Consumption of *Helicoverpa armigera* eggs by the ladybirds *Harmonia octomaculata* and *Coelophora inaequalis*

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Abstract

Ladybirds are common beneficial predators that feed primarily on aphids in Australian cotton crops. Predation by ladybirds on *Helicoverpa* spp. eggs has been observed, however the relationship between predator density, egg density, aphid availability and habitat size has not been investigated. Under laboratory conditions three banded ladybirds were the most effective egg predators and variable ladybirds the least effective of the four ladybird species tested. In greenhouse experiments three banded and variable ladybirds showed similar predatory capability and under natural conditions variable ladybirds may be the most effective coccinellid predators of *Helicoverpa* spp.

Introduction

Ladybird beetles (Coleoptera: Coccinellidae) are a conspicuous part of the beneficial insect fauna found in cotton. Adults and larvae of four species in the subfamily Coccinellinae (*Coccinella transversalis, Coelophora inaequalis, Harmonia octomaculata, Micraspis frenata*) are primarily aphid feeders (Bishop and Blood 1978, Pope 1988, Stanley 1997, Yee 1998). However adult beetles can eat alternate prey items such as *Helicoverpa* spp. eggs and small larvae, cicadellids and mites (Room 1979, Stanley 1997, Johnson et al. 2000, Scholz et al. 2000). Coccinellids can be extremely abundant in cotton in some seasons. However the potential for *Helicoverpa armigera* suppression from these predators is not known. To predict the impact of these predators on *H. armigera* in cotton, the probability of predation under different conditions must be established.

Several factors affect the amount of prey consumed by a polyphagous predator including the relative abundance of different prey types, prey and predator density and the amount of habitat available for predators to search (e.g. Geden et al. 1988, Hazzard and Ferro 1991, Siddiqui et al. 1999). No previous study has evaluated the interactions between predator and prey density, alternate prey and habitat size for the coccinellid-aphid-*Helicoverpa* system in cotton. Here I describe the effect of prey density and aphid availability on *H. armigera* egg consumption under laboratory conditions by transverse, variable, three banded and striped ladybirds (*C. transversalis, C. inaequalis, H. octomaculata* and *M. frenata* respectively). Two species (*C. inaequalis* and *H. octomaculata*) were then used to examine the effect of predator and prey density on *H. armigera* egg consumption in glasshouse cages. Finally, *H. armigera* egg consumption by the same two predator species was tested in field cages under natural conditions.

Methods

Predator and prey rearing

Adult and larval ladybirds of all species were collected from cotton, sorghum, lucerne, sunflowers and dock around Narrabri, Wee Waa and Pilliga (NSW, Australia) during the 2000-01 cotton season. The ladybirds were kept in a perspex cage (950 x 750 x 900 mm) with a sliding door and one sleeve on each side and top (200 mm^2) and back (300 mm^2) windows covered with silkscreen. The cage was held in a glasshouse at 35 ± 5°C and aphid-infested cotton plants placed inside as a food source. Water was supplied in specimen jars with cotton wicks through the lid. Additional ladybirds were added to the colony to maintain numbers as necessary over the season. All predators were used only once and were starved for 24h prior to an experiment. Cotton aphids (*Aphis gossypii*) were reared on cotton plants in the same glasshouse. *H. armigera* eggs were supplied from a laboratory colony maintained by CSIRO Entomology at ACRI, Narrabri, NSW. Eggs were stored at 10°C and used within 48h of collection from the moth colony.

Laboratory tests

Single adult ladybirds were confined in a 100 x 70 x 50 mm plastic container (Décor Corporation, Burwood, NSW 2134) with 3, 6 or 12 *H. armigera* eggs and a small piece of moistened sponge to provide water. After 24h the number of missing eggs was recorded. Each egg density level was replicated 15 times for the four ladybird species (*C. transversalis, C. inaequalis, H. octomaculata* and *M. frenata*). The entire experiment was repeated for the four predators and three egg densities with the addition of approximately 15 - 20 aphids to each container.

