An Evaluation of the Parasitoid, *Aphidius colemani* Viereck (Hymenoptera: Braconidae) and the Predator *Aphidoletes aphidimyza* Rondani (Diptera: Cecidomyiidae) for Biological Control of *Aphis gossypii* Glover (Homoptera: Aphididae) on Cucumber[1]

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ABSTRACT Developmental time and fecundity of *Aphidius colemani* Viereck and *Aphidoletes aphidimyza* Rondani were studied under laboratory conditions on cucumber plants infested with *Aphis gossypii* Glover at a constant temperature of 20° C, photoperiod of 18 hours and 70% R. H. Developmental time from egg to adult for *A. colemani* lasted 13.9 days and for *A. aphidimyza*, from egg to larva was 3 days, larva to pupa 5.8 days, from pupa to adult 11.9 days, and total developmental time was 20.6 days. The average lifetime fecundity was 57.7 for *A. colemani* and 55.07 for *A. aphidimyza*. The variation for both species was considerable. Percentage of females for *A. colemani* was 58% and for *A. aphidimyza* 66%. One larva of *A. aphidimyza* will, on average, kill 23.8 *A. gossypii* during its life. Predation of parasitized aphids by *A. aphidimyza* was observed. Production of parasitoids was lower when the predator was present. The use of the two natural enemies together in control programs against *A. gossypii* is discussed.

KEY WORDS *Aphidoletes aphidimyza, Aphidius colemani, Aphis gossypii,* biological control

The cotton aphid, *Aphis gossypii,* has become one of the most important pests of cucumbers in glasshouses. This species has a very high rate of development; it can increase up to 12 times per week (Wyatt and Brown 1977) and is resistant to pirimicarb (van Schelt et al. 1990). Broad spectrum pesticides used for the control of the aphid can hardly be a solution as they interfere seriously with the use of natural enemies in IPM programs in cucumbers.

Recently, some observations (van Schelt et al. 1990, Bennison and Corless 1993) indicate that the aphid parasitoid *A. colemani* and the aphidophagous midge *A. aphidimyza* are the most promising species for use in biological control of *A. gossypii* and may be an important alternative to chemicals.

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Different aspects of the biology of these two natural enemies have been studied on several hosts/prey. Fecundity, oviposition, development and longevity of *A. colemani* and interspecific competition between this species and *Ephedrus cerasicola* Stary were investigated on *Myzus persicae* with bell pepper as the host plant (Hofsvang and Hågvar 1975a,b, Hågvar and Hofsvang 1988). The biology of the parasitoid on *A. gossypii* has also been studied (van Steenis 1993a). The midge *A. aphidimyza* occurs throughout the northern hemisphere and is well known as a predator of more than 60 species of aphids (Harris 1973). In all previous studies the two species have been evaluated separately.

Bennison and Corless (1993) demonstrated that *A. gossypii* can be controlled biologically on cucumbers on a commercial scale using both species. But when a parasitoid and a predator are put together, some interaction between them may occur. There is no evidence as to whether a predator can or cannot recognize a parasitized prey while the parasitoid is still in the egg or larval stage.

The present paper describes research on some aspects of the biology of both species, reared on *A. gossypii* on cucumber and at the same environmental conditions. One of the objectives was to find out if there is interference between the two natural enemies. For example, does the predator eat parasitized aphids? Using the results from these studies, we discuss how best to use these enemies in a biological control program against *A. gossypii.*

Materials and Methods

The cotton aphid, *A. gossypii,* was reared on cucumber, variety Vestervang at 20°C. The predator, *A. aphidimyza*, and the parasitoid, *A. colemani*, were received as pupae from Predator AB (Helsingborg, Sweden), agent for Koppert Biological Systems. They were then reared on cucumber plants infested with *A. gossypii* at 20°C in 40 × 40 × 70 cm cages. Cages were placed in climate cabinets at 70% RH with a photoperiod of 18L:6D. The climatic parameters were chosen as representative for mean environmental conditions in glasshouses in summer in Sweden.

