Biology and harmfulness of *Eriosoma* (= *Schizoneura*) *ulmi* (L.) (Aphidinea, Pemphigidae) in elm

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ABSTRACT: The paper deals with the occurrence, development, natural enemies and harmfulness of a heteroecious aphid *Eriosoma* (= *Schizoneura*) *ulmi* (L.) which showed outbreaks in elm *Ulmus glabra* Huds. in Moravia in 2002. At main localities under study in Bílovice nad Svitavou and Brno-Jundrov, the aphid damaged about 63% leaves. Larvae of fundatrices hatched from mid-April and their development from hatching to maturity took about 14 days. Mature fundatrices occurred in May and reproduced for a period of 14 days. Their average physiological fecundity amounted to 311 larvae and ecological fecundity 291 larvae. Migrantes alatae occurred in galls from 18 May to 15 June and their physiological fecundity was about 22 larvae. Leaves were damaged even by 3 galls of an average length of 41 and width 11 mm. Sucking affected on average 11 cm^2, i.e. 27% (in case of the occurrence of 2 or 3 even 100%) leaf area. Natural enemies killed 90% aphids. A bug *Anthocoris confusus* Reut. killing aphids in 80% galls was the most effective control agent. Its eggs occurred from 25 April to 25 May and nymphs from 3 May to 25 June. Larvae of Syrphidae [mainly *Syrphus ribesii* (L.)] killed the aphids in 4 and birds in 6% galls. *E. ulmi* should be considered to be an important occasional pest of orchards and forests.

Keywords: *Eriosoma* (= *Schizoneura*) *ulmi*; *Ulmus* spp.; outbreak; host species; development; gall characteristics; predators; harmfulness

In 2002, a cecidogenous aphid *Eriosoma* (= *Schizoneura*) *ulmi* (L.) showed outbreaks in *Ulmus glabra* Huds. at some localities in Moravia. For example, in a riparian and accompanying stand along the Svitava river, it attacked about 50% leaves in the area between Brno-Obřany and Bílovice nad Svitavou. Leaves of elm trees growing along the Svratka river in Brno-Jundrov and Brno-Pisárky were damaged even more (75%). The outbreak of the aphid was used to study its occurrence, development, natural enemies and harmfulness.

In the Czech Republic (CR), *E. ulmi* is one of the most abundant representatives of a developmentally advanced and economically important family of Pemphigidae (= Eriosomatidae) in elms. The family includes about 250 species. According to HOLMAN and PINTERA (1977), about 40 species occur in the CR. Their amphigonic individuals are apterous showing a reduced mouth and digestive system. In apterous parthenogenetic forms, well-developed wax glands producing wax dust, fibres etc. occur very often. Their antennae are relatively short, 6-segment, in winged individuals mostly with narrowly annular secondary rhinaria. Siphunculi and cauda are not marked or are missing, anal plate is rounded. In the course of the year, great majority of species migrates from primary (main) host plants (woody species) to secondary host plants (grasses, herbs and woody species). Through sucking in primary hosts they usually induce the formation of species-specific galls on shoots, petioles and leaves while in secondary hosts, they live loosely, viz. on roots and underground parts of axes.

E. ulmi has been described under various synonyms, e.g. *Chermes ulmi* L., *Aphis ulmi campestris* Deg., *A. foliorum ulmi* Deg., *Cinara gallarum-ulmi* Rur., *Schizoneura ulmi* Kalt., *S. fodiens* Buckt., *S. grossulariae* Tasch., *S. ampelorrhiza* Del. Guer., *Eriosoma japonicum* Matsum., etc. Numerous authors class the species into a later distinguished genus *Schizoneura* Htg., 1837 (= *Eriosoma* Leach, 1818). The name *Schizoneura ulmi* (L.) was originally applied to species of aphids rolling up leave galls and migrating from elm to various species of *Ribes*. Numerous names are related to the relatively complex developmental cycle. During the cycle, aphids migrate yearly from primary (elm) to secondary hosts (various species of *Ribes* and rarely also *Vitis vinifera* L.). In the development of

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the heteroecious species, the only amphigonic generation (sexuales) alternates with several parthenogenetic generations. In the complete generation cycle (holocycle), seasonal genetically conditioned polymorphism is reflected manifesting itself in several morphologically different types of apterous and pterygote females (so-called morphs).

The developmental cycle of *E. ulmi* begins in spring in the period of elm budbreak. Larvae of fundatrices (1st generation of the aphid) hatch from eggs wintering in fissures of the bark of stems and large branches. After a short rest, larvae travel towards buds and settle on the abaxial face of unfolding leaves. Due to secretions of salivary glands injected into young leaf tissues the lateral edge (more rarely apex) of a leaf blade rolls up downwards thus gradually forming a fusiform leaf roll (pseudogall). Galls are established usually by one, sporadically even several young fundatrices. Under protection of the relatively firm rolled up part of a leaf blade, larvae moult four-times and after the last ecdysis (in May) they mature. Mature fundatrices produce larvae (fundatrigeniae) (2nd generation of the aphid) for a period of 2 to 4 weeks. Fundatrigeniae also moult four-times and after the last moult, winged females of migrantes alatae occur usually in the second half of May and in June.

Migrants leave the galls and fly over mostly to shrubs of *Ribes* spp. On the root collar of the shrub or on the soil surface in the proximity of the root collar, they produce larvae of virginogeniae (exules) (3rd generation of the aphid). The larvae move to thin roots of a diameter of about 1 mm where they suck and after 4 moults they quickly mature. The aphids live on roots loosely (not in galls) under a thick protective layer of wax fibres. On roots of secondary hosts, several (according to JANISZEWSKA-CICHOCKA, 1971 in total 7) generations of virginogeniae develop during summer and at the beginning of autumn (i.e. in the course of about 3 months). The last generation of them is formed by winged females of sexuparae (reemigrantes). Usually in September and October, sexuparae return back to host species of elm and produce larvae of the last generation in fissures of the bark of stems (sporadically also of large branches). These larvae moult 2–3 times and without taking food they mature in males and females of sexuales. Females of this generation lay always the only egg into bark fissures after copulation. Soon after oviposition, they die and their bodies then usually overlap the eggs. According to not very numerous literature data virginogeniae can also winter on roots of *Ribes* spp. (anholocyclic hibernation).

E. ulmi occurs in the predominant part of Eurasia and North America. Unlike the originally non-arctic species *E. lanigerum* (Hsm.) introduced to Europe, *E. ulmi* (similarly as *E. lanuginosum* Htg. and *E. patchae* Börn. et Blunck) has its centre of distribution in the western part of palaearctic region. In the CR, it is abundant wherever its primary and secondary host plants occur. In the large part of its range (including the CR), it often shows outbreaks and causes considerable damages to some species of *Ulmus* and *Ribes*.

Innumerable entomological, aphidological and zoocecidiological papers deal with the occurrence and development of *E. ulmi* in *Ulmus* spp. (and later also in *Ribes* spp.). However, there is a very small number of special papers dealing with biology and harmfulness of the aphid. Its potential migration to roots of *Ribes* spp. mentions for the first LICHTENSTEIN (1884) when he remarks that *Schizoneura fodiens* Bckt., 1981 can be an underground form of *E. ulmi* L. Migration to roots was later confirmed by CHOLODKOVSKY (1896, 1897) and TULLGREN (1909). The dicyclic development of the aphid mention VAN DER GOOT (1915), BÖRNER and BLUNCK (1916), MORDVILKO (1929), BÖRNER (1952), PINTERA (1959), RUPAJS (1961, 1965, 1981, 1989), MATESOVA et al. (1962), NARZIKULOV (1962), BUHR (1965), JANISZEWSKA-CICHOCKA (1965), DANIELSSON (1979), HEIE (1980), BLACKMAN and EASTOP (1994) and many others. CHOLODKOVSKY (1897) for the first time mentioned the aphid in roots of *Vitis vinifera* L. in Crimea and later also e.g. MORDVILKO (1935), BÖRNER and HEINZE (1957), GRIGOROV (1980) etc. noted the species.

JANISZEWSKA-CICHOCKA (1971) reported in detail on the geographical distribution, hosts, development, control factors and harmfulness. Morphology of three species of the genus *Eriosoma* Leach (including *E. ulmi*) and their food preferences in secondary hosts was studied by DANIELSSON (1982). Effects of diluted extracts of *E. ulmi* and some other species of aphids on cut off shoots of host woody species were dealt with by KAZDA (1962). Biology of bugs from the genus *Anthocoris* F. significantly participating in killing *E. ulmi* in galls was studied e.g. by PESKA (1931), LESTON (1954), HILL (1957, 1965), ANDERSON (1962), COLLYER (1967), PIASECKA (1969), PARKER (1984) etc. Parasitoids of the aphid are mentioned e.g. by STARÝ (1966, 1976), TANASIJTSHUK et al. (1976), DESSART and GARDENFORS (1985) etc.

MATERIAL AND METHODS

Main field and laboratory studies were conducted in 2002. Sets of 51 to 100 galls of *E. ulmi* were sampled from *U. glabra* in 2-week intervals near Bílovice nad Svitavou (about 230 m alt.) and in Brno-Jundrov (about 205 m alt.). In Bílovice nad Svitavou, the elms were part of a species-, age- and space-differentiated riparian and accompanying stand of the Svitava river, in Brno-Jundrov they were part of a similar stand of the Svratka river. In 10 main check terms from 8 May to 9 October, 788 leaves with 846 galls were examined (Table 1). At main localities and also elsewhere (e.g. in Brno-Obřany and Brno-Pisárky), partial examinations were carried out in additional terms.

