Larval phenologies and parasitoids of two seed-feeding weevils associated with hoary cress and shepherd's purse (Brassicaceae) in Europe

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Abstract—In Europe, *Ceutorhynchus turbatus* Schultze and *Ceutorhynchus typhae* (Herbst) (Coleoptera: Curculionidae) feed on seeds from hoary cress and shepherd's purse (*Cardaria draba* (L.) Desv. and *Capsella bursa-pastoris* (L.) Medik.); both plants are invasive in North America. In North America, *C. turbatus* is a candidate for biological control of hoary cress, *C. typhae* is adventive, and both are sympatric with cabbage seedpod weevil (*Ceutorhynchus obstrictus* (Marsham)), an invasive alien pest of canola (*Brassica napus* L. and *Brassica rapa* L., Brassicaceae). We investigated host associations among *C. turbatus*, *C. typhae*, and their parasitoids in Europe. Of particular interest was host specificity of *Trichomalus perfectus* (Walker) and *Mesopolobus morys* (Walker) (Hymenoptera: Pteromalidae), candidates for biological control of *C. obstrictus* in North America. We found no evidence that *T. perfectus* attacks *C. turbatus* or *C. typhae*; however, *M. morys* was the most common parasitoid associated with *C. turbatus*.

Résumé—En Europe, *Ceutorhynchus turbatus* Schultze et *Ceutorhynchus typhae* (Herbst) (Coleoptera : Curculionidae) se nourrissent des graines de la cardaire drave et de la capselle bourse-à-pasteur (*Cardaria draba* (L.) Desv. et *Capsella bursa-pastoris* (L.) Medik.), deux plantes envahissantes en Amérique du Nord. En Amérique du Nord, *C. turbatus* est un candidat pour la lutte biologique contre la cardaire drave, *C. typhae* est adventice et les deux espèces sont sympatriques avec le charançon de la graine du chou (*Ceutorhynchus obstrictus* (Marsham)), un ravageur exotique envahissant du colza (*Brassica napus* L. et *Brassica rapa* L., Brassicaceae). Nous avons étudié les associations d'hôtes entre *C. turbatus*, *C. typhae* et leurs parasitoïdes en Europe. La spécificité d'hôte de *Trichomalus perfectus* (Walker) et celle de *Mesopolobus morys* (Walker) (Hymenoptera : Pteromalidae) sont particulièrement intéressantes et ces espèces sont des candidats pour la lutte biologique contre *C. obstrictus* en Amérique du Nord. Nous n'avons aucune indication que *T. perfectus* attaque *C. turbatus* ou *C. typhae*; cependant, *M. morys* est le parasitoïde le plus communément associé à *C. turbatus*.

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Introduction

Canada and the United States of America are currently working to combat invasions of two exotic pests, one arthropod and one weed, the control measures for which are linked. Cabbage seedpod weevil, *Ceutorhynchus obstrictus* (Marsham) (Coleoptera: Curculionidae: Ceutorhynchinae), is a pest of canola (oilseed rape), *Brassica napus* L. (Brassicaceae), in Europe and was accidentally introduced to North America where it is now widespread (Kuhlmann *et al.* 2002). European hoary cress, *Cardaria draba* (L.) Desv. (Brassicaceae), is a widespread introduced weed in North America that is often found in habitats surrounding canola fields (Schwarzlaender *et al.* 2002; Fox and Dosdall 2003; Cripps *et al.* 2006). *Ceutorhynchus obstrictus*

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and hoary cress are currently controlled with chemical pesticides (Dosdall *et al.* 2001; Cárcamo *et al.* 2005; Anonymous 2011). Alternative control strategies are needed to reduce pesticide use and overcome difficulties in current management strategies.

Classical biological control for invasive alien species is cost-effective, permanent, self-sustaining, and ecologically safe when host-specific agents are established (Wittenberg and Cock 2001). In Europe, *C. obstrictus* populations are suppressed by natural enemies, including the ectoparasitoids *Trichomalus perfectus* (Walker) and *Mesopolobus morys* (Walker) (Hymenoptera: Chalcidoidea: Pteromalidae), which may reduce populations of *C. obstrictus* by as much as 90% (Williams 2003). Both species were released in British Columbia in the 1950s but failed to establish (Gillespie *et al.* 2006), and they are being re-evaluated for introduction to Canada (Kuhlmann *et al.* 2002, 2006).

Ceutorhynchus turbatus Schultze is widespread in natural habitats in Europe. Because it undergoes larval development within hoary cress siliques, it is being studied as a hoary cress biological control agent for potential introduction to North America (Cripps *et al.* 2006).

