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Numerical response of ladybird beetles (Col., Coccinellidae) to aphid prey (Hom., Aphididae) in a field bean in north-east India

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Abstract: Two predaceous species of Coccinellidae, *Menochilus sexmaculatus* and *Coccinella transversalis*, occurred abundantly in bean crops infested with the aphid, *Aphis craccivora* Koch in north-east India. The number of eggs and adults of the two coccinellids increased in response to the increase in the population of aphid prey. Reproductive numerical responses were found to be synchronous to prey density whereas aggregative numerical responses appeared asynchronous in the later part of the aphid cycle on beans. *Menochilus sexmaculatus* oviposited smaller clusters of eggs at lower density of aphids than *C. transversalis* which laid larger clusters and showed greater numerical response at higher densities of aphids. Within a species cluster the size of the eggs seems to be directly related to aphid density. The two coccinellid species of this study seem to be efficient predators of *A. craccivora* in terms of their reproductive and aggregative numerical responses.

1 Introduction

The blackbean aphid, *Aphis craccivora* Koch infests grain legumes, vegetable legumes and groundnuts throughout the world, more particularly in the tropics (Blackman and Eastop, 1984). In India, this species causes mild to extensive damage to groundnut crops (Dogra et al., 1966), pulse crops (Chhabra et al., 1986; Nair, 1986; Bandopadhyay and Ghosh, 1986; Singh and Singh, 1991) and vegetable legumes (Dharma Reddy et al., 1983). Bean, *Vigna catjang*, is an important field crop throughout India and *A. craccivora* is the principal aphid pest of this crop in north-east India (Ghosh, 1974; Ganguli and Agarwala, 1985). Heavy infestation of young seedlings can cause death, and can stunt the growth, distort leaves and cause delay in flowering of older plants. Infestation after flowering causes pod shrivelling and a reduction in yield (Ofuya, 1991).

The role of insecticides and host-plant resistance in the control of *A. craccivora* have been investigated (Jackai and Daust, 1986; Chhabra et al., 1986) but little is known about the natural control of blackbean aphid. Several species of predators and parasitoids attack *A. craccivora* in India (Stary and Ghosh, 1983; Agarwala et al., 1984; Agarwala and Ghosh, 1988) but their role in determining aphid abundance has not been evaluated. A knowledge of the oviposition and aggregation responses of predators to prey density is vital for understanding the dynamics of predator–prey interactions in field crops (Chambers, 1991). The numerical response of the adult coccinellids to the density of aphid is particularly important in determining the effectiveness of these natural enemies because they can respond to the lower range of aphid densities (Mills, 1982) and are not vulnerable to intraguild predation (Agarwala and Dixon, 1991). In the present study the numerical responses of two species of coccinellids, *Menochilus sexmaculatus* (Fabr.) and *Coccinella transversalis* (Fabr.), in terms of oviposition (reproductive numerical response) and adult abundance (aggregative numerical response), to changes in *A. craccivora* density on field bean was investigated. Variation in the cluster size of their eggs were also determined both within and between the two ladybird species. Larvae of coccinellids were not counted as they are a weak forager at lower aphid density (Brown, 1972) and are subject to intraguild predations (Agarwala and Dixon, 1992).

2 Materials and methods

The study area was located in a wet tropical deciduous forest of north-east India. The study was carried out during the winter cropping season of October 1994 to March 1995. Eggs and adults of *M. sexmaculatus* and *C. transversalis*, and the population of *A. craccivora* were sampled in a 415 m^2 field plot of bean, *Vigna catjang,* at the ICAR Experimental Station, Lembucherra. A 12-row buffer zone was maintained around the field plot to reduce the effect of insecticides used in the adjoining fields. The plot was divided into 10 subplots of equal size. The number of aphids, and eggs of the two species of ladybird beetles were sampled at 7-day intervals from the seedling stage to 1 week before harvest of the bean crop. A sample consisted of 10 plants chosen at random from each of the 10 subplots. It was possible to discriminate between the eggs of *M. sexmaculatus* and *C. transversalis* (Agarwala and Bardhanroy, 1997) and also that of the other species of coccinellids that occurred in the beans.

In order to determine the numerical response of the two coccinellid species, log densities of eggs and adult beetles and the log densities of aphids up to the peak density of aphids were regressed. Log density of coccinellids was also regressed against the log density of aphids in the previous week.