Development and fecundity, *Aphidius colemani*. Mummified aphids were removed from leaves and placed singly in small glass vials. On the morning of emergence, the sex of the adults was determined and pairs consisting of one male and one female were released into cylindrical cages and placed in the climate cabinet (20°C, 70% RH, 18L:6D). The cages were 40 cm high and 15 cm cm in diam covered by fine-mesh plastic netting. The top was covered with a piece of thin cloth. Each cage was placed on a plastic tray with sand and contained a potted cucumber plant with 4 to 5 fully expanded leaves. The plants were infested with at least 200 aphids. Extra sugar sources were not provided for the parasitoids.

Developmental time was measured as the time from oviposition until adult emergence. Each day the adults were moved to a new cage to lay eggs. Plants were checked for mummies and adult parasitoids daily. The total number of the adults emerging in each cage was considered to be the fecundity of the female. The sex of all emerging parasitoids was determined.

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Development and fecundity, *Aphidoletes aphidimyza.* The pupae of the predators were placed in plastic Petri dishes (9 cm in diam) until the adults emerged. The newly-emerged females were released singly together with one or two males into cylindrical cages (40 cm high × 15 cm in diam, covered with netting) and placed in the climate cabinet (20°C, 70% RH, 18L: 6D). There was one aphid-infested plant with 4 to 5 leaves per cage. A minimum of 200 aphids, adults and all nymphal instars, was present on each plant. The midges were removed to a new cage every day. Developmental time was measured by daily observations from oviposition until adult emergence. Fecundity was evaluated in the same manner as for the parasitoid.

The consumption abilities of different larval instars and for the whole larval development time were studied using glass Petri dishes, 15 cm in diam, containing one cucumber leaf with an overabundance of aphids and wet cotton to maintain the humidity. Each larva was placed on such a leaf to feed on the aphids for one day. The next day at the same time the killed aphids were counted and the predator placed on another leaf. The petri dishes were kept in a climate cabinet at 20°C at 70% R.H. and a photoperiod of 18 hours.

Predation on parasitized aphids by *A. aphidimyza.* Cucumber plants (N = 20) at the same developmental stage as above were placed in the cylindrical cages together with five female and three male one-day-old parasitoids. In the experiment to determine fecundity, there was considerable variation among individual females. We, therefore, used five females to reduce variation between cages. All plants were heavily infested with *A. gossypii* (minimum 500 aphids). The experiment took place under the same climatic conditions as above. Parasitoids were removed from the cages after two days. Second- through fourth-instar larvae of *A. aphidimyza* (N = 10) were introduced on 10 plants. The remaining 10 plants constituted the control. The total number of emerging parasitoids in each cage was recorded using daily observations.

Results and Discussion

Duration of development and fecundity, *Aphidius colemani.* The average time for development (length of period between oviposition and emergence of the adults), based on the total number of progeny for *A. colemani,* was 13.9 days (SD = 1.1, N = 912) (Fig. 1).

This result is comparable with data reported by van Steenis (1993a) for the same species with *A. gossypii* as host reared on cucumber (12.7 days at 20°C) and by Elliot et al. (1994) (13.3 days at 22°C). The data are also quite similar to results described by Hofsvang and Hågvar (1975a) (14.2 days at 21°C with *M. persicae,* reared on pepper, as a host). Völkl et al. (1990) also found that the developmental time for *A. colemani* with *Pentalonia nigronervosa* as host was 14.2 days at 21°C and 13.7 days at 24°C. The closely related species *A. matricaria* completes its development from egg to adult for 14.4 days at 21°C with *Sitobion avenae* as host (Kaaken 1978) and with *M. persicae* as host at 20°C - 12.8 to 13.9 days (Rabasse and Shalaby, 1980).

The average fecundity for *A. colemani* was calculated by summarizing the daily production of adult parasitoids per female. The mean number of progeny produced was 57.7 (SD=48.6, N=16). The percentage of females was 58%. Variation between