Hoary cress is a reservoir for various economically important pests in North America, including *C. obstrictus* (food source for adults) (Fox and Dosdall 2003; Dosdall and Moisey 2004; Cripps *et al.* 2006). Reducing populations of hoary cress should benefit *C. obstrictus* control by decreasing the availability of one of its food plants, especially in spring, when adults emerge from overwintering sites, until canola crops become suitable for adult feeding and larval development (Dosdall and Moisey 2004). However, introduction of *T. perfectus* and (or) *M. morys* to control *C. obstrictus* could affect control of hoary cress if lack of host specificity enables the parasitoids to attack *C. turbatus*. Another related nontarget seed-feeding species, *Ceutorhynchus typhae* (Herbst), could also be adversely affected. It is widespread in eastern Canada in Ontario, Quebec, New Brunswick, Nova Scotia, and Newfoundland (Bousquet 1991; Bouchard *et al.* 2005) and is associated with shepherd's purse, *Capsella bursa-pastoris* (L.) Medik. (Brassicaceae), an economically important weed in canola and other crops in North America (Moss 1959; Budd and Best 1969). Consequently, these potential interactions must be considered when predicting nontarget effects of biological control agents for *C. obstrictus*.

Assessment of the potential impacts of *C. obstrictus* parasitoids on *C. turbatus* and *C. typhae* requires surveys to determine parasitoid assemblages associated with the hosts in their natural ranges. Such studies can also provide crucial host ecology information for use in selecting nontarget species for host-specificity testing and improving prediction of potential risks associated with introduction of biocontrol agents. Our objectives were to study *C. typhae* and *C. turbatus* to determine the (*i*) phenologies of the species (and potential overlap with phenology of *C. obstrictus*), (*ii*) levels of parasitism of their larvae, and (*iii*) parasitoids associated with these two weevils in their native ranges in Europe.

Materials and methods

Field collections of insects and plants (Table 1)

Shepherd's purse and hoary cress plants were field collected in fallow fields, at field margins, or along road sides at various European localities from May to July 2003 and 2004. Surveys for *C. typhae* were made at seven sites in Germany, Switzerland, and France, where *C. obstrictus* is common. *Ceutorhynchus turbatus* specimens were collected at 14 sites in Switzerland and in two regions of Hungary where populations being evaluated for introduction to North America had been collected previously (Gassmann *et al.* 2001). Insect collections were made in wastelands or abandoned fields because the weevils are generally more abundant in those habitats than they are in recently disturbed sites.

Samples of 10–20 hoary cress or shepherd's purse plants were collected from each site on each sampling date with 2- to 10-day intervals between collections. Larvae of *C. typhae* and *C. turbatus* are morphologically indistinguishable but are specialists found in pods of shepherd's purse (Baur *et al.* 2007) and hoary cress (Cripps *et al.* 2006), respectively; thus, host-plant association was used to identify larvae of

Table 1. Field collection site locations of shepherd's purse, *Capsella bursa-pastoris*, and hoary cress, *Cardaria draba* L. Desv., surveyed in 2003 and 2004 in Europe for the occurrence of *Ceutorhynchus typhae* and *Ceutorhynchus turbatus*, respectively.

				GPS coordinates	
Host plant / weevil species	Country	Region / Town	Site code	Lat. N	Long. E
Capsella bursa-pastoris / *Ceutorhynchus typhae*	Germany	Southern Rhine Valley / Neuenburg*	1	47°47′42.70″	07°34′48.80″
		Southern Rhine Valley / Neuenburg*	2	47°50′53.00″	07°35′34.00″
		Southern Rhine Valley / Buggingen†	3	47°51′30.93″	07°36′59.91″
		Southern Rhine Valley / Zienken†	4	47°50′28.91″	07°35′47.45″
	Switzerland	Jura / Alle†	5	47°26′11.79″	07°08′31.07″
		Valais / Aproz†	6	46°12′46.48″	07°19′07.72″
	France	Alsace / Boron†	7	47°33′19.21″	07°00′22.26″
Cardaria draba / *Ceutorhynchus turbatus*	Switzerland	Valais / Chamoson*	8	46°10′58.56″	07°13′51.44″
		Valais / Ecône*	9	46°10′28.87″	07°12′54.19″
		Valais / Saxon*	10	46°08′40.03″	07°09′51.67″
		Valais / Aproz†	11	46°12′46.48″	07°19′07.72″
		Valais / Martigny†	12	46°06′36.49″	07°06′12.82″
		Valais / Martigny†	13	46°06′47.04″	07°06′54.24″
		Valais / Sion†	14	46°13′11.80″	07°20′43.09″
	Hungary	Csongrad / Hödmezövasarhely†	15	46°24′50.80″	20°00′03.24″
		Csongrad / Hödmezövasarhely†	16	46°24′45.24″	20°17′21.66″
		Csongrad / Hödmezövasarhely†	17	46°15′41.62″	20°12′24.52″
		Bekes / Kardoskut†	18	46°16′41.41″	20°19′34.25″
		Pest / Sari-Bugyi†	19	47°12′09.12″	19°13′50.22″
		Pest / Gyal†	20	47°11′48.19″	19°06′36.40″
		Pest / Sari-Bugyi†	21	47°12′30.24″	19°13′06.06″

