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The Functional Responses of *Hippodamia (Adonia) Variegata* Feeding on the Cotton Aphid, *Aphis Gossypii*

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ABSTRACT

The functional responses of *Hippodamia (Adonia) variegata*, one of the species of coccinellids found in association with aphids in cotton, were investigated by exposing it to increasing densities of cotton aphids in the laboratory. The aim was to determine how *Hippodamia variegata*'s feeding rate changes with increasing prey density and therefore to evaluate its potential as a biological control agent for *Aphis gossypii*. Leaves infested with of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 individuals of *A. gossypii* were placed in pillboxes measuring 2cm high and 5cm in diameter. A single adult of *H. variegata* was placed into each pillbox and the treatments were replicated four times. These treatments were repeated using the third instar larvae of *H. variegata* instead of the adults. Observations were made after 3 and 6 hours of feeding. A plot of the numbers of aphids consumed against the initial numbers of aphids placed in the pillboxes showed that an increase in aphid population resulted in an exponential increase in the feeding rate of coccinellids, before the prey density of 35 aphids was reached. Above 35 aphids, further increases in prey density did not result in further increases in the number of aphids consumed by *H. variegata. H. variegata* therefore displayed a Type 3 functional response and this implies that this coccinellid has potential as a biological control agent for *Aphis gossypii*.

1.0 Introduction

The Cotton aphid, *Aphis gossypii* GLOVER emerged as a major pest of cotton in Zimbabwe in the early 1990s (Brettel, 1995) and is now a harmful species causing not only quantitative decrease in the harvest but also decreased fibre quality (Matthews and Tunstall, 1994). High aphid populations on cotton plants cause up to 40 % yield loss (Chimoga, pers. comm.).

The recommended aphid control strategy in Zimbabwe involves exploitation of the biology of the pest, the state of the plant, weather conditions, natural predators, and chemical pesticides. The aphid control strategy involves monitoring of pest levels. This is achieved through weekly scouting of 24 plants on every 20 hectares of the cotton crop. A scoring system is used to determine aphid population levels. Aphids are capable of causing economic damage, if not controlled, when the total score is 48 or more per 24 plants, or 36 or more per 24 plants during a prolonged dry spell or an increase of aphids is noted before first boll split (Cotton Handbook). Aphids are controlled using insecticides (registered in Zimbabwe) when levels reach or exceed action thresholds as a quick intervention.

Predators such as coccinellids, lacewings and spiders that feed on a number of cotton pests are also scouted. Farmers are encouraged to suspend sprays, even if the aphid threshold is reached when predators suddenly increase in number. This is not a firm recommendation, but farmers have the discretion of making use of predators.

Most pests, worldwide, show pronounced resistance to pesticides that formally killed their species.

High levels of pest control can be achieved if other non-chemical factors in the environment, such as natural enemies, are used to supplement chemical control. Introduction of predators would be a better approach in delaying the onset of resistance in pests since predators feed on pests indiscriminately, without regard of the pest's level of resistance.

Of the many predators of aphids, coccinellids have been found to be the major predators. Among the coccinellids found in cotton in Zimbabwe, *H. variegata* has been found to consume the highest number of aphids compared to other species (Dirorimwe, 1995). The ladybird was considered as having great potential as a biological control agent against the cotton aphid. Potential biological control agents are often first tested under laboratory conditions to evaluate their potential for success (Byeon *et al*., 2010). The specificity of biological control agents and their functional response type are important considerations in their use (Byeon *et al*., 2010). The aim of the study was therefore to determine the nature of the functional response of *H. variegata* and to evaluate its potential as a biological control agent of the cotton aphid, *A. gossypii*.

2.0 Materials and Methods

2.1 Study site

The study was carried out at Cotton Research Institute (CRI) in Kadoma, Zimbabwe.

2.2 Collection of predators

Predators were collected from one of the unsprayed fields at CRI.

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The collected beetles were placed in pillboxes with leaves infested with cotton aphids and they were taken to the laboratory to start permanent cultures.

