

# **TETRASTICHUS GALACTOPUS (HYM.:EULOPHIDAE), A HYPERPARASITE OF APANTELES RUBECULA AND APANTELES GLOMERATUS (HYM.:BRACONIDAE) IN NORTH AMERICA**

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## ABSTRACT

The biology of *Tetrastichus galactopus*, a hyperparasite of *Apanteles rubecula* and *A. glomeratus* in North America, is reviewed. The female hyperparasite attacks its hosts while they are larvae in their primary host, *Pieris rapae*, although free-living cocoons of *A. glomeratus* may also be attacked. In Vancouver, where *A. rubecula* is the only available host, *T. galactopus* is active from July through September and probably overwinters as a pupa or adult within the host cocoon. The significance of hyperparasitism to the success of biological control efforts using *Apanteles* is discussed.

## INTRODUCTION

*Tetrastichus galactopus* (Ratzburg) is a gregarious eulophid hyperparasite of braconid larvae. In Europe, it has been commonly reared from *Apanteles glomeratus* (L.) parasitizing *Pieris brassicae* (L.), the large cabbage white. It is a true hyperparasite, depositing several eggs through the primary host directly into the larval stage of its own host (Picard 1921). Ferrière and Faure (1925) observed oviposition through newly spun cocoons of *A. glomeratus* but thought a different species of hyperparasite was involved. This view, although not supported by morphological evidence (Delucchi 1950), has contributed to taxonomic confusions; *Tetrastichus rapo* Walker is the most common synonym in the literature (Krombien *et al.* 1979). Picard (1921), Gautier and Bonnamour (1924) and Richards (1940) reported hyperparasitism by *T. galactopus* of *Apanteles rubecula* Marshall, a solitary parasite of the imported cabbageworm, *Pieris rapae* (L.). Both *A. rubecula* and *A. glomeratus* attack early instar *P. rapae* larvae, emerge from the fourth and fifth instars respectively, and spin a pupal cocoon. The former parasite normally lays one egg to produce a single larva; the latter lays thirty to sixty eggs at a time in each host.

*T. galactopus* must have entered North America with *A. glomeratus* which has been widely distributed for biocontrol of *P. rapae*. In British Columbia, *T. galactopus* attacks *A. rubecula* (Wilkinson 1966). Where releases of *A. rubecula* have been made in areas formerly inhabited by *A. glomeratus* only, local *T. galactopus* parasitize the progeny of the released *A. rubecula* (Parker *et al.* 1971).

During 1981-82, I made several collections of *T. galactopus* from *A. rubecula* in the lower mainland of British Columbia and established colonies using both *A. rubecula* and *A. glomeratus* stocks. *A. glomeratus* is available in the Okanagan Valley but it has not been collected around Vancouver. It is not

known if *T. galactopus* is also in the Okanagan. This paper reports field and laboratory data and reviews the biology of *T. galactopus*.

## MATERIALS AND METHODS

Field collections made during 1981-82 were from two sites in the Vancouver area. One was a cooperative garden plot allotment near the Fraser River in Burnaby (BBY), which had been one of Wilkinson's (1966) original sites; the other site was an isolated research plot of less than 100 plants, on the Plant Science Field Station at the University of British Columbia (UBC). From both sites in 1981 and at BBY in 1982, *P. rapae* larvae were brought to the laboratory, separated by instar and reared on potted kale. If *Apanteles* emerged from the caterpillars, the cocoons were weighed and kept individually in gelatin caps at 22°C and a 16L:8D photoperiod. *Apanteles* cocoons collected in the field were treated similarly. In 1982 *A. rubecula* reared at UBC for diapause studies were an additional data source. These primary parasites were allowed to emerge from the host caterpillar and spin a cocoon in the field, then collected and held at 22°C and a 16L:8D photoperiod. *T. galactopus* that emerged from these cocoons were sexed and counted. This technique measured the density and sex ratio of *T. galactopus* per *A. rubecula* cocoon and permitted estimates of parasitism rates according to the age of the primary host, through the season.

Adult *T. galactopus* live several weeks at low temperatures if water and honey are available. I kept adults in styrofoam cup-cages and exposed *A. rubecula* and *A. glomeratus* to them as cocoons and at various stages within their host larvae. I was thus able to observe the oviposition behaviour of *T. galactopus*. I also exposed non-parasitized cabbageworms to *T. galactopus* as well as final instar *A. rubecula* that had experienced a pre-treatment that would induce diapause i.e. less than 14 h photophase. Some *Apanteles* were exposed to un-

TABLE 1. Number and per cent parasitism of *Apanteles rubecula* by *Tetrastichus galactopus* according to the stage in which the primary host (*Pieris rapae*) was collected. Data pooled from all collections BBY, 1981 and 1982.