*Collections made in 2003.
†Collections made in 2004.

each species. Twenty pods per plant were dissected to detect weevil eggs and larvae; larvae were then determined to instar. Mature third instars of both species leave seed pods to pupate in soil. Thus, pod exit hole counts were also used for estimating numbers of third-instar larvae.

Estimates of parasitism level

For each plant dissected, parasitoid eggs and larvae found on or near host larvae and pupae found near host bodies were recorded to estimate parasitism levels on each collection date for every field site. Mortality due to host feeding by parasitoid adults (as evidenced, *e.g.*, by brownish punctures on larval integument) was recorded separately as an indirect effect of parasitism. Parasitism was calculated for each site as follows:

$$\%\ Parasitism = \frac{\sum_1^n \text{paras.}}{\sum_1^n \text{avail.hosts}} \times 100$$

$$= \frac{\sum_{\text{larv}}{}^{\text{par}} + \sum_{\text{larv}}{}^{\dagger} + \sum_{\text{par}}{}^{\text{alone}}}{\sum_{\text{larv}}{}^{\text{healthy}} + \sum_{\text{larv}}{}^{\text{par}} + \sum_{\text{larv}}{}^{\dagger} + \sum_{\text{holes}} + \sum_{\text{par}}{}^{\text{alone}}} \times 100$$

where Σ_1^n paras. and Σ_1^n avail.hosts are the total numbers within a plant of parasitoids and of hosts (second- and third-instar larvae) available for parasitism, respectively; $\Sigma_{\text{larv}}^{\text{par}}$ and $\Sigma_{\text{larv}}^{\dagger}$ are the numbers of parasitized larvae and of dead larvae with traces of host feeding, respectively; $\Sigma_{\text{par}}^{\text{alone}}$ is the number of parasitoids (pupae and newly eclosed adults) found alone near dead hosts; $\Sigma_{\text{larv}}^{\text{healthy}}$ is the number of healthy host larvae; and Σ_{holes} is the number of exit holes found on shoots or pods during dissections.

A representative parasitism level was estimated for each site on the date when the maximum number of larvae still available for parasitism was present in the plant (*i.e.*, just before exit holes appeared in the pods). Host density was determined by considering the maximum number of hosts parasitized or available for parasitism during the season. Only second- and third-instar larvae were used for calculations. At high larval infestation levels, a maximum of two larvae can develop within the same pod, but they are separated from each other by a partition (replum). Occasionally, two third-instar larvae may exit a plant through the same hole; this may have led to a slight under-estimation of larval numbers.

Parasitoids

Parasitoids were reared on filter paper discs in 5.5 cm diameter Petri dishes in a controlled-environment chamber at 20 ± 2 °C, 70% ± 10% RH, and 16L:8D and were checked daily until emergence of adults. Parasitoid eggs and larvae were reared on the host larvae upon which they were collected; pupae were reared individually. Adults were killed with ethyl acetate, card-mounted, and labelled. Voucher specimens were deposited in the Natural History Museum of Bern, Switzerland; the Canadian National Collection of Insects, Ottawa, Canada; the National Museum of Natural History, Washington D.C., United States of America; and at CABI Europe-Switzerland, Delémont, Switzerland.