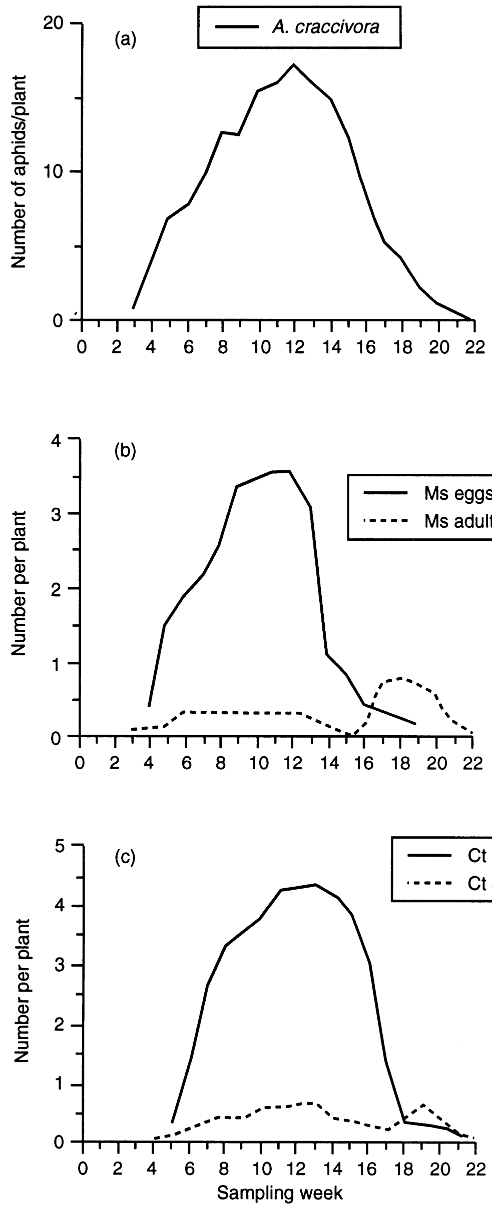


Fig. 1. *Weekly records of mean number of aphids of* Aphis craccivora *(a), eggs and adult beetles of* Menochilus sexmaculatus *(Ms) (b), and* Coccinella transversalis *(Ct) (c), respectively, in a bean field during the winter season of October 1994–March 1995*

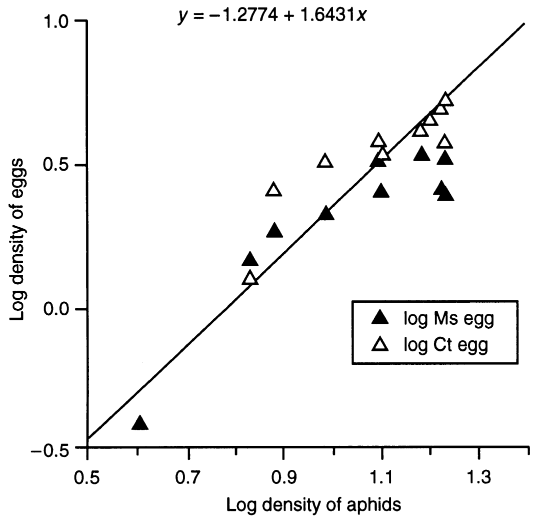


Fig. 2. *Regression relationship between the log density of aphids and the log density of eggs of* Menochilus sexmaculatus *and* Coccinella transversalis *based on weekly records in a bean field during the increasing aphid abundance*

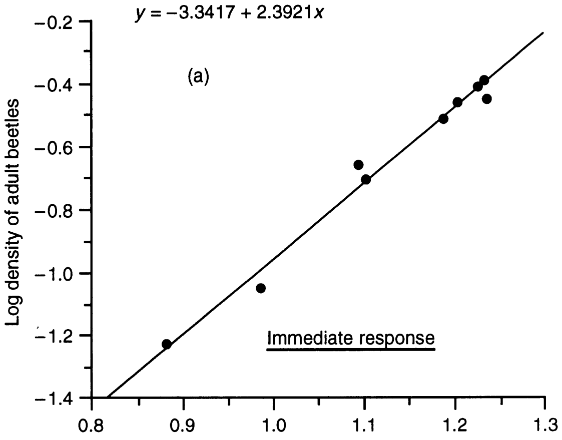
3 Results

Aphids were first noticed on the bean plants in the third week of the study (fig. 1a). Adults of *M. sexmaculatus* also appeared in the same week and their eggs in the fourth week (fig. 1b). In case of *C. transversalis*, adults and eggs were first recorded in fourth and fifth weeks, respectively (fig. 1c). The number of the two coccinellids and aphids both showed a single peak in abundance. Increased oviposition by the beetles with increase in aphid density was the most striking feature. A rapid decrease in aphid density was followed by an equally rapid decline in oviposition by the coccinellids. Oviposition trend was similar in the two species despite the late appearence of eggs of *C. transversalis*. Population census data of the two coccinellid species, however, indicated high egg mortality.

A smaller peak of adults declined close to the lowest population of their respective eggs. A few days later adults were emerging from the pupae in the beans and respective populations of the two coccinellid species gradually surged to touch a second peak. The second peak of *C. transversalis* was delayed by 2 weeks compared with that of *M. sexmaculatus*. These populations gradually declined to almost zero following the trend of aphid population when most beetles moved to alternate habitats for other aphid or pollen food.