Glasshouse tests

Perspex cages (480 x 500 x 600 mm) were used for these experiments in the same glasshouse as the ladybird and aphid colonies. Each cage had a cloth sleeve on one side and a sliding door on the opposite side to allow transfer of plants into and out of the cage. The remaining two sides had a window (200 mm^2) covered with silkscreen to allow airflow. 1, 3 or 6 adult ladybirds were confined in each cage with a young cotton plant but no aphids. 3, 6 or 12 *H. armigera* eggs were individually glued to three leaves on the cotton plant with a water-based glue (Starch and Chemical Pty. Ltd., Tullamarine, VIC 3043). Predators were left in the cages for 24h and the number of missing eggs was then counted. Each combination of predator and prey density was replicated 10 times for two ladybird species (*C. inaequalis* and *H. octomaculata*). Logistical constraints prevented repetition of this experiment with aphids present in the cages or testing of additional ladybird species.

Field cage tests

The field cages had a $1m^3$ metal frame with a fine mesh cover (polyester lining, Broadway Textiles, Sydney, NSW 2007) and two zips on opposite sides. Tent pegs through two eyelets at each corner of the cover secured the cage to the soil. Frames were placed approximately 10 m apart over single rows of cotton in field 18 at ACRI from December to February. The covers were only kept over the frames during the course of an experiment. Cages were assigned to one of four treatments in a Latin Square design: addition of five *H. octomaculata* ladybirds, addition of five *C. inaequalis* ladybirds, control (no predators added) or open cage control (no predators added, cage sides left open to allow free insect movement). Five sentinel egg cards, each with five *H. armigera* eggs, were stapled to leaves in the upper canopy of the cotton plants within the cage, left for 24h and the number of missing eggs recorded. Sentinel egg cards were used instead of directly gluing the eggs to leaves because it was too difficult to find the eggs again unless they were attached to visible cards. This experiment was replicated four times from December to February, with four cages per treatment in December and three cages per treatment for all other replicates. All insects (pest and beneficial) already present on plants inside the cages were left untouched.

Results

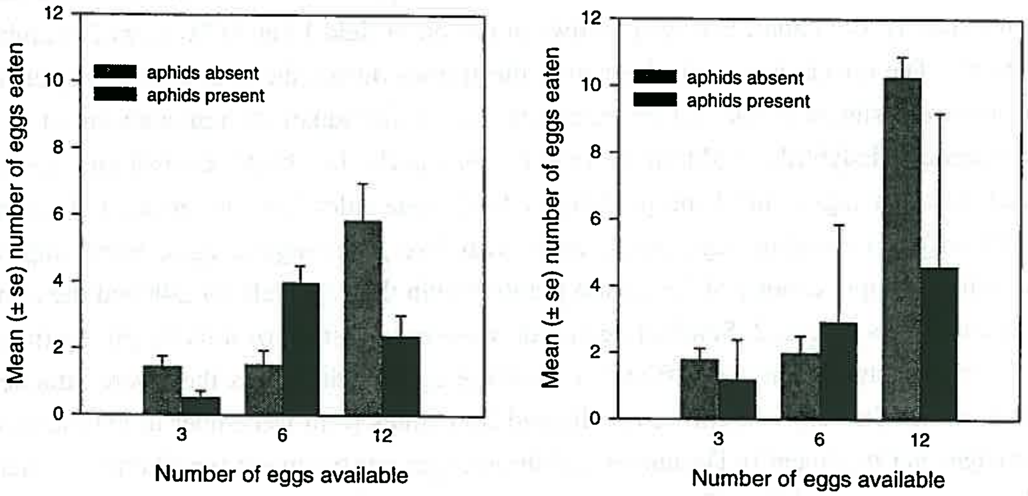
Laboratory tests

H. armigera egg consumption increased with higher prey density and differed between predator species (Table 1). Although alternate prey (aphids) did not affect egg consumption significantly overall, the interaction between species and aphids shows that the feeding patterns of some coccinellids changed when aphids were present. *C. transversalis* and *M. frenata* consumed more *H. armigera* eggs in the absence of aphids than when aphids were available (Fig. 1a-b). *H. octomaculata* consumed the most eggs of the four ladybird species tested (Fig. 1c) and *C. inaequalis* consumed the least (Fig. 1d), with or without aphids available.