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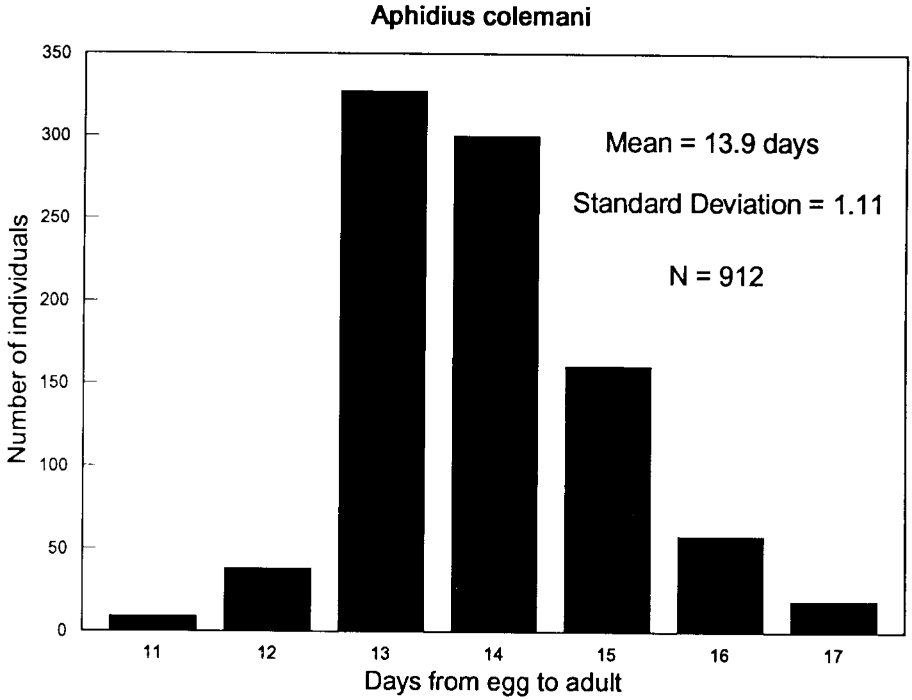

Fig. 1. Frequency distribution of developmental time for the parasitoid *A. colemani* on the aphid *A. gossypii*.

individual females was considerable with a range of 5 to 151 offspring. Hofsvang and Hågvar (1978) found similar fecundity at 21°C with *M. persicae* as host (46 mummies per female). These two results differ notably from the results of van Steenis (1993a). The lifetime fecundity found in that study was 302 eggs per female at 20°C and *A. gossypii* as host. One possible reason for this difference is the method used for obtaining the fecundity data: the number of eggs laid was counted by dissecting aphids soon after parasitoid oviposition. There is always a certain percentage of mortality during the egg, larval and mummy stages, though immature mortality found by van Steenis (1993a) was rather low (14.1%). In one of their experiments with *M. persicae* as host and pepper as host plant, Hofsvang and Hågvar (1975a) obtained 25% mortality when only considering the mummy stage. We think that the mortality may be high because 4 out of 16 females in the experiment produced only 5 to 16 offspring, which is well below their potential.

Duration of development and fecundity, *Aphidoletes aphidimyza.* The total development time was 20.6 (SD = 0.9, N = 268) (Fig. 2). Average development

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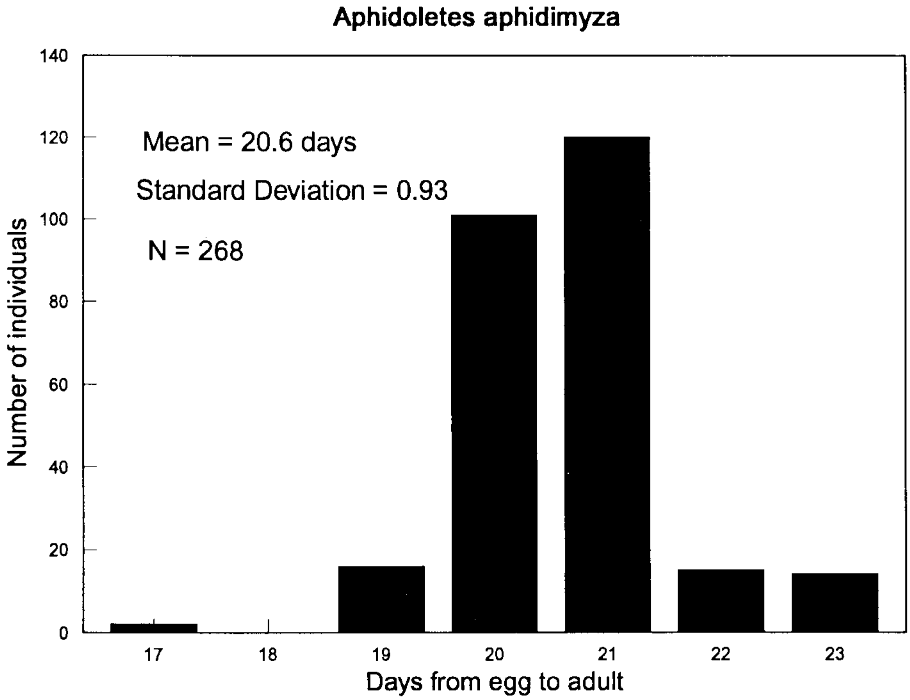