The regression of the log of the densities of the eggs of the two cocinellid species on the log of the density of the aphids for both immediate (same day) and lag (one week earlier) showed no significant differences (immediate response: *M. sexmaculatus*, $Y = -0.916 + 0.814X$; *C. transversalis*, $Y = -1.012 + 0.854X$; lag response: *M. sexmaculatus*, $Y = -0.923 + 0.917X$; *C. transversalis*, $Y = -0.954 + 0.864X$). Therefore, $Y = -1.2774 + 1.6431X$ is a general regression describing the response of oviposition of the two coccinellid species to *A. craccivora* in the beans (fig. 2). Although the eggs of *M. sexmaculatus* appeared earlier than eggs of *C. transversalis*, there is a stronger correlation between aphids and eggs of *C. transversalis* for the immediate and lag responses ($r = 0.96$; 0.94, respectively) than for aphids and eggs of *M. sexmaculatus* ($r = 0.83$; 0.81, respectively). At the highest density of aphids, *C. transversalis* laid more eggs than *M. sexmaculatus* but there was no statistical difference between the responses of the two species (Mann Whitney test, $U = 48.2$, NS).

The relationship between the densities of aphids and adult coccinellids was determined by regression analysis during the period of increasing aphid abundance. The correlation coefficients were greater for both species for an immediate rather than a lag response (*M.*



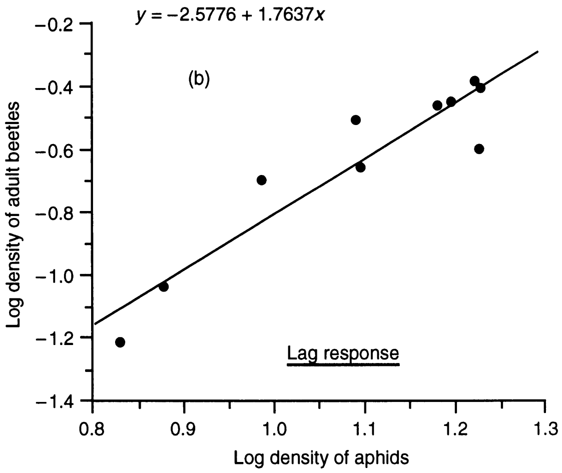
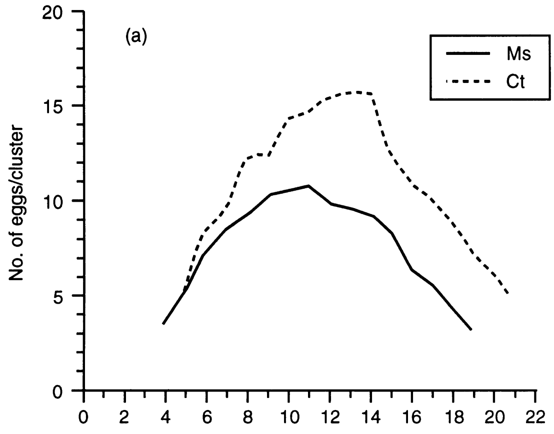


Fig. 3. *Regression relationship between the log density of adult beetles of* Menochilus sexmaculatus *and* Coccinella transversalis, *and the log density of aphids observed on the same day (immediate response) (a) and 1 week earlier (lag response) (b) during the period of increasing aphid abundance*



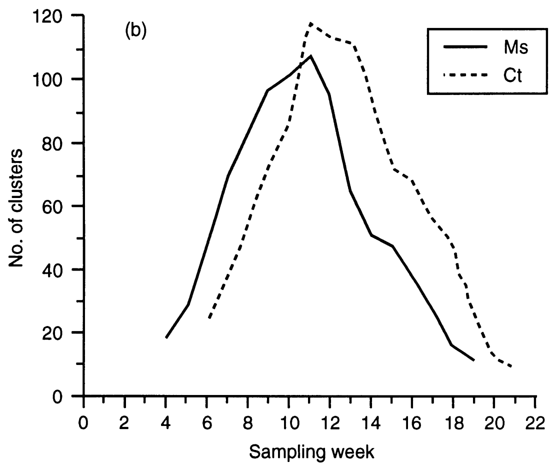


Fig. 4. *Egg cluster production by* Menochilus sexmaculatus *and* Coccinella transversalis *expressed as number of eggs per cluster (a), and number of egg clusters produced (b) on bean plants*

sexmaculatus, $r = 0.89$ versus 0.78, and *C. transversalis*, $r = 0.82$ versus 0.70)(figs 3a,b).