Results

Ceutorhynchus typhae on shepherd's purse

Phenological data for *C. typhae* are presented for three study sites for 2003 (Fig. 1). Some phenological characteristics of *C. typhae* varied between sites and years, apparently in relation to the developmental biology of shepherd's purse. Shepherd's purse flowered throughout the season, so fresh pods were available until late summer (Muller 2006). Nevertheless, some weevil phenological trends were consistent across sites and years. For instance, eggs of *C. typhae* were laid from May to the end of June, but egg numbers declined from early to late in the sampling period as a proportion of all life stages observed. Eggs typically comprised more than 70% of all life stages in May to early June, but declined to less than 10% by the end of June. First-instar larvae were present in pods of shepherd's purse on every sampling date from mid-May onwards; their proportion of all life stages present usually did not decline over time. Numbers of second and third instars increased beginning in the third week of May, and densities ranged from 0.15 ± 0.08 larvae per plant in the southern Rhine Valley of Germany (site 4) to 4.60 ± 0.29 in the Swiss Jura near Alle (site 5) (Table 2). Third-instar larvae were first found in early to mid-June, and mature larvae began to exit plants beginning in the second week of June (Fig. 1).

Parasitoids associated with *Ceutorhynchus typhae*

Parasitoids were observed within siliques of shepherd's purse for about 3 weeks beginning in the first week of June (Fig. 1). Parasitism increased over time at most (*e.g.*, sites 1, 5), but not all (*e.g.*, site 7) sites (Fig. 1). In Germany, parasitism was highest at site 2 near Neuenburg in the southern Rhine Valley (Table 2). In Switzerland, parasitism reached a maximum of 59.5% at site 5 near Alle, in the Swiss Jura on 21 June 2003, and parasitism at the site in France was 16.7%.

Thirty-eight specimens of *Mesopolobus gemellus* Baur and Muller (37) and *Stenomalina gracilis* (Walker) (1) (Hymenoptera: Pteromalidae) were reared in association with *C. typhae*. *Mesopolobus gemellus* oviposited on late-instar larvae of *C. typhae* in May and June. Adults of the new generation emerged and left the senesced pods in late June of the same year.

Fig. 1. Proportions of eggs, larval instars 1–3, parasitism, and exit holes (egression of mature larvae) of *Ceutorhynchus typhae* in Germany, Southern Rhine Valley, Neuenburg (site 1), Switzerland, Jura, Alle (site 5), and France, Alsace, Boron (site 7) between May and July 2003.