In the laboratory, the content of every gall was evaluated (above all the number, size and health condition of fundatrices and fundatrigeniae). The instar of fundatrices was determined according to the number of exuviae or according to the body size (length and width) measured

Table 1. Number of damages (galls/sucked spots) caused by *Eriosoma* (= *Schizoneura*) *ulmi* including the size of damaged leaves of *U. glabra* and sucked leaf area. Bílovice nad Svitavou (8. 5., 22. 5., 5. 6. and 19. 6.) and Brno-Jundrov (other controls), 2002

Date	Number			Mean length of the leaf blade (cm)	Mean width of the unfolded/ folded blade	Mean area			% sucked area
	leaves	galls/ sucked spots	damage to 1 leaf			leaf blades (cm^2)	sucked by 1 colony of aphids (cm^2)	sucked on 1 leaf (cm^2)	
8. 5.	51	57/1	1.1	5.0	3.3/2.3	(10.0)	?	?	?
22. 5.	100	100/0	1.0	7.2	5.1/3.3	23.0	8.6	8.6	37.4
31. 5.	80	94/0	1.2	8.5	5.9/3.9	36.6	10.9	12.4	33.9
5. 6.	84	84/0	1.0	8.4	5.7/3.5	32.9	11.9	11.9	36.2
19. 6.	84	89/0	1.1	8.6	5.8/3.8	38.3	9.9	10.5	27.4
3. 7.	84	91/1	1.1	10.1	6.2/4.0	46.4	11.1	12.2	26.3
17. 7.	60	62/1	1.1	10.2	6.5/4.1	50.3	12.2	12.6	25.0
14. 8.	84	96/0	1.1	9.9	6.0/3.9	40.8	10.6	12.1	29.7
11. 9.	83	94/1	1.1	10.1	6.2/4.2	45.6	9.8	11.2	24.6
9. 10.	78	79/1	1.0	10.2	6.5/4.7	47.5	8.8	9.1	19.2
Total	788	846/5	–	–	–	–	–	–	–
Mean* (3. 7.–9. 10.)	–	–	1.1	10.1	6.3/4.2	45.8	10.4	11.4	24.9

*Considered checks after completing the growth only

micrometricly. The instar of fundatrigeniae was derived mainly according to the body size. Through the microscopic dissection of died fundatrices, the number of unborn larvae was determined and by means of dissection of living females of migrantes alatae before emergence from galls their physiological fecundity was determined. Considerable attention was paid to natural control factors. The length and width of galls and unfolded leaves were measured. The undamaged and sucked area of leaf blades was determined using planimetry.

The outbreak under study affected well thriving trees free of evident symptoms of Dutch elm disease caused by *Ophiostoma ulmi* (Buism.) Nannf. In the second half of the last century, the mycosis of vascular bundles heavily damaged upland and submontane *U. glabra* including its decorative cultivars which were often planted mainly in warm regions. Perhaps even more serious damages by Dutch elm disease were noticed in *U. minor* occurring in the CR mainly in floodplain forests and warm uplands. Also in *U. minor* growing in riparian and accompanying stands along the Svitava and Svratka rivers, the disease was not observed. However, a cecidogenous aphid *Tetraneura* (= *Byrsocrypta*) *ulmi* L. showed mass outbreak on its leaves.

RESULTS AND DISCUSSION

Host tree species

The most frequent primary host species of *E. ulmi* is *U. glabra* Huds. (BUHR 1965; RUPAJS 1989, etc.). In the elm and in its variety *U. glabra* v. *pendula* Lond is mentioned by JANISZEWSKA-CICHOCKA (1971). According to BAUDYŠ (1954), PINTERA (1959), STEFFAN (1972), DANIELSSON (1982), JASIČ et al. (1984) etc., *U. minor* Mill. and its varieties also belong to the main primary hosts. The aphid occurs only sporadically in *U. americana* L. and *U. laevis* Pall. (BAUDYŠ 1954) or in *U. minor* f. *suberosa* (Moench.) Sóo, *U. procera* Salisb. and *U. pumilla* L. (RUPAJS 1989). According to DANIELSSON (1982), however, the aphid never occurs in *U. laevis.* The broad (though by far not quite complete) spectrum of host species of elms mention BLACKMAN and EASTOP (1994). According to the authors, the aphids develop in *U. glabra* Huds., *U. minor* Mill., *U. laevis* Pall., *U. japonica* (Rehd.) Sarg., *U. americana* L., *U. pumilla* L. *Pinnatoramosa*, *U. procera* Salisb. and *U. thomasii* Sarg. In places where elm died (for example central parts of Siberia), the aphids develop as exules on roots of secondary hosts, i.e. anholocyclic development (MORDVILKO 1929).

At all localities under study in the Brno region, *E. ulmi* showed outbreak in *U. glabra* only. In *U. minor,* the aphid was found only rarely (e.g. in Bílovice nad Svitavou). In an abundantly occurring and rather resistant to Dutch elm disease *U. laevis* the aphid has not been ever detected. Thus, our findings support the opinion of DANIELSSON (1982) on unsuitability of *U. laevis* for the development of *E. ulmi*.

According to DANIELSSON (1982), the main secondary host plants of *E. ulmi* are *Ribes nigrum* L., *R. rubrum* L. and *R. aureum* Pursh. According to the author, the aphid forms small colonies also in *R. sanguineum* Pursh. and *R. uva-crispa* L., however, not in *R. alpinum* L. DANIELSSON (1982) regards as *E. ulmi* a form only which shows brown (no light-green) fundatrigeniae in galls. JANISZEWSKA-CICHOCKA (1971) observed exclusively brown fundatrigeniae in leaf rolls and considers *R. nigrum* L., *R. rubrum* L., *R. alpinum* L., *R. uva-crispa* L. and *R. aureum* Pursh. to be secondary host plants. *Vitis vinifera* L. belongs to rare (according to GRIGOROV 1980, however, nearly exclusive in Bulgaria) secondary hosts. At mountain locations of Tadzhikistan where *Ribes* spp. grow only rarely the aphid has to migrate to other host plants (NARZIKULOV 1962). At studied localities in the Brno region, gardens with abundantly grown *R. nigrum*, *R. rubrum* and *R. uva-crispa* [= *Grossularia uva-crispa* (L.) Mill.] occurred everywhere in the near vicinity of attacked elms.

Fig. 1. Young leaves of *Ulmus glabra* with pseudogalls (rolls) of *Eriosoma* (= *Schizoneura*) *ulmi*. Bílovice nad Svitavou, 8 May 2002

The development of fundatrices

E. ulmi winters as an egg in fissures of bark of stems and large branches of elms. Larvae hatch usually in the second half of April. Eggs protected by a dead body of a female winter best. In spite of this, with respect to high mortality larvae hatch from about 30% eggs only (JANISZEWSKA-CICHOCKA 1971). Light-coloured larvae become dark during about 1 day. Then, they move towards unfolding buds where they settle on the abaxial face of unfolding and newly unfolded leaves. Under more marked incoincidence of budbreak and hatching (for example in the course of late spring and sudden warming) the larvae starve and die. In Bílovice nad Svitavou and Brno-Jundrov, larvae of fundatrices hatched as early as mid April, i.e. roughly in the same time as fundatrices *Tetraneura ulmi* in *U. minor.*

After reaching young leaves, fundatrices begin immediately to suck. Physiologic-biochemical processes in rapidly growing leaves and shoots favourably influence the nutrition of fundatrices. At the beginning of the growing season, however, the largest amount occurs in growing tissues of valuable soluble carbohydrates, aminoacids, vitamins and other biopolymers arising through the conversion of storage starch. In the course of sucking, larvae inject into unfolding leaves secretions of salivary glands. Under the effect of the secretions, leaf blades turn towards the abaxial face under the formation of fusiform pseudogalls (Fig. 1). In the course of 2 weeks from hatching, the larvae moult 4 times and after the 4th ecdysis, they mature. However, leaf rolls are formed already after the 1st ecdysis.

Grown-up fundatrices are on average 3.1 mm long and 2 mm wide before the beginning of reproduction. In the period of life, they are dark-green and densely covered from above by very fine white wax fibres 0.7 to 1.5 mm long (on average 1 mm). Well-developed wax cover of the body is, however, evident already in larvae of the 4th instar. Wax protects larvae against drying up and on a rainy day against wetting. It plays also an important role in protection against parasitoids and predators. A thin wax coat covers liquid excrements of aphids immediately after secretion. Colourless globular droplets of excrements begin to occur in galls more abundantly as late as the occurrence of the 4th instar. The droplets are at first very tiny (diameter about 0.05 mm). With the increase of fundatrices they increase to 0.1–0.5 mm or merge reaching then a diameter of even 3 mm. A fine wax dust isolates excrements and together with the body wax coat protects aphids against staining by excrements.

According to VAN DER GOOT (1915), in one leaf roll usually one fundatrix occurs only and sporadically as many as three (according to BUHR 1965 one to two) fundatrices. RUPAJS (1989) found in one gall as many as 5 (on moist biotopes often 8 or even 15) fundatrices. Unusually high numbers (even 33) of fundatrices are mentioned by JANISZEWSKA-CICHOCKA (1971). Such a high number of fundatrices found DANIELSSON (1982) in *E. ancharlotteae* Dan. only. In the majority (74%) of analysed galls in *U. glabra* in the Brno region, 1 fundatrix occurred only and in 26% galls 2 to 4 fundatrices (Fig. 2).

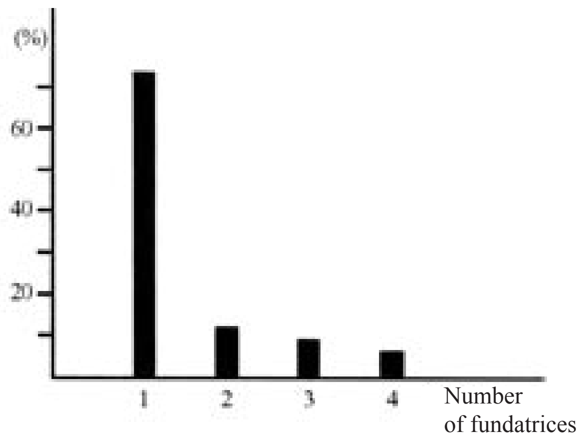

Fig. 2. The percentage of fundatrices of *E. ulmi* according to their number in one gall. Bílovice nad Svitavou and Brno-Jundrov, 8 May 2002

Table 2. Fecundity of mature fundatrices of *E. ulmi* in galls on leaves of *U. glabra* without *A. confusus* and with *A. confusus* (according to the length of fundatrices). Bílovice nad Svitavou, 22 May 2000

Length of fundatrices (mm)	Galls without *A. confusus*		Galls with *A. confusus*	
	mean number of larvae/embryos	mean number total	mean number of larvae/embryos	mean number total
≤ 2.5	208.0/46.5	254.5	203.0/51.4	254.4
2.6–3.0	320.0/77.0	397.0	248.1/99.0	347.1
≥ 3.0	–	–	268.0/99.4	367.4
Mean	236.0/54.0	290.1	232.3/78.7	311.0