Fig. 2. Frequency distribution of developmental time for the predator *A. aphidimyza* on the aphid *A. gossypii*.

time was 3.0 days for eggs, 5.8 days for larvae (SD = 1.0, N = 247) and 11.9 days (SD = 1.3, N = 247) for pupae. These results are similar to those shown by Havelka (1980) - 2.6 days for egg, 7.0 days for larvae, 10.8 days for pupae and 20.4 days for total development time at 20°C. The mean number of progeny produced was 55.1 (SD = 21.8, N = 14). The percentage of females was 65.9%. Other studies (Harris 1973, Uygun 1971) found between 70 and 100 eggs per female. El Titi (1973) found that the number of *A. aphidimyza* eggs laid is almost directly proportional to aphid density. This may be a disadvantage for the midge at low aphid population levels.

The number of the aphids killed per larval instar when larvae were offered *ad libitum* was as follows: Larval instar I, 1.2 aphids killed (SD = 0.4, N = 12); larval instar II, 2.3 (SD = 1.8, N = 12); larval instar III, 10.4 (SD = 2.3, N = 12); larval instar IV, 9.9 (SD 3.3, N = 12); and for the entire larval period a mean of 23.8 (SD = 4.2, N = 12) aphids were killed. Considerable variation exists in the number of aphids killed by each larva in the course of its development according to different authors: Uygun (1971) reports a minimum requirement of 7 *M. persicae* and Roberti (1946), working with *A. gossypii* reports a figure of 60-80 aphids killed per larva. Obviously the number of aphids killed varies with the

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circumstances and more aphids may be killed than are actually required to fulfill the nutritional needs of the predator.

Interaction between the predator and parasitoid. Our preliminary observations showed that larvae of *A. aphidimyza* killed aphids which were previously parasitized by *A. colemani* and obviously did not differentiate between parasitized and nonparasitized aphids. The mean number of the parasitoids emerging from the cages which contained only parasitized aphids was 123.0 (SD = 23.9, N = 10). The number of the adults of *A. colemani* emerging from the aphids subjected to both parasitism and predation was 92.3 (SD = 25.9, N = 10). The means from the two treatments are statistically significantly different (*t*-test, $t = 2.61$, df = 18, $P < 0.05$). The predator reduced parasitoid reproduction by about 25% in this experiment.

Conclusions. Both *A. colemani* and *A. aphidimyza* complete their development on the cotton aphid (*A. gossypii*) and, according to van Steenis (1993b), this aphid is the most suitable host for the parasitoid.

The number of offspring per female parasitoid was about 58. Each female parasitoid is, therefore, responsible for the death of at least 58 aphids. Predators produce about 55 offspring, each of these larvae will eat 24 aphids. Each female midge is then responsible for the death of 1320 aphids. However, the generation time of the predator is nearly twice as long as the parasitoid. During one generation of the predator, about one month, the parasitoid will have killed about 2000 aphids. Because of the shorter developmental time of the parasitoid, it is probably a better biocontrol agent. In fact, Bennison and Corless (1993) found many more parasitoids than predatory midges during their trials using both natural enemies. In a comparative study between a parasitoid and gall midges (Hofsvang and Hågvar 1982), the same level of control of *M. persicae* on peppers was achieved using a much lower number of parasitoids than gall midges.

Concurrent use of the predator and the parasitoid may reduce parasitoid reproduction. In our lab experiment, 25% fewer parasitoids emerged from cages infested with the midge larvae. In a study on the use of both a generalist and a specialist predator, Gillespie and Quiring (1992) found that predation by the generalist *Orius tristicolor* on the specialist *Amblyseius cucumeris* was dependent on alternative prey. The aphid midge, however, only preys on aphids and, therefore, no alternative prey is available. The two natural enemies are direct competitors for the same resource. The predatory *A. aphidimyza* larvae may, therefore, reduce the reproductive success of the parasitoid and in this case two biocontrol agents may not be better than one.

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