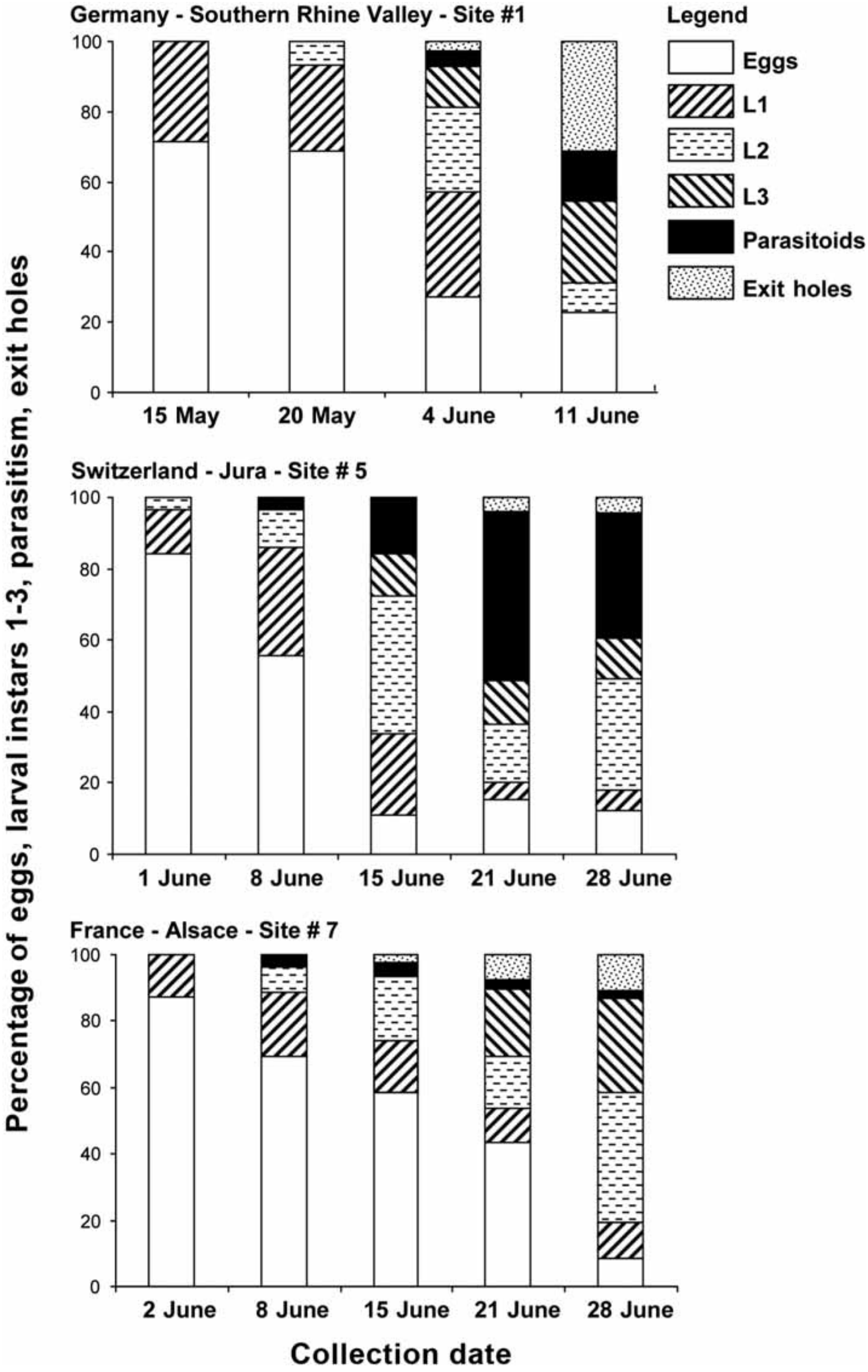


Table 2. Mean numbers (± SE) of second- and third-instar larvae of *Ceutorhynchus typhae* available for parasitism and percent parasitism observed in Germany, Switzerland, and France in 2003 and 2004.

Country	Location	Site code	Plants dissected	Mean (± SE) larvae per plant	Parasitism (%)
Germany	Southern Rhine Valley / Neuenburg*	1	160	1.58 (0.45)	10.0
	Southern Rhine Valley / Neuenburg*	2	160	3.05 (0.44)	11.5
	Southern Rhine Valley / Buggingen†	3	160	0.00	0.0
	Southern Rhine Valley / Zienken†	4	160	0.15 (0.08)	0.0
Switzerland	Jura / Alle†	5	200	4.60 (0.29)	59.5
	Valais / Aproz†	6	200	1.85 (0.33)	15.0
France	Alsace / Boron†	7	200	1.85 (0.15)	16.7

*Collections made in 2003.
†Collections made in 2004.

Ceutorhynchus turbatus on hoary cress

Phenological data for *C. turbatus* are presented for two study sites for 2004 (Fig. 2). As for *C. typhae*, phenological details varied somewhat across sites and years, but some observations were consistent. Eggs of *C. turbatus* typically comprised greater than 90% of all life stages from early to late May. First-instar larvae were first observed from the last week of May to the first week of June; second-instar larvae were present beginning in the second week of June. Densities of second and third instars per plant in the Swiss Valais ranged from 0.75 ± 0.23 at Aproz (site 11) to 11.25 ± 0.64 at Sion (site 14) (Table 3). In Hungary, densities tended to be lower on average at all sites surveyed, with a maximum of 7.50 ± 0.70 second- and third-instar larvae per plant observed at site 15 near Hödmezövasarhely and a minimum of no larvae at another site near the same town (site 16) (Table 3). Mean densities of second and third instars per plant in 2003 and 2004 were 6.8 ± 1.7 in Switzerland and 2.1 ± 1.6 in Hungary.