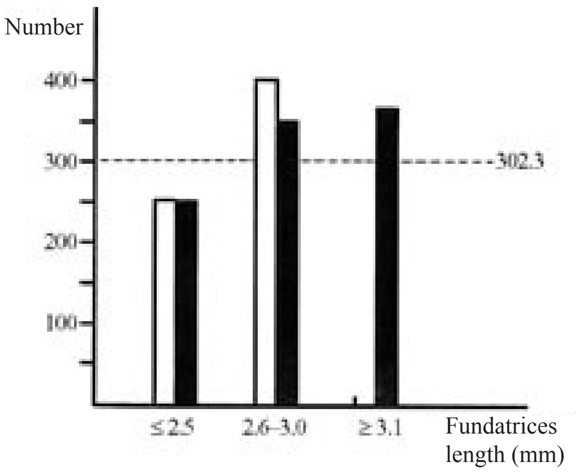

Fig. 3. Average physiological fecundity of fundatrices of *E. ulmi* in relation to their body length in galls without *Anthocoris confusus* (light columns) and in galls with *A. confusus* (dark columns). Average physiological fecundity of fundatrices in all galls is depicted by dashed lines (galls without *A. confusus* 290.1 larvae and galls with *A. confusus* 311.0 larvae). Bílovice nad Svitavou, 22 May 2002

According to JANISZEWSKA-CICHOCKA (1971), mature fundatrices appear in the second half of May, according to RUPAJS (1989) in the 3rd decade of May and in the NW part of Latvia, at the end of the 1st decade of June. In the studied galls in Bílovice nad Svitavou and Brno-Obřany, the first mature fundatrices occurred far earlier, viz. at the beginning of May. In Bílovice nad Svitavou, therefore, in galls with undisturbed development 75% grown up fundatrices with fundatrigeniae in the 1st and 2nd instars occurred as early as 8 May and 25% larvae of fundatrices only in the 3rd and mainly in the 4th instar. In ovaries of females, 67% larvae of fundatrigeniae occurred, 30% larvae were in the 1st instar and 3% in the 2nd instar. The development of fundatrices from hatching to maturity took on average 14 days there. Detailed investigations showed that on larger leaves, fundatrices were in a somewhat more advanced stage of development compared with smaller leaves and on larger leaves fundatrices reached also somewhat larger dimensions.

Mature fundatrices usually settle near elevated leaf veins (mainly between their forks) and produce light yellow-green larvae for a period of about 2 weeks. The fecundity of fundatrices is very high. According to JANISZEWSKA-CICHOCKA (1971), fecundity in galls in *U. glabra* amounts to 56 to 412 larvae whereas in *U. glabra* v. *pendula* 56 to 182 larvae only. According to data from Latvia, fundatrices produce on average 247 larvae (RUPAJS 1961) and from Bulgaria 250 to 290 larvae (GRIGOROV 1980).

In galls on *U. glabra* in Bílovice nad Svitavou, physiological fecundity of fundatrices was 152 to 460 larvae. An average physiological fecundity derived by the

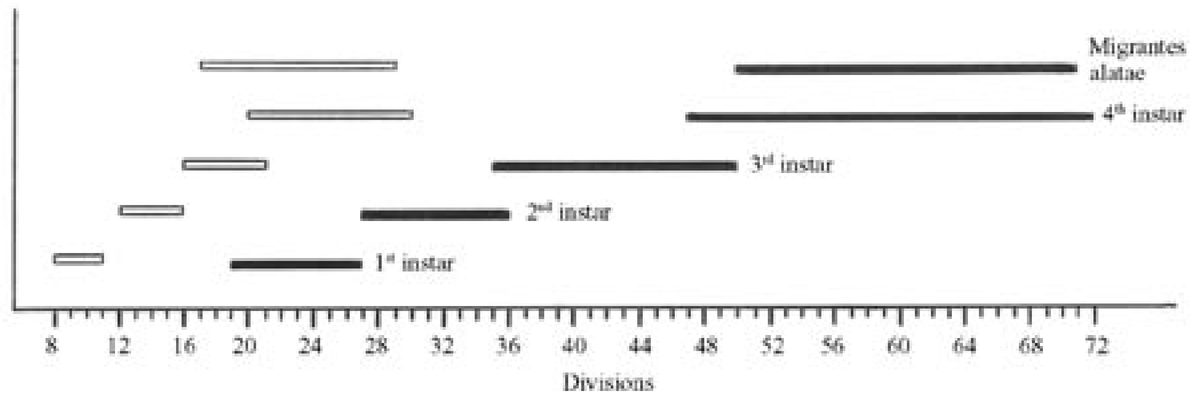

Fig. 4. The length (dark figures) and width of the body of particular instars of fundatrigeniae including migrantes alatae of *E. ulmi* (light figures) (1 division = 0.0357 mm). Bílovice nad Svitavou and Brno-Jundrov, 8 May–5 June 2002

dissection of 40 fundatrices in galls with bugs *Anthocoris confusus* Reut. and 56 fundatrices in galls free of *A. confusus* amounted to 311 larvae (Table 2, Fig. 3). Based on the study the reproduction potential of fundatrices in comparison with *Tetraneura ulmi* is nearly 9 times higher. The high fecundity is, however, already in galls to a great extent eliminated by extraordinary mortality of aphids caused by natural enemies. Fundatrices live 4 to 5 weeks. After 2 to 7 days after completing the reproduction, they die. In ovaries of dead fundatrices, 2 to 11% (on average 6.5) of unborn larvae were present.

The development of fundatrigeniae including migrantes alatae

According to the author's findings, fundatrigeniae develop rather quickly. The first pterygote females migrantes alatae occur in galls as early as 18 May and the last on 15 June. As compared with *Tetraneura ulmi* which leaved galls from 5 to 30 June, galls of *E. ulmi* were left on average 2 weeks earlier. Owing to the irregular maturation of fundatrices and the long period of their reproduction, both fundatrigeniae of higher instars and pterygote migrantes

Table 3. Length of particular instars of fundatrigeniae including migrantes alatae of *E. ulmi* in galls on leaves of *U. glabra* (1 division = 0.0357 mm). Bílovice nad Svitavou and Brno-Jundrov, 8 May–5 June, 2002

Body length (divisions)	1st instar	2nd instar	3rd instar	4th instar	Migrantes alatae
18–19	5	–	–	–	–
20–21	10	–	–	–	–
22–23	64	–	–	–	–
24–25	39	–	–	–	–
26–27	5	3	–	–	–
28–29	–	22	–	–	–
30–31	–	60	–	–	–
32–33	–	27	–	–	–
34–35	–	6	2	–	–
36–37	–	2	3	–	–
38–39	–	–	11	–	–
40–41	–	–	43	–	–
42–43	–	–	25	–	–
44–45	–	–	20	–	–
46–47	–	–	10	1	–
48–49	–	–	4	8	–
50–51	–	–	1	17	1
52–53	–	–	–	25	3
54–55	–	–	–	28	8
56–57	–	–	–	27	10
58–59	–	–	–	27	11
60–61	–	–	–	27	15
62–63	–	–	–	28	12
64–65	–	–	–	28	10
66–67	–	–	–	27	9
68–69	–	–	–	26	9
70–71	–	–	–	20	3
72–73	–	–	–	2	–
Number	123	120	119	291	91
Length (from–to) (divisions)	19–27	27–36	35–50	47–72	50–71
Mean	23.0	30.8	42.1	60.3	61.3
Length (from–to) (mm)	0.68–0.96	0.96–1.29	1.25–1.78	1.68–2.61	1.78–2.53
Mean	0.82	1.10	1.50	2.15	2.19

Table 4. Width of particular instars of fundatrigeniae including migrantes alatae of *E. ulmi* in galls on leaves of *U. glabra* (1 division = 0.0357 mm). Bílovice nad Svitavou and Brno-Jundrov, 8 May–5 June, 2002

Body width (divisions)	1st instar	2nd instar	3rd instar	4th instar	Migrantes alatae
8	12	–	–	–	–
9	33	–	–	–	–
10	58	–	–	–	–
11	20	–	–	–	–
12	–	8	–	–	–
13	–	24	–	–	–
14	–	49	–	–	–
15	–	30	–	–	–
16	–	9	8	–	–
17	–	–	23	–	1
18	–	–	31	–	3
19	–	–	31	–	5
20	–	–	19	5	10
21	–	–	7	26	11
22	–	–	–	41	12
23	–	–	–	49	13
24	–	–	–	54	10
25	–	–	–	45	9
26	–	–	–	30	8
27	–	–	–	21	6
28	–	–	–	14	2
29	–	–	–	5	1
30	–	–	–	1	–
Number	123	120	119	291	91
Width (from–to) (divisions)	8–11	12–16	16–21	20–30	17–29
Mean	9.7	14.1	18.4	24.1	22.9
Width (from–to) (mm)	0.29–0.39	0.43–0.57	0.57–0.75	0.71–1.07	0.61–1.04
Mean	0.35	0.50	0.66	0.86	0.82

alatae occur together in galls in the second half of May and at the beginning of June. Larvae moult 4 times during 14 to 21 (on average 17) days and after the 4th ecdysis, mature pterygote females appear. All fundatrigeniae without any exception mature in winged females. Tables 3 and 4 and Fig. 4 show that the average size (length/width) of larvae of the 1st instar is 0.82/0.35 mm, 2nd instar 1.1/0.5 mm, 3rd instar 1.5/0.66 mm, 4th instar 2.15/0.86 mm and migrantes alatae (measured without wings) 2.19/0.82 mm. Unlike fundatrices, fundatrigeniae including migrants are very movable being capable to leave temporarily leaf rolls. At the end of the period of development of the second generation of aphids, galls open somewhat facilitating thus mature females to leave the galls. Winged individuals leave the galls both through holes at their ends and through lengthwise fissures.

During the development of numerous fundatrigeniae, the amount of liquid excrements increases in galls being highest in the period of the occurrence of migrantes alatae. The excrements in the form of droplets and drops (of a diameter of even 10 mm) fulfil considerable part of the inner space of galls. Part of droplets in the form of so-called honeydew often falls out from leaf rolls on the soil surface or sticks on leaves and shoots. It is of interest that in spite of the large amount of produced 'honeydew' the aphid is not surprisingly visited by ants.

The data on the period of flying out of aphids from galls correspond to a great extent with the opinion of VAN DER GOOT (1915). According to the author, the development of pterygote aphids in the Netherlands is completed in the last days of May and in the first half of June. On average about 2 weeks later (at the end of May and in June), the

Fig. 5. The grown up gall of *E. ulmi* on a leaf of *U. glabra* (bottom view). Bílovice nad Svitavou, 15 June 2002

Fig. 6. The leaf of *U. glabra* damaged by *E. ulmi* (top view). Bílovice nad Svitavou, 15 June 2002

emergence of aphids occurs in Kazakhstan (MATESOVA et al. 1962) and Poland (JANISZEWSKA-CICHOCKA 1971). According to DANIELSSON (1982), in Sweden aphids migrate to secondary host plants as late as June and July, and according to PARKER (1984) supposedly at the end of July and in the first half of August.