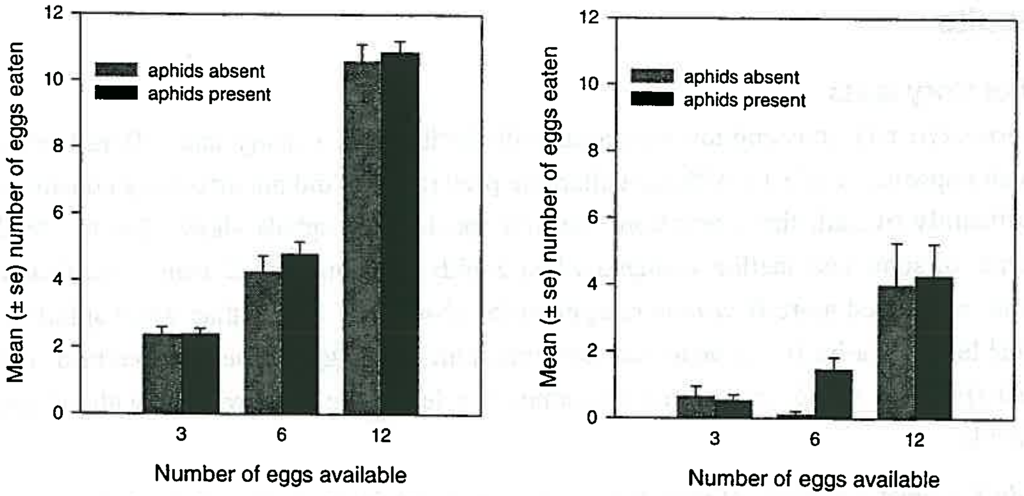
Table 1. Logistic analysis of predator species, prey density and alternate prey effects in the laboratory tests of *H. armigera* egg consumption. * $P < 0.0001$.

Factor	df	χ^2
Predator species	3	291.59*
Prey density	2	45.32*
Aphids	1	0.01
Species x prey	6	51.54*
Species x aphids	3	25.14*
Prey x aphids	2	70.23*
Species x prey x aphids	6	32.17*

Figure 1. Mean consumption of *Helicoverpa armigera* eggs at three densities by four coccinellid species under laboratory conditions, with and without aphids as alternate prey.


a) *Coccinella transversalis*

b) *Micraspis frenata*


c) *Harmonia octomaculata*

d) *Coelophora inaequalis*

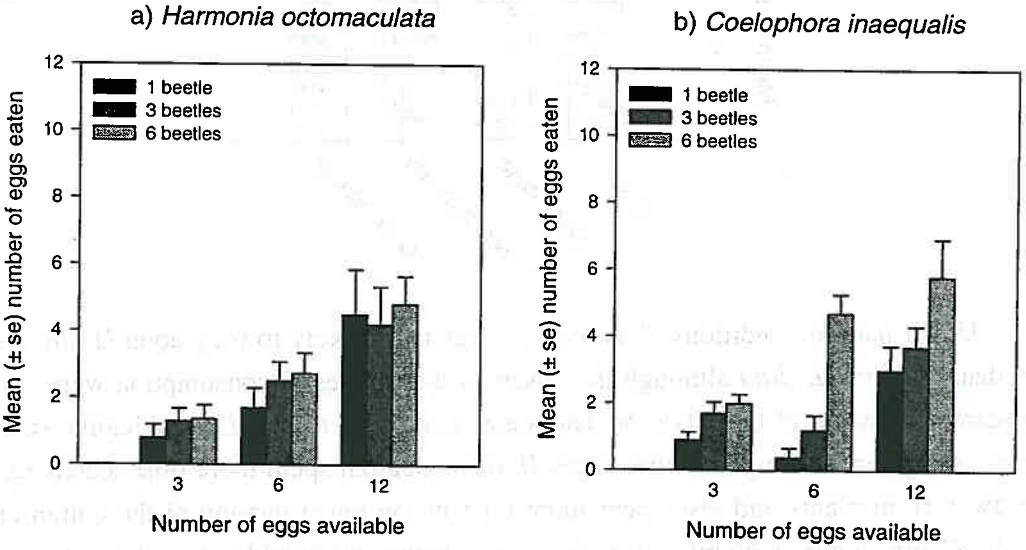
Glasshouse tests

The two coccinellid species tested in the glasshouse cages consumed similar amounts of *H. armigera* eggs although their responses to prey and predator density differed (Table 2). Egg consumption by *H. octomaculata* increased as egg density increased but predator density did not affect egg consumption (Fig. 2a). In contrast, egg consumption by *C. inaequalis* increased with both prey and predator density, particularly at the higher egg densities (Fig. 2b).