2.3 Rearing of predators

In the laboratory, the collected adult beetles were placed in a glass rearing jar measuring 15cm high and 8cm in diameter and kept at a mean temperature of 25.9^0C. The cotton aphid populations were very low in the fields and to keep the beetles alive, they were fed with vegetable aphids and the source of food in the jar was renewed every two days. Eggs were collected and their numbers were recorded. The beetles collected from the fields were removed and discarded when they had completed laying eggs. The eggs hatched and the life cycle was allowed to continue. The life cycle was repeated several times so that at any one time both larvae and adults were available for feeding investigations to be carried out. Mortalities that occurred before the feeding investigations were not recorded or accounted for.

2.4 Rearing of the Aphids

Okra plants (*Hibiscus esculentus*), the alternative host for *A. gossypii*, were grown in the green house and were allowed to get infested with *A. gossypii*. Only one okra plant developed aphids early and these were used to infest the other plants. The aphid culture grew and these were taken to the laboratory to carry out the feeding investigations.

2.5 Determination of the functional responses of *H. variegata* to increasing *A. gossypii* density

Adults and third instar larvae of *H. variegata* were used in the investigations. First, second and fourth instar larvae were not used in the investigations because first and second instars were very small and therefore difficult to handle while the fourth instars were not known when they were going to pupate. The beetles used in the investigations were starved for 24 hours before the investigations started. Ladybird beetles that emerged or hatched on the same day were used in the investigations and aphids of almost the same size were used. Treatments of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 aphids were used and each treatment had four replications. Larvae and adults were placed individually in pillboxes measuring 2cm high and 5cm in diameter. Records of the number of aphids consumed in 3 hours and 6 hours were taken. This was done by counting the number of aphids left after feeding. The number of aphids eaten was obtained by subtracting the number of aphids that remained in the pillboxes from the original number of aphids that was put in the pillboxes. The same set of adult beetles was used throughout the investigations but the sets of larvae were changed because the larvae were entering into the fourth instar. Using a soft camel-hair brush, individual aphids were counted and transferred from cotton leaves into pillboxes.

2.6 Data analysis

The data obtained were subjected to Univariate Analysis of Variance using SPSS version 11.

3.0 Results

3.1 Consumption rates of *H. variegata* on the aphid *A. gossypii*

After 3 hours, the mean numbers of aphids consumed by the adults and third instar larvae of *H. variegata* increased with prey density from 3 and 2.25 aphids, respectively, at the initial prey density of 5 aphids until they plateaued at initial prey densities of 40 and 35 individuals, respectively, at which the adults consumed 10.5 aphids and the third instar larvae consumed 7.5 aphids, respectively (Table 1).

Table 1. Mean numbers of aphids eaten by larvae and adults in 3hours.

Number of aphids provided	Mean Number of Aphids consumed by adults of *H. variegata*	Mean Number of Aphids consumed by third instar larvae of *H. variegata*
5	3.0	2.25
10	3.75	3.0
15	5.5	5.0
20	7.75	6.50
25	8.75	7.0
30	10.0	7.25
35	10.25	7.5
40	10.5	7.5
45	10.5	7.5
50	10.5	7.5

Table 2 shows that after 6 hours, the mean numbers of aphids consumed by the adults of *H. variegata* increased with prey density from 3.75 aphids at the initial prey density of 5 aphids until they plateaued at the initial prey density of 40 individuals at which 19.25 aphids were consumed. Predator saturation of the adults of *H. variegata* was reached at an initial prey density of 40 aphids both after 3 and 6 hours. The feeding rate of the third instar larvae after 6 hours, however, plateaued at an initial prey density of 40 aphids as for the adults (Table 2) instead of an initial prey density of 35 aphids as seen after 3 hours.

Table 2. Mean numbers of aphids consumed by third instar larvae and adults in 6 hours.

Number of aphids provided	Mean Number of Aphids consumed by adults of *H. variegata*	Mean Number of Aphids consumed by third instar larvae of *H. variegata*
5	3.75	3.25
10	4.5	4.0
15	8.25	7.75
20	11.5	10.5
25	15.0	12.5
30	18.2	15.0
35	19.0	15.3
40	19.25	15.5
45	19.25	15.5
50	19.25	15.5

3.2 Functional responses of the adults and third instar larvae of *H. variegata*

A plot of the mean number of prey consumed after 6 hours against initial prey density was a close approximation of a type III functional response for both the adults and third instar larvae of *H. variegata* (Figure 1).