In spite of the subtlety and relatively low sclerotization of a body migrantes alatae are generally good fliers. By means of an active flight they are able to overcome a distance of more than 1 km. After reaching a secondary host, females produce orange-yellow larvae (virginogeniae, exules). According to VAN DER GOOT (1915), MORDVILKO (1929), RUPAJS (1989) etc. they place them on a root collar. According to JANISZEWSKA-CICHOCKA (1971), females produce 10 to 21 larvae on the soil surface in the immediacy of host species of the genus *Ribes.* In galls on *U. glabra* in Brno-Jundrov, 15 to 30 (on average 22.5) unborn larvae of an average length of 0.52 and width 0.21 mm occurred in ovaries of mature females. With the increasing length and width of females the number of larvae significantly increased. JANISZEWSKA-CICHOCKA (1971) brings valuable findings on the development of females of summer generations including sexuparae (reemigrantes) on roots of several species of the genus *Ribes* and the sexuales generation in elm.

Gall characteristics

According to the author's findings, galls are established usually by 1 fundatrix only, rarely by more (even 4) fundatrices. Owing to sucking of fundatrices on the abaxial face of leaves, lateral edges (sporadically also apex) of leaves rapidly roll up downwards and to a central vein. Thus, a lengthwise fusiform leaf roll originates which tapers towards both ends and in the apical part of the leaf blade, it reaches across the central vein (Figs. 5–8). Through the sucking caused by fundatrices, the leaf blade between veins also irregularly crinkles and surges upwards in the form of 'bubbles'. Veins on the abaxial face of leaves very markedly project and the leaf blade thickness somewhat increases due to sucking. Vivid green colouring of leaf blades changes to light-green to yellow-white. The whole or almost whole sucked part of the leaf blade changes to a pseudogall. At both ends of galls, also adjacent un-

Fig. 7. The gall of *E. ulmi* formed by nearly the whole leaf of *U. glabra*. Bílovice nad Svitavou, 15 June 2002

Fig. 8. The gall of *E. ulmi* at the apex of the *U. glabra* leaf. Bílovice nad Svitavou, 15 June 2002

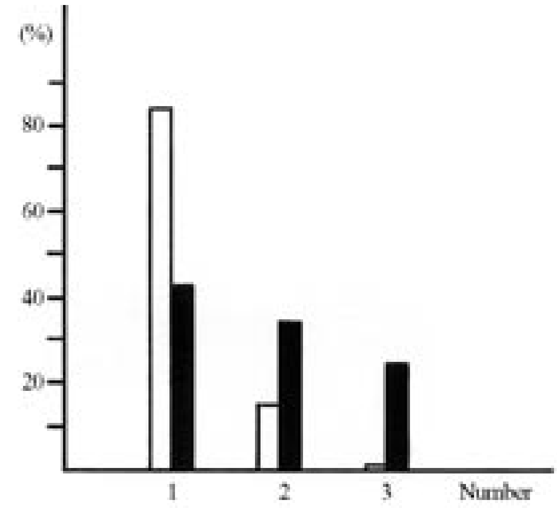

Fig. 10. The percentage of galls (including uncreated galls, i.e. mere sucking of leaves) of *E. ulmi* (light columns). Dark columns depict the average area of leaves damaged by one, two or three galls. Bílovice nad Svitavou and Brno-Jundrov, 8 May–9 October 2002

damaged parts of blades used to be often rolled up. The formation of galls is induced by sucking fundatrices only and to a smaller extent also fundatrigeniae. After the death of fundatrices, the growth of galls ceases. The study has demonstrated that galls grow up in the 3rd week in May whereas leaves as late as June, i.e. at least 3 weeks later.

On *U. glabra* in Brno-Jundrov, the majority (about 47%) of galls was localized predominantly in the apical third of the leaf blade. About 34% galls were localized in the central third of the blade and about 19% galls largely in the basal third of the blade. At the locality, galls affected most frequently (71.1%) the markedly eccentric blades. Less frequently (20.6%), the roll was formed in the larger 'half' of the blade and 8.3% rolls only were placed at the leaf apex on both sides of the blade. RUPAJS (1989) noticed already earlier the most frequent occurrence of galls on the smaller 'half' of blades. The distribution of galls on the leaf blade is undoubtedly affected by the onset and course of budbreak and different availability of various parts of the abaxial face of a leaf to the attack by young larvae of fundatrices.

The budbreak and density of the 1st instar of fundatrices is related both to the percentage of leaf attack and the number of galls on 1 leaf. Under the very heavy (on average 60%) attack of leaves at studied localities in Bílovice nad Svitavou and Brno-Jundrov, 85.5, 13.8 and 0.7% leaves were damaged by 1, 2 and 3 galls (or by sucking only), respectively (Figs. 9 and 10). A general overview on the number of galls (including mere sucking the leaves) and their distribution on leaf blades gives Table 5. Grown up galls were 7 to 73 (on average 40.8) mm long and

Fig. 9. Two side rolls of *E. ulmi* on the leaf of *U. glabra*. Brno-Jundrov, 15 June 2002

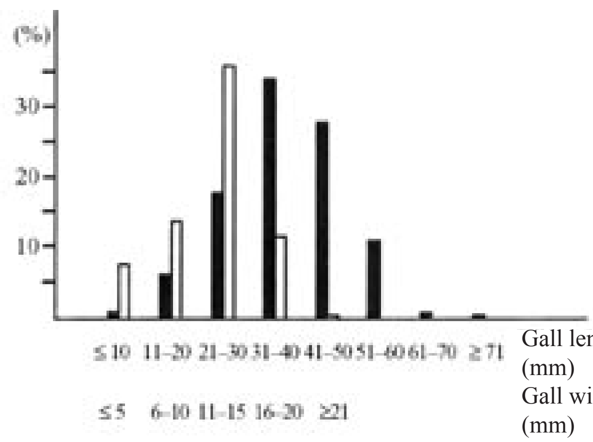

Fig. 11. The percentage of galls of *E. ulmi* according to their length (dark columns) and width (light columns). Bílovice nad Svitavou and Brno-Jundrov, 31 May–9 October 2002

Table 5. Number and localization of damages caused by *E. ulmi* on leaves of *U. glabra*. Bílovice nad Svitavou and Brno-Jundrov, 8 May–9 October 2002

Damage to leaves	Number of leaves	(%)	Number of damages	(%)
One lateral gall	656	83.2	656	77.1
Two lateral galls	49	6.2	98	11.5
One apical galls	45	5.7	45	5.3
One lateral and one apical gall	6	0.8	12	1.4
Two lateral and one apical galls	2	0.3	6	0.7
One lateral gall and one sucked spot (without a gall)	4	0.5	8	0.9
Laterally folded blade (atypical damage)	21	2.7	21	2.5
Sucked blade only (without a gall)	5	0.6	5	0.6
Total	788	100.0	851	100.0

Table 6. Mean length/width of galls of *E. ulmi* on leaves of *U. glabra* of three length categories. Bílovice nad Svitavou and Brno-Jundrov, 2002

Length of leaves (mm)	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	11. 9.	9. 10.	Mean (31. 5.–9. 10.)
≤ 70	28.2/5.8	40.0/12.2	40.6/10.0	42.3/12.3	35.3/10.1	37.0/12.7	35.8/9.3	30.4/8.4	31.9/7.7	26.7/8.2	36.7/10.2
71–90	34.2/6.7	45.5/12.2	51.2/13.6	49.5/14.6	46.4/11.9	37.9/11.9	40.0/11.3	39.4/10.2	33.0/9.3	33.6/9.3	43.2/12.0
≥ 91	30.0/6.1	47.5/12.0	46.2/12.3	49.6/13.9	46.6/12.8	43.7/10.7	42.6/13.0	42.2/10.6	38.4/10.2	32.6/9.8	41.2/11.2
Mean	29.0/5.9	42.2/12.2	46.4/12.1	47.0/13.6	42.0/11.4	41.2/11.3	40.9/12.0	40.0/10.2	36.4/9.8	31.7/9.5	40.8/11.2

4 to 23 (on average 11.2) mm wide. Frequency of the occurrence of galls of various length and width is given in Fig. 11. On blades of below-average length, width and area, galls were on average smaller than on blades of medium size or on above-average blades (Tables 6–8, Figs. 12–14).

Measurements of sucked area on leaves of three size categories (Table 9, Fig. 15) brought interesting results. The table and figure indicate that the average size of a sucked area increases with the size of leaves while the percentage of the sucked area (from the total area of attacked leaves) decreases with the size of leaves. Under the average size of grown up attacked leaves 40.4 cm^2, sucking affected 8.5 to 12.9 (on average 11.0) cm^2, i.e. 27.2% from the total leaf area. On small leaves (area 30 cm^2 and less), under the occurrence of 1 gall (or damage), on average 8.5 cm^2 were sucked (37.3% from the total leaf area). On leaves of a medium size (area 31 to 45 cm^2), under the occurrence

Table 7. Mean length/width of galls of *E. ulmi* on leaves of *U. glabra* of three width categories. Bílovice nad Svitavou and Brno-Jundrov, 2002

Width of leaves (mm)	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	11. 9.	9. 10.	Mean (31. 5.–9. 10.)
≤ 55	29.0/5.9	40.3/11.4	42.1/10.3	42.6/12.0	37.9/9.9	35.3/10.7	36.2/9.4	35.9/9.3	35.7/8.7	30.3/8.7	38.0/10.0
56–65	–	44.9/13.6	49.0/12.4	49.3/14.7	43.7/12.6	41.5/11.5	41.0/12.7	39.6/9.6	33.9/9.1	34.0/9.6	41.3/11.3
≥ 66	–	52.5/15.0	50.7/15.1	53.8/15.9	48.9/13.5	43.8/11.3	43.2/12.7	45.8/12.2	40.2/11.7	30.7/9.8	43.3/12.4
Mean	29.0/5.9	42.2/12.2	46.4/12.1	47.0/13.6	42.0/11.4	41.2/11.3	40.9/12.0	40.0/10.2	36.4/9.8	31.7/9.5	40.8/11.2

Table 8. Mean length/width of galls of *E. ulmi* on leaves of *U. glabra* of three areal categories. Bílovice nad Svitavou and Brno-Jundrov, 2002