Table 2. Logistic analysis of predator species, predator density and prey density effects in the glasshouse tests of *H. armigera* egg consumption. * $P < 0.001$, ** $P < 0.05$.

Factor	df	χ^2
Predator species	1	< 0.005
Predator density	2	54.92*
Prey density	2	5.32
Species x predator density	2	20.78*
Species x prey density	2	5.89
Predator density x prey density	4	22.75*
Species x predator density x prey density	4	12.89**

Figure 2. Mean consumption of *Helicoverpa armigera* eggs by two ladybird species at different predator and prey densities in perspex cages under glasshouse conditions.



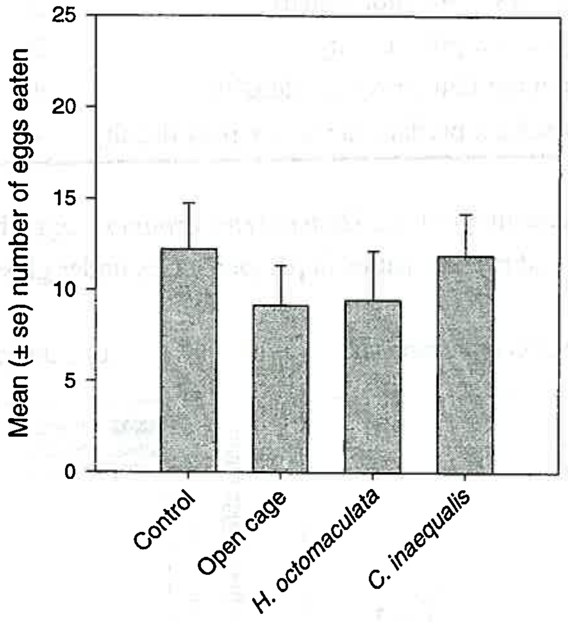
Field cage tests

The probability of *H. armigera* egg consumption differed between the four treatments ($\chi^2 = 16.63$, df = 3, $P < 0.001$). More eggs disappeared from control cages and cages with *C. inaequalis* than from open cages and cages with *H. octomaculata* (Fig. 3).

Discussion

At the smallest habitat size in the laboratory, *H. octomaculata* appears to be the most effective coccinellid predator of *H. armigera* eggs. *C. transversalis* and *M. frenata* appear less likely to contribute to *H. armigera* predation because these species usually occur in cotton only when aphids are present and aphids were the more important prey item under laboratory conditions. However this hypothesis has not been tested in the field. *C. inaequalis* was a less effective egg predator than *H. octomaculata* at the smallest habitat size, although this difference disappeared at larger habitat sizes.

Figure 3. Mean consumption of *Helicoverpa armigera* eggs by two coccinellid species in field cages in a cotton field at ACRI, Narrabri, NSW.



Under natural conditions *C. inaequalis* was more likely to prey upon *H. armigera* eggs than *H. octomaculata* although the observed differences in consumption were small. The search behaviour of these two predators may contribute to the effect of habitat size on prey consumption. In the glasshouse cages *H. octomaculata* spent more time searching for prey away from plants and also spent more time in the lower canopy of the cotton crop than did *C. inaequalis* (J. Nobilo, pers. obs.). Such behaviour would reduce the opportunity to encounter *Helicoverpa* spp. eggs, particularly later in the season when eggs are laid predominantly in the upper canopy (Pyke and Brown 1996). The higher rates of predation observed in the control cages were unexpected and could result from cage effects such as increased humidity, reduced light, or confinement of other naturally occurring predators within the cages. It is possible that coccinellid egg predation is of little significance relative to other sources of predation such as predatory bugs or ants.

Serological tests that are currently in development (S. Mansfield, unpub.) will be used to test the hypotheses generated from these data and to confirm which, if any, coccinellid species contribute to *Helicoverpa* spp. control in Australian cotton crops.

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