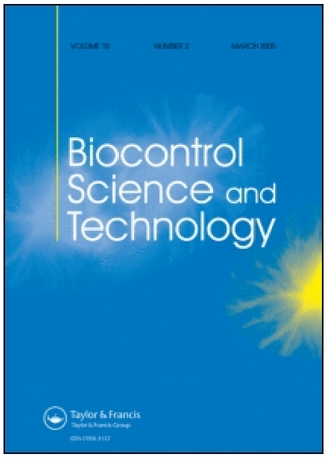

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Consumption of Damson-hop Aphids (*Phorodon humuli*) by Larvae of *Coccinella transversoguttata* and *Hippodamia convergens* (Coleoptera: Coccinellidae)

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Based on biomass, larvae of Hippodamia convergens *Guérin consumed an average of 318 adult damson-hop aphids (* Phorodon humuli *(Schrank)), during their development at 20°C. Female larvae of* Coccinella transversoguttata *Falderman ate 413 adult* P. humuli *and males ate 357. This difference in the consumption of prey occurred only in the fourth stadium and was reflected in a corresponding size dimorphism between female and male larvae at pupation.*

Keywords: Phorodon humuli, Coccinella transversoguttata, Hippodamia convergens

INTRODUCTION

Hippodamia convergens Guérin and *Coccinella transversoguttata* Falderman were the most numerous predators of the damson-hop aphid (*Phorodon humuli* (Schrank)) reported in a study of the impact of natural enemies of the aphid on hops in Washington State (Campbell & Cone, 1994). As part of an integrated chemical–biological approach to the management of this aphid, it is important to determine the consumption of prey by predators. However, other than a study by Clausen (1916) using *H. convergens*, data are lacking. Certain generalizations about the consumption of aphids can be made from the literature but, as pointed out by Wipperfürth *et al*. (1987), not all species of aphid are equally suitable diets for coccinellids. Hodek and Honěk (1996) reviewed the subject of the suitability of different prey species for Coccinellidae.

METHODS

Larval coccinellids were obtained by isolating field-collected, mated female beetles in ventilated plastic boxes with aphids as food and with water until they oviposited. Larvae

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were reared from eclosion to pupation in gelatine capsules (size 00) on apterous adult damson-hop aphids at 20 ± 1°C. The larvae were presented each day with an excess of aphids. The weights of aphid tissue consumed by individual larvae and the corresponding weights of the larvae were recorded 1–3 times each day using a Sartorius microanalytical balance (sensitivity 0.1 μg) (Sartorius, Göttingen, Germany). The control treatment was a capsule loaded at the same time with similar numbers of aphids and no predator. The percentage weight loss between inspections by control aphids (average 9%) was used to adjust the weights of prey consumed by predators in the same time interval.

Fifteen newly hatched larvae of each species were used in the experiment from which seven female plus seven male *C. transversoguttata* and five female plus seven male *H. convergens* pupated and emerged successfully. Data from beetles not completing development were discarded. The data were analyzed as from a 2^2 (two species × two sexes) factorial design, replicated seven-fold. The two female *H. convergens* needed to balance the experimental design were treated as missing values.

RESULTS

Fourth-instar coccinellids were the only larval stage to ingest whole aphids. Younger larvae digested their prey extra-orally, sucking out the body fluids and discarding the solid remains. Larvae of *C. transversoguttata* consumed a significantly greater weight of damson-hop aphids than *H. convergens* larvae, both in total ($F_{1,22} = 19.8$; $P < 0.001$) and during each of their first ($F = 4.92$; $P < 0.05$) and third ($F = 44.05$; $P < 0.001$) instars. Fourth-instar female larvae of *C. transversoguttata* also consumed more than the equivalent-stage larvae of *H. convergens* ($t = 2.90$; $P < 0.01$), although males did not (Figure 1(a)). Within each larval stadium, male and female *H. convergens* consumed similar weights of aphids, as did those of *C. transversoguttata* during their first three instars (Figure 1(a)). Size dimorphism in the latter species became apparent only in the fourth instar, as male larvae ate significantly less than females in that stadium (Table 1: $F = 7.35$; $P < 0.05$ for sex–species interaction). Fourth-instar male *C. transversoguttata* ate 27 times as many aphids as they did in their first instar, whereas the others ate 34–38 times more.

The larvae of *C. transversoguttata* were significantly heavier than those of *H. variegata* at the end of their second instar (Figure 1(b): $F = 6.13$; $P < 0.05$). The differences between the two species increased with successive moults ($F = 82.13$ and $F = 188.21$; $P < 0.001$). Size dimorphism in *C. transversoguttata* developed in the fourth stadium ($F = 11.27$; $P < 0.01$ for sex–species interaction) with female larvae being 20% heavier than males. Male and female larvae of *H. convergens* did not differ significantly in weight (Figure 1(b)).