Parasitoids associated with *Ceutorhynchus turbatus*

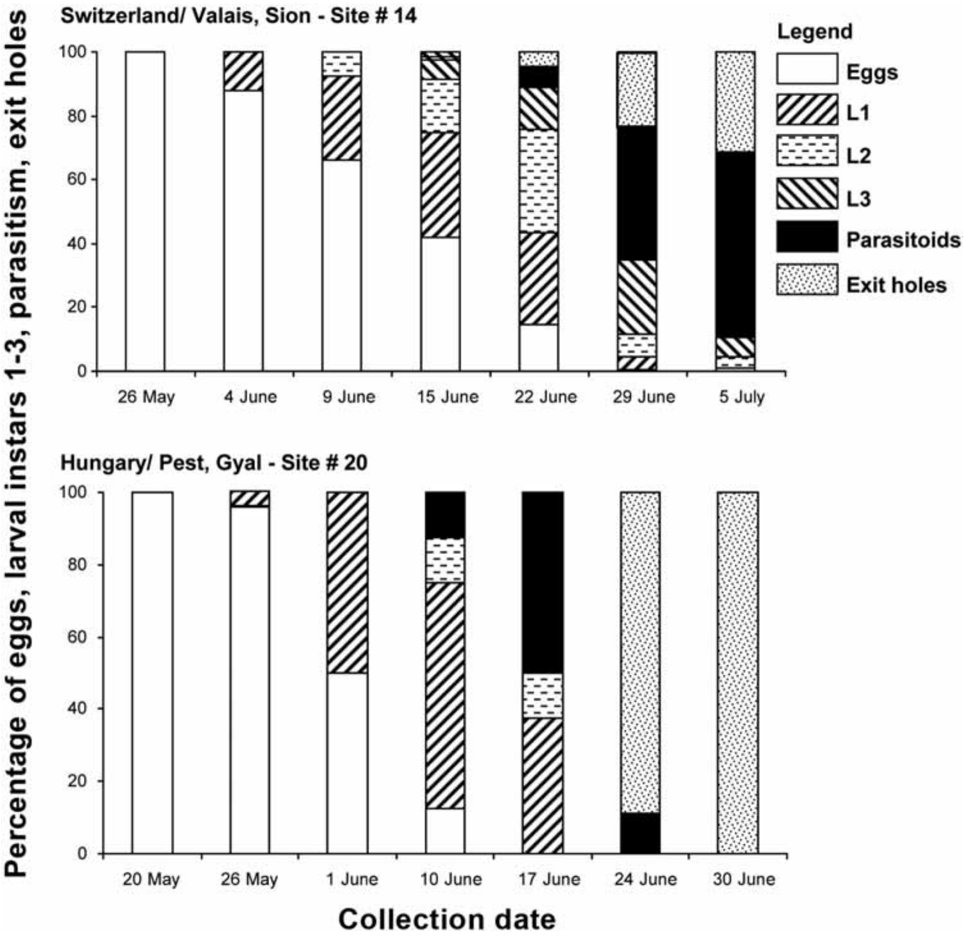
Parasitoids were present earlier in the season in Hungary than in Switzerland at all sites surveyed. In 2004, parasitism was first evident in the second week of June in Hungary, as soon as second-instar larvae were observed; in the Swiss Valais, parasitism was first evident in the last week of June (Fig. 2). All larvae had exited plants by 24 June 2004 in Hungary at site 20 near Gyal; at the same time in Switzerland, all larval instars were found in plants. Parasitism levels in Switzerland ranged from 15.4% to 80.0% in 2003, and 18.2% to 44.0% in 2004. Similar parasitism levels (11.1%–41.8%) were observed in Hungary, except for site 18 near Hödmezövasarhely, where no parasitoids were found.

Ten chalcidoid species (Table 4) were associated with *C. turbatus* collected from hoary cress: *Eurytoma curculionum* Mayr (Eurytomidae), *Mesopolobus morys* (Walker), *Pteromalus sequester* Walker, and *Trichomalus* cf. *perfectus* (Walker) (Pteromalidae), as well as an unidentified species of each of *Baryscapus* Förster and *Closterocerus* Westwood (Eulophidae), *Eupelmus* Dalman (Eupelmidae), *Pteromalus* Swederus, *Syntomopus* Walker, and *Trichomalus* Thomson (Pteromalidae). Parasitoid species compositions varied considerably among sites, with *M. morys* found at all sites except site 16 in Hungary (Table 4). None of the parasitoids of *C. turbatus* were confirmed as *T. perfectus*.

Discussion

Distributions of the three weevil species, *C. obstrictus*, *C. typhae*, and *C. turbatus*, are sympatric in Europe (Bonnemaison 1957; Cripps *et al.* 2006), and our observations indicate

Fig. 2. Proportions of eggs, larval instars 1–3, parasitism, and exit holes (egression of mature larvae) of *Ceutorhynchus turbatus* in Sion, Valais, Switzerland (site 14) and Gyal, Pest, Hungary (site 20) between May and July 2004.



that some overlap also occurs in their phenological development. For instance, females of *C. turbatus* and *C. typhae* oviposit in pods of their host plants during May and June. Larvae develop through three instars and, when mature, each chews a hole in its pod wall, drops to the ground, and pupates in the soil. Weevils of the new generation emerge during June and July of the same year. Both species overwinter as adults and resume activity the following spring. Larvae of *C. obstrictus* also develop from May through July (Bonnemaison 1957; Dosdall and Moisey 2004), confirming that their pre-imaginal development coincides temporally with that of larvae of *C. turbatus* and *C. typhae* in the field.