Area of leaves (cm^2)	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	11. 9.	9. 10.	Mean (31. 5.–9. 10.)
≤ 30	29.0 5.9	41.2 11.8	41.5 9.7	42.2 12.0	37.7 9.9	36.1 9.9	34.3 8.8	34.4 8.8	33.2 7.2	27.7 7.7	37.7 9.7
31–45	–	46.3 13.7	50.1 13.3	50.6 14.9	45.2 12.9	39.1 10.4	42.5 12.7	40.7 9.7	33.9 9.3	34.2 9.8	42.1 11.6
≥ 46	–	43.0 13.0	50.5 15.0	50.3 14.3	47.3 12.9	44.8 12.5	42.3 12.7	43.7 11.8	39.6 11.2	31.3 9.8	42.0 12.0
Mean	29.0 5.9	42.2 12.2	46.4 12.1	47.0 13.6	42.0 11.4	41.2 11.3	40.9 12.0	40.0 10.2	36.4 9.8	31.7 9.5	40.8 11.2

Table 9. Mean area of leaves sucked by *E. ulmi* (numerator) and its percentage from the total area of damaged leaves of *U. glabra* of three areal categories (denominator). Bílovice nad Svitavou and Brno-Jundrov, 2002

Area of leaves (cm^2)	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	Mean (31. 5.–14. 8.)
≤ 30	?	8.0/40.4	8.8/36.5	9.5/42.4	8.1/38.4	8.5/32.8	8.4/37.2	7.6/32.7	8.5/37.3
31–45	?	11.1/31.7	12.0/32.1	13.3/35.5	11.4/30.9	10.3/26.8	13.5/34.6	10.8/27.9	11.8/31.1
≥ 46	?	12.0/23.5	13.7/24.9	15.4/28.3	12.3/17.6	12.7/21.8	12.8/19.6	12.5/22.6	12.9/21.4
Mean	?	8.6/37.4	10.9/29.8	11.9/36.2	9.9/25.8	11.1/23.9	12.2/24.2	10.6/26.0	11.0/27.2

of 1 gall on average 11.8 cm^2 were sucked (31.1% of the leaf blade) and on above-average leaves (area 46 cm^2 and more) 12.9 cm^2 (21.4% of the leaf blade). Under the occurrence of 2 or 3 galls on 1 leaf, the percentage of leaf damage by sucking is higher and in below-average leaves, even the whole blade is often affected.

Thus, it is possible to conclude that *E. ulmi* damages 20 to 100% of the leaf blade. The attack also substantially reduces the size of leaves (Table 10). Leaves with 1 gall reached on average 42.7 cm^2 while leaves with 2 galls 34.3 cm^2 only and leaves with 3 galls 24.0 cm^2. On sucked places of the leaf blade, the decrease or even the total loss of chlorophyll occurs so that assimilation is significantly decreased. Seriously damaged blades become brown and die already in June and mainly in July (Fig. 16). Dead tissues get dry and the whole leaf roll frequently markedly

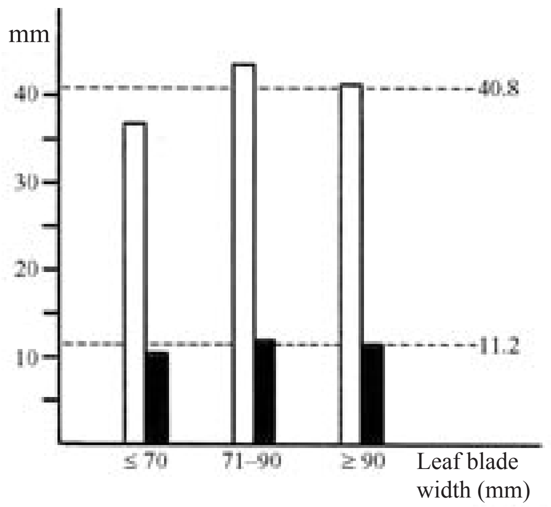

Fig. 12. The mean length (light columns) and width of galls of *E. ulmi* (dark columns) on leaves of *U. glabra* of three length categories. The mean length and width of all galls is depicted using dashed line. Bílovice nad Svitavou and Brno-Jundrov, 31 May–9 October 2002

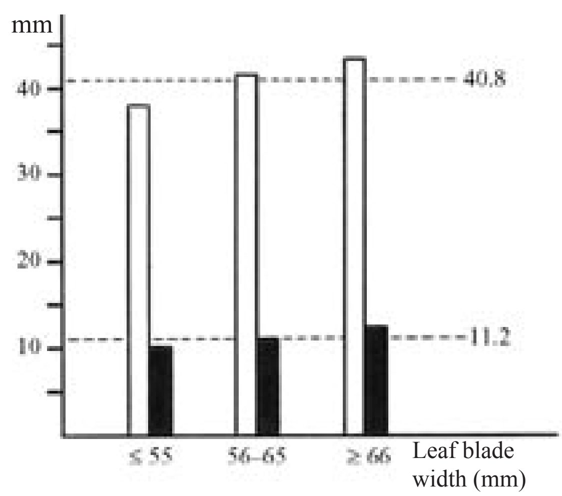

Fig. 13. The mean length (light columns) and width of galls of *E. ulmi* (dark columns) on leaves of *U. glabra* of three width categories. The mean length and width of all galls is depicted using dashed line. Bílovice nad Svitavou and Brno-Jundrov, 31 May–9 October 2002

Table 10. Mean area of leaves of *U. glabra* in relation to the number of galls of *E. ulmi* on one leaf. Bílovice nad Svitavou and Brno-Jundrov, 2002

Number of damages on 1 leaf	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	11. 9.	9. 10.	Mean
1	38.5	32.9	39.8	46.9	51.4	41.0	46.9	47.6	42.7
2	27.2	–	14.2	42.6	30.0	39.3	38.5	44.0	34.3
3	25.0	–	–	–	–	–	23.0	–	24.0
Total	36.6	32.9	38.3	46.4	50.3	40.8	45.6	47.5	41.9

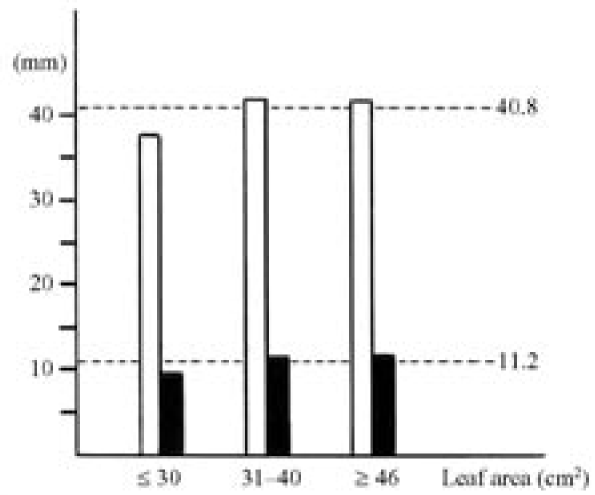

Fig. 14. The mean length (light columns) and width of galls of *E. ulmi* (dark columns) on leaves of *U. glabra* of three areal categories. The mean length and width of all galls is depicted using dashed line. Bílovice nad Svitavou and Brno-Jundrov, 31 May–9 October 2002

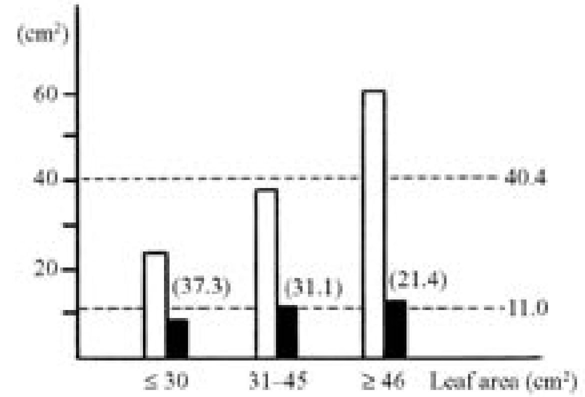

Fig. 15. The mean area of leaves of *U. glabra* with galls of *E. ulmi* (light columns) and mean sucked area (dark columns) on leaves of three size categories (the percentage of sucked area is given in parentheses). The mean area and mean sucked area of all leaves are depicted using dashed line. Bílovice nad Svitavou and Brno-Jundrov, 31 May–14 August 2002

Fig. 16. The gall of *E. ulmi* on a leaf of *U. glabra*. Heavily sucked part of a roll dies away. Bílovice nad Svitavou, 15 June 2002

Fig. 17. The gall of *E. ulmi* on a leaf of *U. glabra*. The gall died out and diminished due to shrinkage. Bílovice nad Svitavou, 17 July 2002

contracts (Fig. 17). The rolls are partly formed by an undamaged blade at their ends so that the size of assimilation area exposed to direct solar radiation is further lowered.

Mortality factors

The development and population density of *E. ulmi* are significantly affected by climatic and trophic conditions and insect predators. In the period of hatching and search of food, fundatrices often starve mainly due to the inco-incidence of budbreak and hatching of fundatrices. After the formation of leaf rolls, fundatrices and fundatrigeniae are rather well protected against unfavourable climatic effects (particularly low humidity, precipitation and direct insolation). High mortality of aphids can be caused by rainy weather in the period of migration to secondary host plants. Owing to long-term precipitation (frequently accompanied by marked temperature fluctuations), predominant part of pterygote females of the sexuparae generation can be also killed. The generation of sexuales developing in fissures of the cracked bark of elm trees is relatively considerably resistant to precipitation and mainly low temperatures. Individuals of the generation are able to tolerate rather well temperatures down to –6°C (JANISZEWSKA-CICHOCKA 1971). Wax secretions on the body of apterous females and undoubtedly also excrements play an important role in the protection of aphids against unfavourable effects of the outer environment. Even after the emergence of aphids from galls, whitish wax coat is evident on the inner side of roles. Hundreds of whitish exuviae of larvae and a lot of 'honeydew' which becomes brown and reduces its volume after a certain time occur often inside the rolls.

In galls, individuals of *E. ulmi* are, however, protected very imperfectly against biotic enemies (for example insect predators). Their species spectrum is rather broad. According to JANISZEWSKA-CICHOCKA (1971), predatory bugs *Anthocoris gallarum-ulmi* (Deg.) and *A. nemoralis* (F.) (Anthocoridae), *Syrphus vitripennis* Mg. and *S. balteatus* (Deg.) (Syrphidae) and *Leucopis annulipes* Zett. (Chamaemyiidae) belong to the main control factors of abundance. According to the author, a squirrel *Sciurus vulgaris* L. (Sciuridae) consuming honeydew together with aphids is ranked among less significant predators. It eats up the galls mainly at the end of the development of the 2nd generation of aphids when the number of aphids and the amount of honeydew in galls are largest. So far, the greatest attention has been paid to the biology of *Anthocoris gallarum-ulmi* (Deg.) (PIASECKA 1969, PARKER 1984, etc.), *A. nemorum* (L.) (PESKA 1931; HILL 1957; COLLYER 1967; PARKER 1975, etc.) and *A. confusus* Reut. (HILL 1965, etc.). All the species of bugs are considered to be significant predators of *E. ulmi* in galls.