DISCUSSION

In the present study, the estimated consumption of prey by the predators was adjusted for the weight loss of aphids in the absence of a predator. Injury or death caused by the predator but without consumption would cause additional weight loss in the group with the predator and so could result in an overestimation of actual consumption or suggest less efficiency in food conversion. Prey damaged in this manner by first- to third-instar predators (fourth-instar larvae ingested whole aphids) may be distinguished from those killed and fed upon, as the latter were discarded after feeding as flattened husks. Errors from profligate prey-capture behaviour were probably small for the predator–prey combinations studied here, as the estimated consumption figures for larvae of *H. convergens* of 309 ± 34 and 328 ± 34 damson-hop aphids for females and males respectively (Table 1) are similar to the 308 ± 82 found by Clausen (1916) on the same diet. Similarly, Clausen (1916) showed that 73% of food eaten by larvae of *H. convergens* was consumed in the fourth stadium, compared with the figures from the present study of 72 and 74% for female and male larvae respectively. Hodek and Honěk (1996; Table 6.32) summarized the proportions of prey eaten by individual

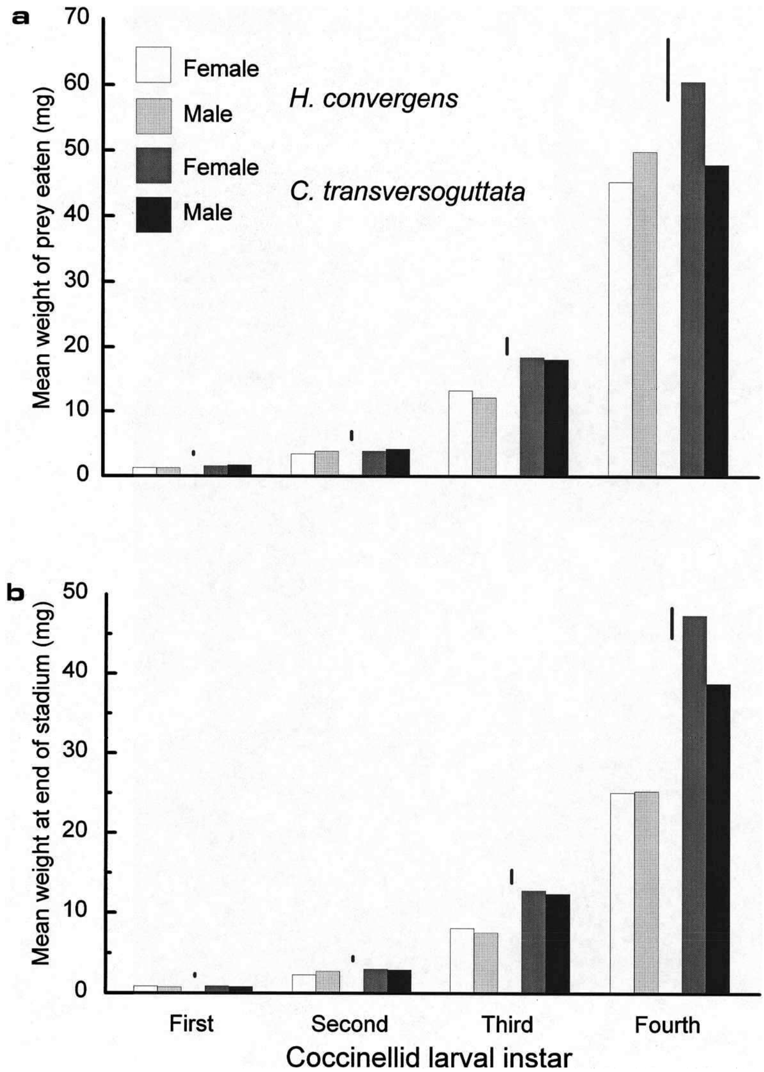

FIGURE 1. (a) The mean weight of *P. humuli* eaten by larvae of *H. convergens* and *C. transversoguttata* during development. (b) The mean weight of larval coccinellids at the end of each stadium. (Vertical lines are 5% least significant differences.)

instars for 11 species of aphidophagous coccinellid, which varied between 45 and 82% in the fourth stadium.

Larvae of *C. transversoguttata* also consumed approximately 70% of their prey during the fourth instar, compared with 83% found by Shands and Simpson (1972) with *Myzus persicae* as prey. The numbers of *P. humuli* eaten here by *C. transversoguttata* were little more than half those on *M. persicae*, a closely related and slightly larger species. Although the final larval weights of *C. transversoguttata* were heavier by 88% (females) and 52% (males) than those of *H. convergens* (Figure 1(b)), the 30% extra weight of aphids eaten by females and 7% by males indicated that *C. transversoguttata* made more efficient use of the prey consumed. The data suggest, too, that *P. humuli* is a particularly nutritious diet for this

TABLE 1. Estimated numbers[a] of apterous adult *P. humuli* eaten by larval coccinellids (relative to first-instar predator in parentheses)

	H. convergens		*C. transversoguttata*	
Instar	Female	Male	Female	Male
First	6.5	6.5	7.9	8.7
Second	17 (2.6)	19 (2.9)	19 (2.4)	21 (2.4)
Third	65 (10.0)	60 (9.2)	91 (11.4)	89 (10.2)
Fourth	221 (34.2)	243 (37.7)	296 (37.3)	234 (26.9)
All	309	328	413	357

[a]The average mass (± standard deviation) of one adult hop aphid estimated from weighing 10 samples of 10 aphids was 0.205± 0.0281 mg.

predator, falling in to the category of 'essential' food for both predator species as defined by Hodek and Honěk (1996). Malyk and Robinson (1971) showed that larvae of *C. transversoguttata* ate 1.1–1.6 times more cereal aphids than those of *H. convergens*; this compares well with the figures in the present study of 1.3-fold for females and 1.1-fold for males (Table 1).

The data provide a means for estimating aphid consumption by individual coccinellid larvae collected from hops and facilitate predictions of the likely impact on the development of aphid populations of varying the densities of these predators. The results are presented in terms of numbers eaten of a standard-sized prey item (in this case adult apterous *P. humuli*). However, in the field, predators would have the opportunity to attack the range of different-sized prey encountered while foraging. The behavioural success of different-sized aphids at avoiding capture would be an important factor influencing an individual predator's pattern of prey consumption, and this too would have an impact on aphid population dynamics.

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