The increasing population of *A. craccivora* had two major effects on oviposition in the two species of coccinellids in beans. The first was an increase in number of eggs per cluster. Early in the ovipositional period, the number of eggs per cluster was low for both species. This number increased rapidly up to an average of 10.80 eggs per clusters for *M. sexmaculatus* and 15.70 eggs per cluster for *C. trasversalis* (fig. 4a). The second effect was to stimulate egg production, especially in *C. transversalis*. The number of egg clusters observed per adult beetle on the same day in relation to counts of aphids also varied. Both the coccinellid species maintained synchronous trend of oviposition to increase or decrease in aphid population. Between the two species, *C. transversalis* exhibited a higher peak of egg clusters (fig. 4b). Regression relationship of cluster size to aphid number showed rising slopes for cluster size in both the coccinellid species (fig. 5). Such a relationship in coccinellid predators of aphid prey is suggestive of intimate predator–prey interaction in terms of prey foraging and reproduction efficiency.

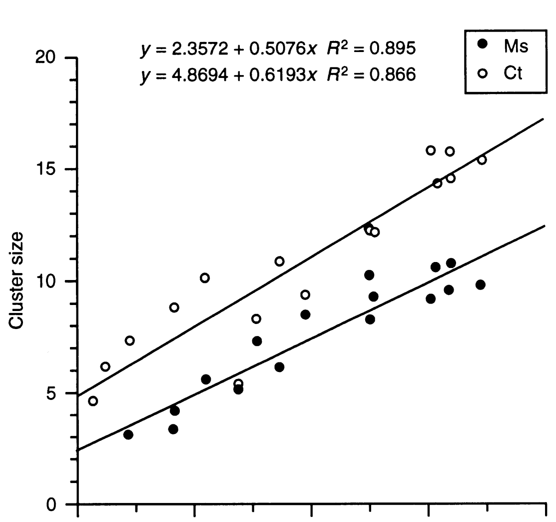


Fig. 5. *Regression relation between cluster size of* Menochilus sexmaculatus *and* Coccinella transversalis *and aphid number on beans*

4 Discussion

Field studies show that ladybird beetles of the two species aggregate and lay eggs throughout the duration of incidence of aphid on beans. It was also observed that higher number of adults of *M. sexmaculatus* occurred at low aphid densities, these laid smaller egg clusters and a relatively lower output of clusters per beetle. In contrast, higher number of adults of *C. transversalis* occurred at high aphid densities, these laid larger egg clusters and a higher output of clusters.

This result is not in agreement with other findings in the case of *Adalia bipunctata* (Fabr.) in which ladybird beetles synchronize their reproduction with the early development of aphid colonies (DIXON, 1997). This tendency is considered to be advantageous because the survival of newborn ladybird larvae is very dependent on an abundance of young aphids (DIXON, 1959). It is also suggested that oviposition late in the development of an aphid population could result in the older larvae being short of food and failing to complete their development. In addition, low aphid abundance promotes conspecific and interspecific competition (AGARWALA and DIXON, 1992). In the present study, although a substantial proportion of oviposition by the two species of coccinellids occurred in the increasing phase of aphid population, female beetles continued to lay eggs when aphid density was low in the declining phase of aphid population. Similar observations have also been reported from studies in Japan (OSAWA, 1992; HIRONORI and KATSUHIRO, 1997) and Canada (WRIGHT and LAING, 1980). These results tend to suggest that oviposition in ladybirds is a function of prey abundance. Egg production and size of egg clusters of ladybirds appear to be sensitive to aphid population density. The present field study and also an earlier laboratory study (AGARWALA and BARDHANROY, 1997) suggest that in an abundant food supply female ladybirds lay more eggs and larger clusters compared with less eggs and smaller clusters at low prey abundance. From these results it follows that in times of food stress ladybirds vary the size of their clusters of eggs. Results also indicated that a higher proportion of the eggs of the two coccinellid species suffered mortality. A number of factors contribute to the mortality of eggs. These include infertility (MAJERUS, 1994), egg cannibalism by larvae and adults and egg predation from interspecific insects (AGARWALA and DIXON, 1992). It has been suggested that density-dependent egg cannibalism in the field, both from sibling and nonsibling sources, was responsible for 30% of the mortality (MILLS, 1982; OSAWA, 1992). Egg predation from interspecific coccinellids and other insects sharing the same habitat also occurs (AGARWALA and BARDHANROY, 1997; AGARWALA et al., 1998). A life-table study of *Harmonia axyridis* Pallas shows that less than 8% of the eggs oviposited in the field reached the adult stage (OSAWA, 1992).

However, the results of this study do not explain the fate of newborn larvae which hatch late in the aphid cycle on beans. The information so far available on the oviposition and reproductive strategy for different coccinellid predators of aphid prey are far from complete. More study is required to explain the intricacy of prey–predator interaction, in particular, how predators respond to rapid changes in aphid population.

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