Fig. 18. Two nymphs of the last instar and an imago of *Anthocoris confusus* Reut. Bílovice nad Svitavou, 15 June 2002

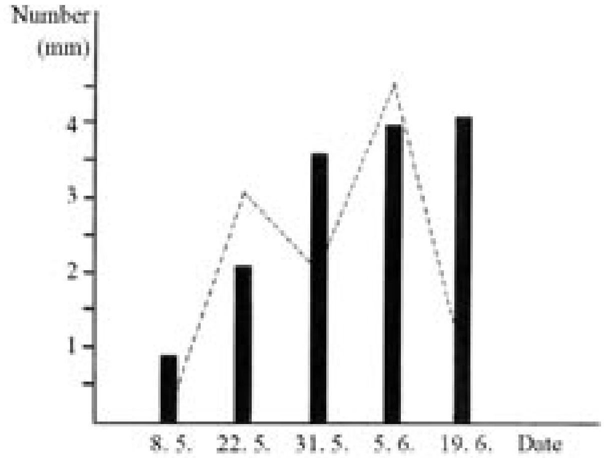

Fig. 19. The mean length of a body (columns) and the mean number of nymphs of *A. confusus* in galls of *E. ulmi* (dashed line) in the period 8 May–19 June. Bílovice n. Sv. and Brno-Jundrov, 2002

In galls on *U. glabra* in Bílovice nad Svitavou and Brno-Jundrov, natural enemies killed about 90% aphids (Table 11). *A. confusus* participated most in the mortality (Fig. 18). The bug occupied 75 to 93% of all galls and nearly always killed in them all aphids. In Brno-Pisárky, a bug *Deraeocoris lutescens* (Schill.) (Miridae) (determined by Dr. P. Kment, Brno) was seldom found in galls.

The bug *A. confusus* winters in the stage of imagoes. After wintering, it feeds on various free living prey for

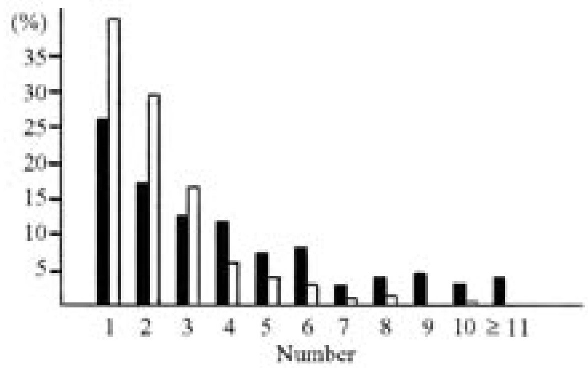

Fig. 20. The percentage of galls of *E. ulmi* with the various number of nymphs (dark columns) and exuviae of *A. confusus* (light columns). From 841 galls analysed in the period 8 May to 9 October, nymphs were present in 249 (29.6%) galls. From 506 galls analysed in the period 19 June to 9 October, exuviae were present in 338 (66.8%) galls. Bílovice nad Svitavou and Brno-Jundrov, 2002

Table 11. Results of the analysis of health conditions of *E. ulmi* in galls on leaves of *U. glabra* (absolute numbers/percentage). Bílovice nad Svitavou and Brno-Jundrov, 2002

Galls with	8. 5. Bílovice n. Sv.	22. 5. Bílovice n. Sv.	31. 5. Brno-Jundrov	5. 6. Bílovice n. Sv.	19. 6. Bílovice n. Sv.	3. 7. Brno-Jundrov	17. 7. Brno-Jundrov	14. 8. Brno-Jundrov	11. 9. Brno-Jundrov	9. 10. Brno-Jundrov
undisturbed development of aphids	31 54.4	19 19.0	15 15.9	4 4.8	8 9.0	14 15.7	8 12.9	6 6.4	9 9.6	4 5.1
dead aphids – unknown cause	9 15.8	4 4.0	1 1.1	–	7 7.9	3 3.4	3 4.9	7 7.4	3 3.2	2 2.6
Anthocoris	3 5.3	57 57.0	64 68.1	72 85.7	67 75.3	63 70.8	37 59.7	40 42.5	23 24.5	15 19.2
Anthocoris + Syrphidae	3 5.3	4 4.0	7 7.4	1 1.2	–	1 1.1	–	–	–	–
A. + Syrphidae + *Chrysopa*	–	1 1.0	–	–	–	–	–	–	–	–
Anthocoris + *Chrysopa*	–	1 1.0	–	–	–	–	1 1.6	2 2.1	1 1.1	2 2.6
Anthocoris + Aphidiidae	2 3.5	–	–	–	–	–	–	–	–	–
Anthocoris + *Adalia*	–	–	–	–	–	–	–	2 2.1	2 2.1	–
A. + *Adalia* + Araneida	–	–	–	–	–	–	–	1 1.1	1 1.1	2 2.5
A. + *Adalia* + Aves	–	–	–	–	–	2 2.3	–	1 1.1	–	–
Anthocoris + Thysanoptera	1 1.7	–	–	–	–	–	–	–	–	–
Anthocoris + *Forficula*	–	–	–	–	–	–	1 1.6	1 1.1	4 4.2	1 1.3
A. + *Forficula* + Araneida	–	–	–	–	–	–	1 1.6	3 3.2	5 5.3	4 5.1
Anthocoris + *Psocoptera*	–	–	–	–	–	–	–	1 1.1	1 1.1	–
Anthocoris + Araneida	–	–	–	–	–	1 1.1	2 3.2	17 18.1	29 30.8	33 42.3
A. + Araneida + Acarina	–	–	–	–	–	–	–	1 1.1	–	–
Anthocoris + Aves	–	4 4.0	4 4.3	5 5.9	5 5.6	–	3 4.9	3 3.2	2 2.1	–

Table 11 – to be continued

Galls with	8. 5. Bílovice n. Sv.	22. 5. Bílovice n. Sv.	31. 5. Brno-Jundrov	5. 6. Bílovice n. Sv.	19. 6. Bílovice n. Sv.	3. 7. Brno-Jundrov	17. 7. Brno-Jundrov	14. 8. Brno-Jundrov	11. 9. Brno-Jundrov	9. 10. Brno-Jundrov
A. + eaten up Insecta	–	2 2.0	–	–	1 1.1	–	–	1 1.1	2 2.1	–
Syrphidae	2 3.5	4 4.0	2 2.1	–	–	–	–	–	–	–
Syrphidae + Thysanoptera	1 1.7	–	–	–	–	–	–	–	–	–
Syrphidae + Araneida	1 1.7	–	–	–	–	–	–	–	–	–
Chrysopa	–	–	–	–	–	1 1.1	2 3.2	–	–	–
Chrysopa + Araneida	–	–	–	–	–	–	–	1 1.1	–	–
Chrysopa + *Adalia*	–	–	–	–	–	–	–	–	1 1.1	–
Adalia	–	–	–	–	–	3 3.4	2 3.2	–	2 2.1	–
Forficula	–	–	–	–	–	–	1 1.6	–	–	–
Forficula + Araneida	–	–	–	–	–	–	–	1 1.1	2 2.1	–
F. + Acarina + Aves	–	–	–	–	–	–	–	1 1.1	–	–
Lepidoptera	–	–	–	–	–	–	–	1 1.0	–	1 1.3
Thysanoptera	3 5.3	–	–	–	–	–	–	–	–	–
Araneida	–	–	–	–	–	–	1 1.6	2 2.1	6 6.4	14 18.0
Araneida + Aves	–	–	–	–	–	–	–	1 1.0	–	–
Acarina	1 1.8	–	–	–	–	–	–	–	–	–
Aves	–	4 4.0	1 1.1	–	1 1.1	1 1.1	–	1 1.0	1 1.1	–
Number of galls (%)	57 100.0	100 100.0	94 100.0	84 100.0	89 100.0	89 100.0	62 100.0	94 100.0	94 100.0	78 100.0

Table 12. Number of nymphs/imagoes of *A. confusus* in galls of *E. ulmi* on leaves of *U. glabra*. Bílovice nad Svitavou and Brno-Jundrov, 2002

Number of nymphs/ imagoes in a gall	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	11. 9.	9. 10.	Number of galls total
0	50/53	34/99	30/94	11/83	50/48	89/75	62/52	94/77	94/75	78/75	592/731
1	5/3	13/1	16/–	11/1	20/29	–/12	–/6	–/13	–/16	–/3	65/84
2	1/1	9/–	15/–	8/–	9/4	–/2	–/3	–/4	–/2	–	42/16
3	1/–	8/–	10/–	9/–	2/3	–	–/1	–	–/1	–	30/5
4	–	9/–	10/–	8/–	2/3	–	–	–	–	–	29/3
5	–	6/–	5/–	3/–	4/1	–	–	–	–	–	18/1
6	–	8/–	5/–	7/–	–/1	–	–	–	–	–	20/1
7	–	3/–	–	3/–	1/–	–	–	–	–	–	7/–
8	–	1/–	1/–	8/–	–	–	–	–	–	–	10/–
9	–	1/–	–	9/–	1/–	–	–	–	–	–	11/–
10	–	3/–	1/–	3/–	–	–	–	–	–	–	7/–
11	–	–	–	1/–	–	–	–	–	–	–	1/–
12	–	–	1/–	1/–	–	–	–	–	–	–	2/–
13	–	2/–	–	1/–	–	–	–	–	–	–	3/–
14	–	1/–	–	–	–	–	–	–	–	–	1/–
15	–	1/–	–	1/–	–	–	–	–	–	–	2/–
16	–	–	–	–	–	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–
18	–	–	–	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	–	–	–	–	–
20	–	1/–	–	–	–	–	–	–	–	–	–
Number of galls	57	100	94	84	89	89	62	94	94	78	841
Number of *Anthocoris*	10/5	312/1	201/–	390/1	88/69	–/16	–/15	–/21	–/23	–/3	1,001/154
Mean	0.2/0.1	3.1/ 0.01	2.1/–	4.6/ 0.01	1.0/0.8	–/0.2	–/0.2	–/0.2	–/0.2	–/0.04	–

Table 13. Length of nymphs of *A. confusus* in galls of *E. ulmi* on leaves of *U. glabra*. Bílovice nad Svitavou and Brno-Jundrov, 2002