HOST STAGE COLLECTED		PARASITES	
<u><i>Pieris rapae</i></u>	<u><i>Apanteles rubecula</i></u>	<u><i>Tetrastichus galactopus</i></u>	(%)
III	124	9	(7.2)
IV	352	132	(37.5)
<u><i>A. rubecula</i></u> cocoons	94	37	(39.3)

mated female *T. galactopus* to determine the sex of haploid progeny. Attacked larvae were reared individually on plants or, in cases where I intended only to confirm oviposition, were dissected undersaline.

#### RESULTS AND DISCUSSION

My observations confirm earlier studies that *T. galactopus* attacks both *A. rubecula* and *A. glomeratus* while they are inside the primary cabbageworm host. Although oviposition is normally directly into the primary parasite, a few eggs were found in the caterpillar's body cavity. It is unlikely that these eggs can develop and eventually enter the appropriate host (Richards 1940). Picard (1921) described *T. galactopus* attacking non-parasitised *P. rapae* but eggs were never found in the body cavity. I observed *T. galactopus* inserting their ovipositors through the body wall of several non-parasitised *P. rapae* but only once were eggs found in the dissected caterpillars. Oviposition must require a further stimulus provided only by the presence of a primary parasite.

Most parasitism of *A. rubecula* by *T. galactopus* occurs when the cabbageworm is in the fourth instar, that is, when *A. rubecula* is close to emergence (Table 1). In laboratory trials, *A. rubecula*, one-quarter and midway through the total parasitic period, were exposed to *T. galactopus*. The results showed that successful parasitism of *A. rubecula* was unlikely before the second instar and in most cases not until a few days before emergence. I have never succeeded in obtaining parasitism of *A. rubecula* after the larva has emerged from the primary host and spun a cocoon. *T. galactopus* walks over *A. rubecula* cocoons but does not oviposit. The silk may be too dense to permit insertion of the ovipositor. In comparison, *T. galactopus* parasitizes *A. glomeratus* either through the primary host or after the free-living cocoon is formed but before pupation of the primary parasite. All individuals in a cluster are not necessarily attacked.

The number of *T. galactopus* emerging from one host cocoon varies widely. More emerge from *A. rubecula* cocoons ( $10.6 \pm 0.89$  hyperparasites per cocoon; range 1-21) than from the smaller cocoons of *A. glomeratus* ( $4.3 \pm 0.52$  hyperparasites per cocoon; range 2-7). The highest hyperparasite densities may be due to superparasitism as more than one *T. galactopus* is often seen on a single primary host in the field. The data relating the density of *T. galactopus* to the weight of *A. rubecula* show that host size does not significantly influence parasite density ( $r = 0.142$ ;  $df = 52$ ). Rather, a high hyperparasite density per host leads to a smaller average size as has been shown for other gregarious parasites (Bouletreau 1971).

Mature *T. galactopus* larvae bite emergence holes through the host body wall but remain within the host cocoon to pupate. Adults emerge over a protracted period, through one to several holes in the host cocoon. What appears to be a strong positive phototaxis results in rapid dispersal of these adults.

*T. galactopus* is arrhenotokous; unmated females produced only male progeny. Most field collected parasitized *A. rubecula* yielded both sexes of adult *T. galactopus*; only a small proportion were all female (10.5%) or all male (6.6%). Nevertheless, the sex ratio in the collections after August was always skewed in favour of females and varied through the remainder of the season (Figure 1a). Richards (1940) also found a preponderance of female *T. galactopus* in field samples.

When *A. rubecula* were reared under field or laboratory conditions that normally induced diapause and were used as hosts of *T. galactopus*, the hyperparasite developed continuously. It is not known if there is a true diapause in *T. galactopus* but if so, it seems from these observations that it is independent of the host's response to environmental conditions.

In Europe, *T. galactopus* is widely distributed over the range of *A. glomeratus*, parasitizing over 50% of the available larvae at some times of the year (Mook and Haeck 1965; Richards 1940). There