Host-plant phenologies also overlap in Europe and North America. On both continents, shepherd's purse can overwinter as a seedling or a seed, and flowering occurs from March to June or July (Defelice 2001; Iannetta *et al.* 2007). Hoary cress flowers from March to July in Europe and North America (Mulligan and Findlay 1974; Larina 2003), a period overlapping with the range of flowering time of canola on the two continents (Lefol *et al.* 1996; Thomas 2002). As a consequence of this phenological overlap, *C. turbatus* and *C. typhae* could be attacked by a nonhost-specific

Table 3. Mean numbers (± SE) of second- and third-instar larvae of *Ceutorhynchus turbatus* available for parasitism and percent parasitism observed in Switzerland and Hungary in 2003 and 2004.

Country	Location	Site code	Plants dissected	Mean (± SE) larvae per plant	Parasitism (%)
Switzerland	Valais / Chamoson*	8	70	3.90 (0.42)	15.4
	Valais / Ecône*	9	70	1.88 (0.36)	80.0
	Valais / Saxon*	10	140	9.15 (0.21)	39.8
	Valais / Aproz†	11	140	0.75 (0.23)	18.2
	Valais / Martigny†	12	140	10.50 (0.72)	19.9
	Valais / Martigny†	13	140	10.10 (1.02)	32.8
	Valais / Sion†	14	140	11.25 (0.64)	44.0
Hungary	Csongrad / Hödmezövasarhely†	15	140	7.50 (0.70)	25.6
	Csongrad / Hödmezövasarhely†	16	140	0.00 (0.00)	0.0
	Csongrad / Hödmezövasarhely†	17	140	3.35 (0.40)	41.8
	Bekes / Kardoskut†	18	140	1.15 (0.27)	28.6
	Pest / Sari-Bugyi†	19	140	1.15 (0.31)	33.3
	Pest / Gyal†	20	140	0.90 (0.26)	11.1
	Pest / Sari-Bugyi†	21	140	0.70 (0.21)	21.4

*Collections made in 2003.
†Collections made in 2004.

parasitoid introduced for biological control of *C. obstrictus*.

The phenologies of larval parasitoids collected from *C. turbatus* and *C. typhae* were closely linked with host phenologies. All parasitoids encountered during our surveys oviposited on late-instar host larvae. Parasitoid larvae fed on their hosts for 2–4 weeks and pupated within the siliques. Pupation required 1–2 weeks, and adults of the new parasitoid generation emerged through openings in the senesced pods. This development occurred primarily from early to late June (on *C. typhae*) and mid-June to early July (on *C. turbatus*) (Figs. 1, 2), a period that coincides with the development of *T. perfectus* and *M. morys* on *C. obstrictus* (Williams 2003; Baur *et al.* 2007; Muller *et al.* 2007).

The parasitoid assemblage associated with *C. typhae* was considerably less diverse than that of *C. turbatus*. *Mesopolobus gemellus* was responsible for 98% of *C. typhae* parasitism at all sites studied, and only a single specimen of another parasitoid, *S. gracilis*, was reared from this host. On average, approximately 25% of all *C. typhae* hosts were parasitized. Because all *C. typhae* life stages were present when sampling was terminated (Fig. 1), it is possible that additional parasitoid species that attack later in the season were missed in our study. *Mesopolobus gemellus* appears to be host specific in *C. typhae*: Baur *et al.* (2007) reared many specimens from *C. typhae* but only a single female (of questionable identity) from *C. turbatus*. By contrast, *S. gracilis* has a broad host range, reported from approximately 25 host species including *C. obstrictus* and several other ceutorhynchine weevils (Dosdall *et al.* 2009).

In contrast to *C. typhae* on shepherd's purse, *C. turbatus* on hoary cress had a more diverse parasitoid assemblage with 10 species recovered. *Mesopolobus morys*, a candidate agent for *C. obstrictus* biological control, was the most common parasitoid of *C. turbatus* and accounted for approximately 40% of total *C. turbatus* parasitism. This species was also widespread, occurring at almost all sites in Switzerland and Hungary where *C. turbatus* was collected on hoary cress. *Pteromalus sequester*, the second most important larval parasitoid attacking *C. turbatus*, represented 37% of the parasitoid assemblage and was

Table 4. Parasitoid species and the percent compositions of parasitoids associated with *Ceutorhynchus turbatus* at each European sample site in 2003 and 2004.