Length (mm)	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.– 9. 10.
0.5	2	–	–	–	–	–
1.0	7	6	–	–	–	–
1.5	1	49	7	1	–	–
2.0	–	173	10	6	–	–
2.5	–	68	16	7	–	–
3.0	–	13	28	12	–	–
3.5	–	2	51	46	1	–
4.0	–	1	47	207	63	–
4.5	–	–	34	103	24	–
5.0	–	–	8	8	–	–
Total number	10	312	201	390	88	–
Mean length	0.9	2.1	3.6	4.0	4.1	–

a certain time. It lays eggs either individually or in small loose groups max. of 10 (rarely 20) eggs on galls of *E. ulmi* or in their close proximity. Its reproduction potential is rather high (as many as 181 eggs) (HILL 1965). Eggs occur from 25 April to 25 May, nymphs from 3 May to 25 June and this year's imagoes from 5 June to 15 October. In one gall, usually more (max. 20) nymphs occurred. The greatest number (on average 4.6) of nymphs in galls was found on 10 June in Bílovice nad Svitavou (Table 12 and Fig. 19). The length of nymphs in main control dates is given in Table 13 and Fig. 19. Frequency of the occurrence of nymphs and their exuviae in galls is demonstrated in Fig. 20. The greatest number of this year's imagoes (on average 0.8 and max. 6) occurred in galls on 19 June. During two weeks after hatching, about 75% imagoes left galls and about 25% only (i.e. on average 0.2) remained in galls from the beginning of July to mid-September. In the first half of October, however, also these imagoes left

Table 14. Mean number of nymphs/imagoes of *A. confusus* in galls of *E. ulmi* on leaves of *U. glabra* of three length categories. Bílovice nad Svitavou and Brno-Jundrov, 2002

Length of galls (mm)	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	11. 9.	9. 10.	Mean number of nymphs (8. 5.–19. 6.)	Mean number of imagoes (19. 6.–9. 10.)
≤ 30	0.2/–	2.4/–	0.7/–	1.0/–	0.5/0.3	–/0.1	–/0.1	–/0.2	–/0.3	–/0.05	0.7	0.2
31–50	0.2/–	2.7/–	2.2/–	4.4/–	1.1/0.7	–/0.2	–/0.2	–/0.2	–/0.2	–/0.03	2.4	0.3
≥ 51	–	5.8/–	2.9/–	6.1/–	0.8/2.9	–/0.2	–/0.6	–/0.3	–/0.2	–	4.1	0.9
Mean	0.2/–	3.1/–	2.1/–	4.6/–	1.0/0.8	–/0.2	–/0.2	–/0.2	–/0.2	–/0.04	2.3	0.3

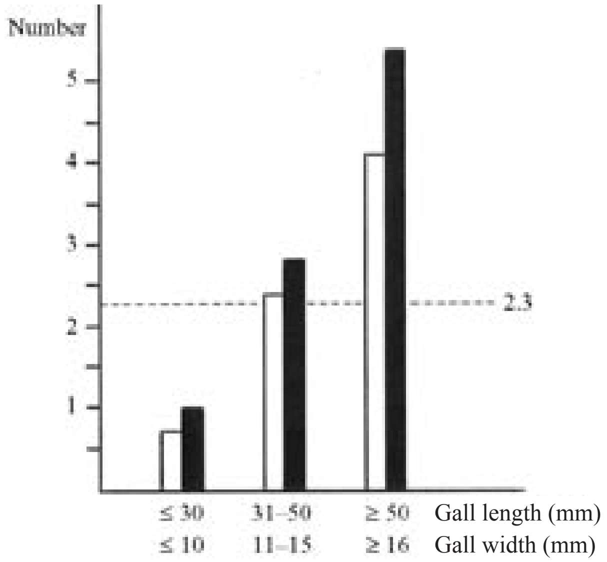

Fig. 21. The mean number of nymphs of *A. confusus* in galls of *E. ulmi* of various length (light columns) and width (dark columns). The mean number of nymphs in a gall is depicted using dashed line. Bílovice nad Svitavou and Brno-Jundrov, 8 May–19 June 2002

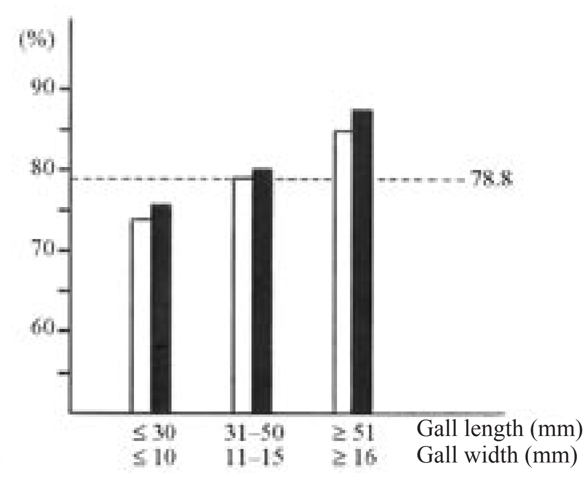

Fig. 22. The percentage of galls of *E. ulmi* with nymphs, imagoes and exuviae of *A. confusus* in relation to the length of galls (light columns) and width of galls (dark columns). The mean per cent of galls occupied *A. confusus* is depicted by dashed line. Bílovice nad Svitavou and Brno-Jundrov, 8 May–9 October 2002

galls and hid in winter habitats (Table 13). The imagoes fly rather well and occasionally they can painfully bite. The development of *A. confusus* is obligatorily univoltine.

The mean number of nymphs and imagoes of *A. confusus* significantly increased with the increasing length and width of galls (Tables 14 and 15, Fig. 21). With the increasing length and width of galls the percentage of galls where aphids were killed by the bug also increases (Table 16 and Fig. 22). The study has positively demonstrated that bugs preferentially occupy galls of a larger size with the considerable number of aphids. Numerous colonies of aphids are a rich source of nutrition for bugs requiring a lot of food. In case of food deficiency, nymphs of medium and higher instars leave galls and search for other galls with living aphids and complete their development in them. If they do not find these galls soon they suck the last rests of aphids and probably consume also excrements. This year's adults which sometimes persist in galls until autumn also obviously additionally consume the excrements. In the course of a 2.5 to 3-month period of pre-hibernation, the majority of imagoes occurs on various woody species feeding mainly on aphids and oc-

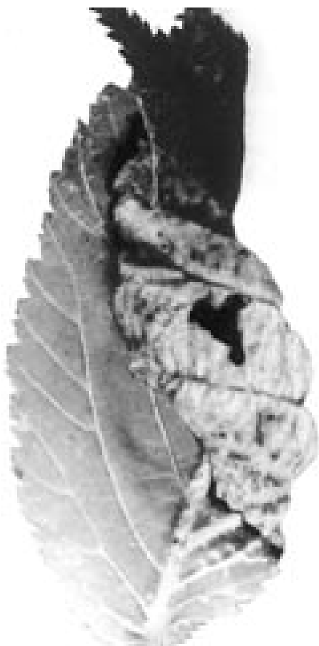

Fig. 23. The gall of *E. ulmi* pecked out by a bird. Bílovice nad Svitavou, 15 June 2002

Table 15. Mean number of nymphs/imagoes of *A. confusus* in galls of *E. ulmi* on leaves of *U. glabra* of three width categories. Bílovice nad Svitavou and Brno-Jundrov, 2002

Width of galls (mm)	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	11. 9.	9. 10.	Mean number of nymphs (8. 5.–19. 6.)	Mean number of imagoes (19. 6.–9. 10.)
≤ 10	0.2/–	2.1/–	1.1/–	1.9/–	0.5/0.5	–/0.2	–/0.1	–/0.2	–/0.2	–/0.06	1.0	0.2
11–15	–	3.0/–	2.1/–	4.8/–	1.3/1.1	–/0.2	–/0.3	–/0.2	–/0.2	–	2.8	0.4
≥ 16	–	6.0/–	4.3/–	6.7/–	2.8/1.9	–/0.3	–/0.6	–/0.3	–/0.4	–	5.4	0.7
Mean	0.2/–	3.1/–	2.1/–	4.6/–	1.0/0.8	–/0.2	–/0.2	–/0.2	–/0.2	–/0.04	2.3	0.3

Table 16. The percentage of galls of *E. ulmi* with nymphs, this year's imagoes and exuviae of *A. confusus*. Galls were classed into three length categories. Bílovice nad Svitavou and Brno-Jundrov, 2002

Length of galls (mm)	8. 5.	22. 5.	31. 5.	5. 6.	19. 6.	3. 7.	17. 7.	14. 8.	11. 9.	9. 10.	Mean
≤ 30	16.2	85.7	68.4	100.0	73.3	66.7	80.0	82.6	70.3	79.1	74.2
31–50	20.0	66.7	84.8	89.7	81.2	83.1	76.6	81.4	76.5	71.4	79.1
≥ 51	–	58.8	86.2	100.0	90.0	88.9	40.0	75.0	83.3	–	84.8
Mean	17.6	68.9	82.5	93.1	81.1	81.5	75.6	80.9	74.7	75.8	78.8

casionally also on caterpillars etc. Imagoes winter always out of galls, e.g. in fissures of the bark of trees. At both localities under study, *A. confusus* was the only highly effective control agent of *E. ulmi* in galls.

Larvae of flies of the family Syrphidae showed far smaller control importance. These occurred in rolls of *E. ulmi* from the beginning of May to the beginning of June and as puparia even later. In particular controls, they occupied 1 to 9.5% galls while in 2/3 of galls with larvae of Syrphidae, *A. confusus* was also present (Table 11). Bugs were never observed at the attack of larvae of Syrphidae even when aphids were completely sucked. The most abundant species was *Syrphus ribesii* (L.) (determined by Dr. J. Láska, Olomouc). Usually one and maximally three larvae occurred in one gall. Imagoes hatched in the laboratory in the 2nd half of June. At the end of May, larvae of the genus *Pipiza* sp. were also sparsely found in galls. Larvae of Syrphidae kill usually all aphids in galls and if they starve they are able to climb over on another gall. They pupate in puparia, viz. nearly always out of galls.

Birds participate in 5 to 8% galls in killing the aphid (Table 11 and Fig. 23). Birds pecked out galls from mid-May to mid-June. Through the pecking out, mostly the part of aphids only was killed. Aphids which were not killed by birds became usually a prey of *A. confusus*. At the end of the development of the 2nd generation of aphids partly abandoned galls were also sometimes pecked out.