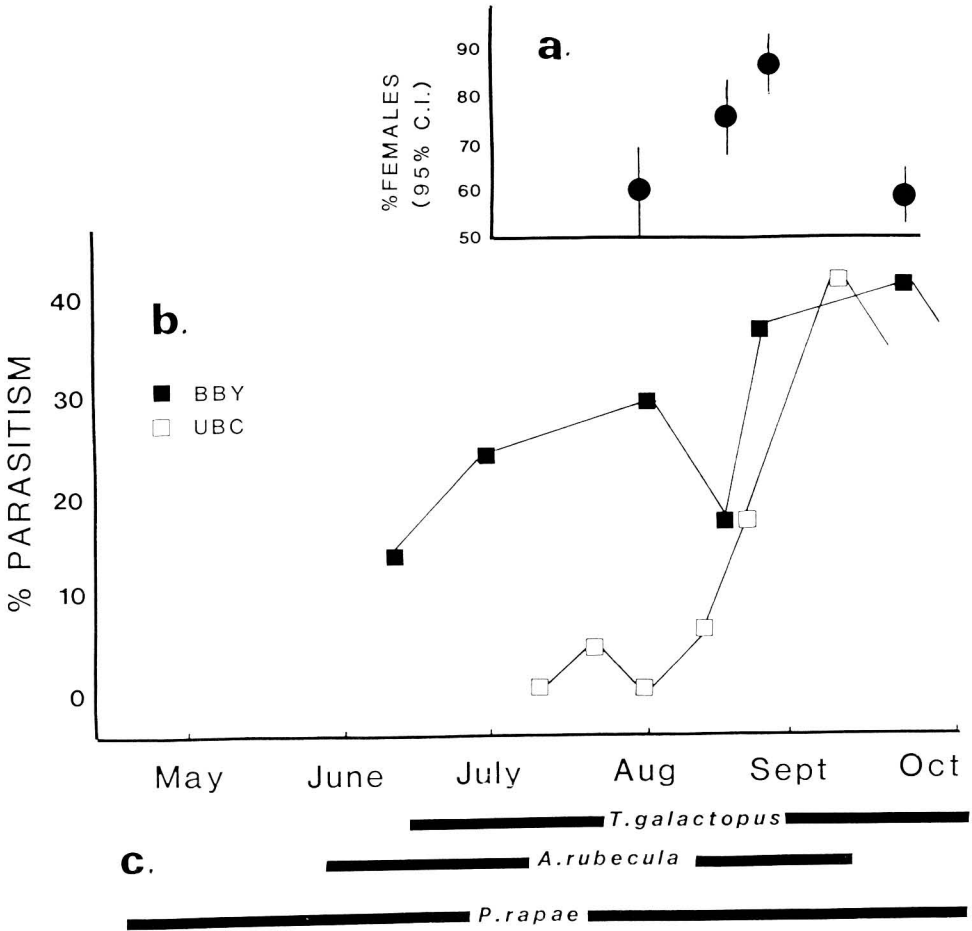


Fig. 1. Phenology of *Tetrastichus galactopus* at two locations in British Columbia during 1982 (BBY-Burnaby; UBC-University of British Columbia). a) Per cent female *T. galactopus* at BBY. b) Per cent parasitism of *A. rubecula* (ex IV-instar *P. rapae* + cocoons only) by *T. galactopus* at BBY and UBC. c) Seasonal activity schedule for adult *P. rapae*, *A. rubecula* and *T. galactopus* in the Vancouver area.

are a few estimates for *A. rubecula* from North America. When *A. rubecula* was released in Missouri, hyperparasitism by *T. galactopus* ranged from 36.6% to 72.4% (Parker *et al.* 1971). At BBY, hyperparasitism of *A. rubecula* reached 62% in 1981 and 41% in 1982. Comparable levels were observed at UBC in 1982. Except for the relatively late start of the UBC population, the same seasonal pattern was evident at both study sites (Fig 1b). Parasites often lag behind their hosts in spring appearance (compare *P. rapae* and *A. rubecula* in Figure 1c). In the case of *T. galactopus*, the lag may be due to a sustained diapause through the spring or a high winter mortality and perhaps frequent local extinction with subsequent slow recolonization of the sample areas. Mook and Haeck (1965) thought dispersal of *T. galactopus* was rapid, an impression

consistent with *T. galactopus* finding the isolated cohorts at UBC; but the evidence is circumstantial. The occurrence of *T. galactopus* in the earliest collections at BBY make it arguable that the hyperparasites are highly synchronized with the first generation of the primary parasite and that the apparent time lag is due to previous local extinctions in that area.

It is difficult to ascertain the effects of hyperparasitism on populations of either *A. glomeratus* or *A. rubecula*. Blunck (1957) states that hyperparasites in Germany "diminish the useful effect of *A. glomeratus*" but offers no data. Parker *et al.* (1971) did not think the "sizeable loss of *A. rubecula* to hyperparasites throughout the season" affected its role in suppression of *P. rapae* populations. But it is true that *A. rubecula* has failed to become establish-

ed at their release sites in Missouri where hyperparasitism by *T. galactopus* was common. However *A. rubecula*'s persistence in Vancouver despite appreciable hyperparasitism by *T. galactopus* argues against hyperparasitism as a predominant limitation to establishing *A. rubecula* in North America.

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