Year	Site	Parasitoid species	No. of individuals	Percentage
2003	Switzerland / Valais-site 10	*Mesopolobus morys**	34	100.0
	Switzerland / Valais-site 9	*M. morys**	2	66.7
		Pteromalus sequester gr*	1	33.3
	Switzerland / Valais-site 14	*M. morys**	4	57.1
		P. sequester gr*	3	42.9
2004	Switzerland / Valais-site 11	*P. sequester* gr*	2	100.0
	Switzerland / Valais-site 12	*M. morys**	13	86.7
		P. sequester gr*	2	13.3
	Switzerland / Valais-site 13	*P. sequester* gr*	20	52.6
		*M. morys**	18	47.4
	Switzerland / Valais-site 14	*P. sequester* gr*	27	55.1
		*M. morys**	21	42.9
		Eupelmus sp.§	1	2.0
	Hungary / Csongrad-site 15	*M. morys**	14	50.0
		P. sequester gr*	11	39.2
		Baryscapus sp.†	2	7.2
		Eupelmus sp.§	1	3.6
	Hungary / Csongrad-site 16	*Baryscapus* sp.†	1	50.0
		P. sequester gr*	1	50.0
	Hungary / Csongrad-site 17	*P. sequester* gr*	20	29.4
		Closterocerus sp.†	13	19.1
		Baryscapus sp.†	10	14.7
		Eurytoma curculionum‡	8	11.8
		*M. morys**	8	11.8
		Eupelmus sp.§	2	2.9
		Trichomalus cf. *perfectus**	2	2.9
		Trichomalus sp.*	2	2.9
		E. curculionum‡	1	1.5
		Pteromalus sp.*	1	1.5
		Syntomopus sp.*	1	1.5
	Hungary / Bekes-site 18	*P. sequester* gr*	11	61.1
		Closterocerus sp.†	4	22.2
		Baryscapus sp.†	1	5.6
		E. curculionum‡	1	5.6
		Eupelmus sp.§	1	5.6
	Hungary / Sari-site 19	*M. morys**	2	50.0
		P. sequester gr*	2	50.0
	Hungary / Gyal-site 20	*P. sequester* gr*	2	50.0
		Eupelmus sp.§	1	25.0
		*M. morys**	1	25.0
	Hungary / Sari-site 21	*M. morys**	2	40.0
		Closterocerus sp.†	1	20.0
		E. curculionum‡	1	20.0
		P. sequester gr*	1	20.0

*Chalcidoidea: Pteromalidae.
†Chalcidoidea: Eulophidae.
‡Chalcidoidea: Eurytomidae.
§Chalcidoidea: Eupelmidae.

also present at nearly all sites studied. Our rearing of *Eurytoma curculionum*, previously associated with *C. obstrictus* (Dmoch 1975), is the first record of its association with *C. turbatus* on hoary cress. Interestingly, although this parasitoid is known to occur in France (Thompson 1955; Herting 1973) and Germany (Freese 1995; Vidal 1997), we only observed it on *C. turbatus* in Hungary. Several other parasitoid species (*e.g.*, *Closterocercus* sp., *Baryscapus* sp., *Trichomalus* sp., *Pteromalus* sp., and *Syntomopus* sp.) were also encountered only in Hungary during our surveys and species of these genera have not previously been associated with *C. turbatus*. Two specimens of *Trichomalus* cf. *perfectus* were collected, together representing less than 1% of all parasitoids obtained during our surveys.

Concerns regarding nontarget effects in arthropod biological control are well documented (Howarth 1991; Simberloff and Stiling 1996; Thomas and Willis 1998; Stiling and Simberloff 2000; Louda *et al.* 2003; Stiling 2004). Consequently, new methods to assess the risks associated with the introduction of non-native species for biological control of arthropods have been proposed (Babendreier *et al.* 2005; Simberloff 2005; Wright *et al.* 2005; Kuhlmann *et al.* 2006). It is clear that the pre-imaginal development of ceutorhynchine weevils that comprise pest (*C. obstrictus*), adventive (*C. typhae*), and potential weed biocontrol agents (*C. turbatus*) overlap, and increased risk to the nontarget species is associated with release of biological agents for control of *C. obstrictus* unless the agents are host specific. *Mesopolobus morys*, an important parasitoid of *C. obstrictus* (Williams 2003), was the most common species parasitizing *C. turbatus* in Switzerland and Hungary. In the event of separate introductions of *M. morys* and *C. turbatus* as biocontrol agents against *C. obstrictus* and hoary cress, respectively, potential conflicts might occur between the two programmes. In contrast, because *T. perfectus* appears to be host specific and does not attack *C. turbatus* or *C. typhae*, this species should pose minimal risk if it is introduced in Canada for biological control of *C. obstrictus*. Therefore, to avoid conflicts with weed biological control our results suggest that further evaluation of *T. perfectus* for classical biological control of *C. obstrictus* would be appropriate.

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