In analysed galls, pedunculate eggs and larvae of the genus *Chrysopa* sp. (Chrysopidae) were found sporadically. In 2 larvae of the 4th instar of fundatrices, more precisely unidentified larvae from the family Aphidiidae developed. Galls with emerged aphids or galls with aphids killed by bugs were abundantly occupied by spiders Araneida from August to October (however, mostly individually). In mid-October, spider occurred in 60% of all galls 42% of which were previously occupied by *A. confusus*. From mid-July, galls were rather frequently (2 to 6%) searched by an earwig *Forficula auricularia* L. (Forficulidae). Also earwigs occupy usually galls previously occupied and left by aphids, viz. ordinarily together with spiders. In the same gall, maximally 2 earwigs were present which found there not only a shelter but also food (honeydew). Exuviae, larvae and imagoes of *Adalia bipunctata* L. (Coccinellidae) occurred rarely (1–3%) in abandoned galls. Table 11 gives a general overview on natural enemies of *E. ulmi* in galls and on arthropods occupying the galls after the emergence of aphids.

Economic importance

Under favourable ecological conditions and the occurrence of primary and secondary hosts max. 1 km apart, *E. ulmi* often shows outbreaks and causes serious damages. Through the sucking of fundatrices on newly unfolded leaves of elms (and partly also initial sucking of numerous fundatrigeniae) conspicuous leaf rolls are formed (pseudogalls) affecting usually 1/4 to 1/2 of the leaf blade.

Ratzeburg (1844) and later a number of other authors mentioned the harmfulness of *E. ulmi* on elms. Recently, for example Vasiljev et al. (1975) consider the aphid to be one of the main pests of park plantings. Janiszewska-Cichocka (1971), Segebade and Schaefer (1979), Rupajs (1989) etc. rank the aphid among important pests in *U. glabra* and its ornamental cultivars.

At studied localities in the Brno region, sucking of aphids damaged 21 to 37% (on average 27) of the leaf blade and under the occurrence of 2 to 3 rolls even 100% of the leaf blade. Moreover, damaged leaves reach substantially lower average dimensions. Sucked spots on the blade quickly get older and die out after the emergence of aphids from galls. At the end of June and at the beginning of July, about 10% seriously damaged leaves dried up completely. Dry leaves fall prematurely and more rarely they remain on trees. Through mass attack, trees are heavily physiologically damaged. Assimilation and respiration substantially decrease and thus also the increment of trees. Aphids produce a large amount of honeydew which partly falls out from rolls and sticks also to leaves where it hampers their assimilation and respiration. Saprophytic fungi (sooty moulds) develop on honeydew inhibiting the access of light to chloroplasts. Due to heavy damage, the resistance of tree species to other harmful factors considerably decreases as well as their aesthetic value. Young trees can dry or even die.

E. ulmi causes also serious damage to currant (particularly *R. nigrum*) and gooseberry. The abundance of viviparous females (and thus also the extent of damage) rapidly increases during summer. Tissues of roots around incisions die being easily liable to rots. Leaves of heavily damaged shrubs get yellow, dry up and prematurely fall. Shrubs become stunted and the amount of yield often rapidly decreases.

It is possible to control the pest effectively in the period of hatching the fundatrices, i.e. before the formation of leaf rolls. Secondary hosts can be protected in the period of invasion of migrantes alatae by means of spraying or watering.

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Biologie a škodlivost *Eriosoma* (= *Schizoneura*) *ulmi* (L.) (Aphidinea, Pemphigidae) na jilmu

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ABSTRAKT: Práce pojednává o výskytu, vývoji, přirozených nepřátelích a škodlivosti heteroekní mšice *Eriosoma* (= *Schizoneura*) *ulmi* (L.), která se v roce 2002 přemnožila na *Ulmus glabra* Huds. na Moravě. Na hlavních studovaných lokalitách v Bílovicích nad Svitavou a Brně-Jundrově mšice poškodila kolem 63 % listů. Larvy fundatrices se tam líhly od poloviny dubna a jejich vývoj od vylíhnutí do dospělosti trval kolem 14 dnů. Dospělé fundatrices se vyskytovaly v květnu a rozmnožovaly se po dobu 14 dnů. Jejich průměrná fyziologická plodnost byla 311 larev a ekologická plodnost 291 larev. Migrantes alatae se v hálkách vyskytovaly od 18. května do 15. června a jejich fyziologická plodnost byla kolem 22 larev. Listy byly poškozeny až 3 hálkami o průměrné délce 41 mm a šířce 11 mm. Sáním bylo postiženo průměrně 11 cm^2, tj. 27 % (při výskytu 2 a 3 hálek až 100 %) listové plochy. Přirození nepřátelé zahubili 90 % mšic. Nejefektivnějším regulátorem byla ploštice *Anthocoris confusus* Reut., která zahubila mšice v 80 % hálek. Její vajíčka se vyskytovala od 25. dubna do 25. května, nymfy od 3. května do 25. června. Kolem 75 % imag ploštic hálky brzy po vylíhnutí opustilo, ostatní imaga hálky opouštěla až koncem září a v první polovině října. V jedné hálce se vyvíjelo průměrně 4,6 (maximálně až 20) nymf. Larvy Syrphidae [hlavně *Syrphus ribesii* (L.)] zahubily mšice ve 4 % hálek a ptáci v 6 % hálek. *E. ulmi* je nutno považovat za sadařsky a lesnicky významného škůdce.

Klíčová slova: *Eriosoma* (= *Schizoneura*) *ulmi*; *Ulmus* spp.; přemnožení; hostitelská dřevina; vývoj; charakteristika hálek; predátoři; škodlivost

Práce se zabývá výskytem, bionomií a škodlivostí heteroekní mšice *Eriosoma* (= *Schizoneura*) *ulmi* (L.), která se v roce 2002 přemnožila na *Ulmus glabra* Huds. na Moravě. Např. v břehovém a doprovodném porostu kolem řeky Svitavy poblíž Bílovic nad Svitavou na Brněnsku napadla na *U. glabra* kolem 50 % listů a v porostu kolem řeky Svratky v Brně-Jundrově kolem 75 % listů. Terénním šetřením a laboratorními analýzami nepravých listových hálek (smotků), odebíraných z uvedených lokalit ve dvoutýdenních (příp. i kratších) intervalech, byly získány tyto nejdůležitější poznatky:

1. Hlavní primární hostitelskou dřevinou *E. ulmi* je *U. glabra* Huds. Na *U. minor* Mill. byla mšice nalézána jen zřídka a na *U. laevis* Pall. vůbec ne.

2. Z vajíček se larvy fundatrices líhly ve druhé polovině dubna a jejich vývoj od vylíhnutí až do dospělosti trval kolem 14 dnů. Dospělé fundatrices se vyskytovaly v květnu. Po dobu 14 dnů se rozmnožovaly a po skončení reprodukce za 2–7 dnů hynuly. Fyziologická plodnost byla 152–460 (průměrně 311) larev, ekologická plodnost 140–412 (průměrně 291) larev. V ovariích uhynulých fundatrices bylo kolem 6,5 % nenarozených larev.
3. Fundatrigenie se během 14–21 (průměrně 17) dnů vyvinuly v okřídlené migrantes alatae. Migranti se v hálkách vyskytovali od 18. května do 15. června a jejich fyziologická plodnost byla 15–30 (průměrně 22,5) larev.
4. V 73 % hálek byla přítomna 1 fundatrix, ve 12 % 2 fundatrices, v 9 % 3 fundatrices a v 6 % 4 fundatrices. Na 85,5 % napadených listů byla pouze jedna hálka, na 13,8 % listů 2 hálky a na 0,7 % listů 3 hálky. Hálky byly průměrně 40,8 mm dlouhé a 11,2 mm široké a dorůstaly již ve třetím týdnu v květnu, kdežto listy až v červnu. Kolem 71 % hálek bylo lokalizováno na menší „polovině" excentrických čepelí, 21 % na větší „polovině" čepelí a 8 % při vrcholu listu (po obou stranách čepelí). Listové smotky zakládají první instary fundatrices, které se také nejvíce podílejí na jejich tvorbě.
5. Při průměrné ploše napadených listů 40,4 cm^2 bylo sáním fundatrices a četných fundatrigenií postiženo 8,5–12,9 (průměrně 11,0) cm^2, tj. 27,2 % z celkové listové plochy. Při výskytu 2–3 hálek na listu byla sáním (zvláště na drobných listech) postižena často i celá čepel. Průměrná velikost listů s jednou hálkou byla 42,7 cm^2, se dvěma hálkami 34,3 cm^2 a se třemi hálkami 24,0 cm^2.
6. Přirozenými nepřáteli bylo v hálkách zahubeno kolem 90 % mšic. Na této mortalitě se daleko nejvíce (80 %) podílela dravá ploštice *Anthocoris confusus* Reut. (Anthocoridae). Její vajíčka se vyskytovala od 25. dubna do 25. května a nymfy od 3. května do 25. června. V hálce se vyvíjelo průměrně 4,6 (nejvíce 20) nymf. Letošní imaga ploštice se v hálkách objevovala od 10. června, nejhojněji (průměrně 0,8 jedinců v hálce) kolem 20. června. Většina (75 %) imag hálky opustila do dvou týdnů po vylíhnutí, ostatní imaga setrvávala v hálkách až do konce září, příp. do poloviny října. Počet nymf a imag ploštic se vzrůstající velikostí hálek průkazně vzrůstal.
7. Menší regulační význam měly larvy dvoukřídlých z čeledi Syrphidae [hlavně *Syrphus ribesii* (L.)], které zahubily mšice ve 4 % hálek. V době od poloviny května do poloviny června bylo asi 6 % hálek vyzobáno ptáky. Ve druhé polovině léta a začátkem podzimu byly hálky *E. ulmi* velmi často (až ze 60 %) obsazovány pavouky (Araneida) a řidčeji (asi ze 4 %) škvorem *Forficula auricularia* L. (Forficulidae).
8. Mšice *E. ulmi* může při přemnožení napadnout na primárních hostitelských rostlinách téměř všechny listy a sáním poškodit nejméně třetinu listové plochy. Napadené listy dosahují obvykle menší velikosti. Poškozené části listů rychle stárnou a často odumírají již po výletu mšic z hálek. Část listů koncem června a začátkem července předčasně usychá a opadává. Masovým napadením jsou primární hostitelské dřeviny značně fyziologicky oslabovány a u dřevin pěstovaných pro dekorační účely je snižována jejich estetická hodnota. Značné poškození může *E. ulmi* působit také na sekundárních hostitelských rostlinách (na rybízech a srstce angreštu). Je proto třeba mšici považovat za lesnicky a ovocnářsky významný druh.

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