berlin. 891 pp.
DOSKOČIL J. (Ed.) (1977): Klíč zvířeny ČSSR. Díl V. Dvoukřídlí. – Academia. Praha. 373 pp.
GRAHAM, M. W. R. DE V. (1969): The Pteromalidae of north-western Europe (Hymenoptera: Chalcidoidea). Bulletin of the British Museum (Natural History) (Entomology) Supplement 16: 1-908.
GREGOR F., ROZKOŠNÝ R., BARTÁK M. & VAŇHARA J. (2002): The Muscidae (Diptera) of Central Europe. Folia Fac. Sci. Nat. Univ. Masaryk. Brun., Biol., 107: 1-. 280.
GURR, G. & WRATTEN, S. (Eds.) (2000): Biological Control: Measures of Success. Kluwer Academic Publishers, Dordrecht, 430 pp.
HOBERLANDT L. (1959): Řád ploštice - Heteroptera. Pp. 277-386 In: Kratochvíl J. (Ed.): Klíč Zvířeny ČSR III, Praha, 869 pp.
KOČÁREK P., HOLUŠA J. & VIDLIČKA Ľ. (2005): Blattaria, Mantodea, Orthoptera & Dermaptera of the Czech and Slovak Republics. Kabourek, Zlín, 350 pp.
LENTEREN J. C. VAN (2000): A greenhouse without pesticides: fact or fantasy? Crop Protection, 19: 375-384.
MACEK J. (1995): A taxonomic revision of European Psilommina (Hymenoptera: Diapriida). Part 2. The Synacra complex. Eur. J. Entomol., 92: 469 – 482.
MOCHNACKÝ S. (2001): Botanická záhrada Univerzity Pavla Jozefa Šafárika v Košiciach. Edičné stredisko UPJŠ v Košiciach, 85 pp.
POLLET M. (2009): Dolichopodidae new to Slovakia, with one genus new to the Western Palaerctic region. Folia Faunistica Slovaca 14: 143-147.
PUJADE-VILLAR J., PARETAZ-MARTÍNEZ J., SELFA J., SECO-FERNÁNDEZ,M. V., FÜLÖP D. & MELIKA G. (2007): Phaenoglyphis villosa (Hartig 1841) (Hymenoptera: Figitidae: Charipinae): a complex of species or a single but very variable species? Annales de la Société Entomologique de France (2): 169–179.
SUVÁK M. (2004): Používanie biologickej ochrany vo svetových botanických záhradách. Rostlinolékař 15(6): 24-25.
SUVÁK M. (2008a): Drobnička *Coenosia attenuata* – vítaný lovec ve sklenících. Živa LVI (XCIV) (3): 128-130.
SUVÁK M. (2008b): *Coenosia attenuata* can behave like a falconers bird. Diptera info. World Wide Web electronic publication http://www.diptera.info/readarticle.php?article_id=17/ [accessed 04-Apr-2008].
TRJAPITZIN V. A. (1978a): Hymenoptera II., Chalcidoidea, 7. Encyrtidae. Pp. 236-328 In: MEDVEDEV, G. S. (Ed.): Opredeliteli Nasekomykh Evropeyskoy Chasti SSR, T. III. Pereponchatokrylye. Ch. 2, Nauka, Leningrad, 757 pp.
TRJAPITZIN V. A. (1978b): Hymenoptera. II., Chalcidoidea, 13. Eulophidae (excl. Tetrastichinae). Pp. 381-487 In: MEDVEDEV, G. S. (Ed.): Opredeliteli Nasekomykh Evropeyskoy Chasti SSR, T. III. Pereponchatokrylye. Ch. 2, Nauka, Leningrad, 757 pp.
VARGA L & FEDOR P. (2008): First interception of the greenhouse pest *Echinothrips americanus* Morgan, 1913 (Thysanoptera: Thripidae) in Slovakia. Plant Prot Sci 44(4):155–158.

Received: August 17th 2011
Revised: November 30th 2011
Accepted: November 30th 2011