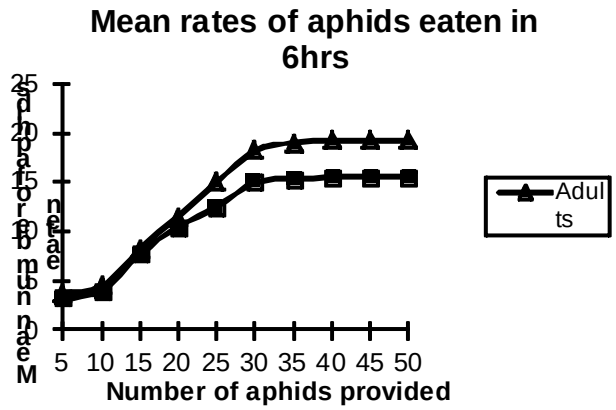

Figure 1. Plot of the numbers of aphids eaten against initial number of aphids provided.

3.3 Foraging behaviour of the coccinellids

At low prey density the ladybird beetles tended to move quickly and randomly but slowed down at high aphid densities. The beetles would come into contact with the prey and remain in the same area, making numerous small turning movements.

4.0 Discussion

The results obtained in this study were difficult to interpret and are inconclusive. The functional response obtained after 6 hours for both the adults and the third-instar larvae was not exactly sigmoid as is expected of a typical type III functional response. The functional response pattern seemed to lie between the type II and type III functional responses.

It seems that a number of factors can affect the type of functional response that will be exhibited by biocontrol agents in laboratory experimental settings. Byeon *et al*. (2010) argue that the number of host densities at which the biocontrol agent is tested is a critical factor in determining the type of functional response it will exhibit. For example, the aphid parasitoid, *Aphidius colemani* Viereck (Hymenoptera: Braconidae) demonstrated a type II functional response following testing at four densities (range: 20 - 80) of *Myzuz persicae* (Sulzer) (Hemiptera: Aphidiade) and six densities of *A. gossypii* while it demonstrated a type III functional response when tested at densities of 5 – 75 *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae) (Byeon *et al*., 2010). The results of the present study seemed to suggest that the period of exposure of the coccinellids to their aphid prey in laboratory experiments has an effect on the type of functional response that will be exhibited.

The present study also showed that *H. variegata* beetles exhibited extensive search at low prey densities, moving quickly and randomly in the rearing jars but at high prey densities, the beetles switched to intensive search, i.e., the beetles would come into contact with the prey and remain in the same area, making numerous small turning movements. This agrees with the observations of Kawai (1976) and Ettifouri and Ferran (1993) who reported that while searching for prey, the larvae of ladybird beetles would use random movements but switch from extensive to intensive search after contact with prey. This is very important because it means the biocontrol agent remains in centres of high prey density and would be able to shorten their search time and increase their consumption rate with increasing prey density.

H. variegata, therefore, has great potential as a biological control agent for the cotton aphid, *Aphis gossypii*, irrespective of whether it displays a type II or type III functional response. This will, however, be dependent upon the size of the pest population to be controlled and/or the type of biological control to be employed. Byeon *et al*. (2010) argue that natural enemies with a type II functional response are more effective for controlling aphids in greenhouses because they can attack prey even at low densities.

In classical biological control programmes, natural enemies with a type III functional response are more likely to be successful in the field than those with a type II response most probably because of the host-density-dependent regulation that has the potential to stabilise predator-prey population dynamics (Byeon *et al*., 2010).

Another critical factor determining the success of *H. variegata* as a biological control agent of *A. gossypii* is the population size of the pest to be managed. Under field conditions, if the population size of the pest is too large predator saturation will occur irrespective of whether the biological control agent has a type II or type III functional response. This means that classical biological control programmes for the control of *A. gossypii* using *H. variegata* are more likely to fail under field conditions considering the potential astronomical rates of increase of aphids. The usefulness of *H. variegata* in the control of *A. gossypii* seems to lie in the inundative releases of laboratory-reared ladybird beetles into aphid infested fields. The success of this strategy will more likely depend on simulation modelling in order to determine the numbers of the coccinellids that should be released per given pest population density in the field. There is need to establish the ratio at which these predators are able to suppress the aphid populations. The number of ladybird beetles against aphid density in the fields can be used to cancel or postpone a planned pesticide application and possibly to reduce the amount of pesticide to be used.

5.0 References

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