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Short communication

Influence of the host plant of the cassava mealybug *Phenacoccus manihoti* on life-history parameters of the predator *Exochomus flaviventris*

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Introduction

To our knowledge, there is still no data available on the influence of plant quality on the trophic suitability of cassava mealybug as prey for *Exochomus flaviventris* Mader (Coleoptera, Coccinellidae). *E. flaviventris*, a polyphagous ladybird indigenous to subsaharan Africa, is the most active predator of the cassava mealybug in Central Africa (Iziquel & Le Rü, 1989). Cassava-mealybug and mealybug-predator systems have been widely studied both in the laboratory and in the field (Fabres & Kiyindou, 1985; Kiyindou et al., 1990; Reyd & Le Rü, 1992). Until now, only van den Meiracker et al. (1990) have analyzed at plant level the influence of cassava mealybug on the searching behavior of *Exochomus* sp. They showed that inexperienced adult females spend more time searching on cassava leaves previously infested with cassava mealybug than on healthy cassava leaves, and that they are arrested by both wax exuviae and honeydew from the mealybug.

Of the three main categories of resistance defined by Painter (1951), antibiosis, which is defined as plant factors that alter the herbivore's growth, fecundity and survival, is most likely to negatively affect the third trophic level (van Emden, 1991). The purpose of this study was to investigate the influence of four different host plants having shown various antibiosis resistance levels to *P. manihoti*, on the survival, development time, fecundity and prey consumption of the ladybird *E. flaviventris*. These life-history components can have an important effect on the efficiency of a predator.

Material and methods

Plants. As host plants, we used two cassava varieties (Incoza and Zanaga (MM79), *Manihot esculenta* Crantz, Euphorbiaceae), the Faux-Caoutchouc (FC) (a hybrid of *M. esculenta* and *M. glaziovii* Muell. Arg., Euphorbiaceae) and *Talinum* (*Talinum triangularae* Jack., Portulacaceae). Both cassava varieties are highly resistant to mealybugs in terms of antixenosis but they are different in terms of antibiosis, with Incoza being the more resistant one (Tertuliano et al., 1993). Faux-Caoutchouc hosts large populations of mealybugs throughout the year, unlike cassava on which mealybugs are present for only 3–5 months (Iheagwam, 1981). *Talinum* is a weed found in cassava fields which can sometimes host large populations of cassava mealybugs (Neuenschwander & Madojemu, 1986). The trophic characteristics of this plant such as lack of cyanogenic glycosides and very low sugar contents are different from those of cassava and provide a baseline for comparisons of the influence of the trophic characteristics of the plant on the predator (Calatayud, 1993). Plants at the 10–15 leaf stage (9–10 weeks, plant height 60 cm) were used in experiments performed in insect greenhouses at 26 °C (range 21–33), 70% r.h. (50–95) and L12:D12 photoperiod.

Insects. The mealybug and predator strains were obtained from field populations in Pointe Noire, Congo, in 1996 and maintained in separate rearing insect greenhouses. Mealybugs reproduce by thelytokous parthenogenesis. As under natural conditions in central Africa, the cassava crop was maintained during two years and mealybug developed 10 generations per year, we used four distinct clones of mealybugs reared

for more than 10 generations on the four host plants studied.

Experimental procedure. On each host plant (treatment), 11 females (replicates) of *E. flaviventris* were tested simultaneously. Two hundred-and-twenty fourth instar mealybugs (adults) (five days old) of equal size were collected daily from each of the mealybug cultures and placed in groups of 20 on 12 leaves of each host plant for fixation and oviposition; adults with ovisac is the preferred stage for *E. flaviventris* females for oviposition (Nsiama She et al., 1984). Five days later, each infested leaf (still intact on the plant) was introduced into a muslin pocket (24 cm wide, 25 cm long) with one female and two male predators. Every 24 h, the predators were transferred in the same muslin pocket to a new leaf infested with 20 adults with ovisac until the predator's death. The number of eggs laid per female ladybird was counted daily with a magnifying glass and the eggs were left on the leaf until eclosion. Then, freshly hatched first instar ladybird larvae were tranferred to another leaf infested with mealybugs. Larval and prepupal development of 10 offspring per female were followed daily on the same leaf until the adult stage; the number of mealybugs was kept constant on each leaf until the experiment was finished. Other predator offspring were transferred to infested plants of the same species kept in wooden cages ($39 \times 39 \times 90$ cm) with fine screen sides and glass tops, until adult emergence. Imagos were sexed and measured using a micrometer.

The following life-history parameters were determined from the data for the four host plants: immature mortality (%), mean development and oviposition times of females (days); total fecundity (eggs/female) and daily and total mean number of adult mealybugs eaten by one female and two males *E. flaviventris.* Data on immature mortalities were arcsine-transformed to stabilize variances. All data were submitted to ANOVA. Means (given $\pm$ S.E.) were separated by the Fisher's PLSD multiple-range test at a confidence level of 5%. Link between total fecundity and oviposition time was done using regression analysis.

Results and discussion

The mean development time of *E. flaviventris* female varied significantly according to the host plant ($P \leq 0.001$). It was shorter on *Talinum* and Incoza than on the two other host plants and, among *Manihot* plants, it was shorter on Zanaga than on Faux-Caoutchouc (Table 1). Furthermore, immature mortality was affected by the host plant fed on by mealybug ($P \leq 0.015$); this was nearly 1.5 higher on Incoza and Faux-Caoutchouc than on Zanaga and *Talinum* (Table 1). Our results are consistent with those reported by Rice & Wilde (1989) and Martos et al. (1992) showing a relationship between the level of plant resistance and coccinellid performance. In particular, Martos et al. (1992) showed that larval development time and the survival of the coccinellid were longer and lower, respectively, when fed aphids reared on a wheat cultivar (*Triticum aestivum* L.) with an intermediate DIMBOA level (an aphid resistance factor in wheat) than on either low and high DIMBOA cultivars. They also showed that predator development times were short when fed aphids of high DIMBOA seedlings. Thus, according to our model, flavonoid glycosides (the rutin ones) are associated with resistance to cassava mealybugs through antibiosis (Calatayud, 1993). Therefore, in this study, the mean development time of *P. manihoti* was short on Incoza (which has a high flavonoid content) while it was low on Faux-Caoutchouc (with an intermediate flavonoid content). In addition, the pre-imaginal mortality was as high on Faux-Caoutchouc as on Incoza.

Mean oviposition time of *E. flaviventris* differed between the four host plants ($P \leq 0.010$); it was longer on Zanaga than on the other plants. As far as we know, plant influences on oviposition time of predators have received little attention. Nevertheless, some studies have examined the influence of different prey species on this parameter, and have shown that prey suitability for coccinellids was related to a long oviposition time when compared with an unsuitable prey (Alassane, 1989; Dreyer et al., 1997). This result is consistent with ours. In fact, in this study, short oviposition time was recorded on the most antibiotic cassava variety Incoza, and a longer period on the less antibiotic cassava variety Zanaga.

Mean daily consumption varied among host plants ($P \leq 0.001$); it was nearly 8 adult mealybugs per female on Incoza and *Talinum* and among *Manihot* plants it was higher on Incoza than on Faux-Caoutchouc and Zanaga by 2.19 and 3.36 adult mealybugs per female respectively. Mean total consumption was also affected by the plants ($P \leq 0.004$): it is 1.3 to 1.8 times higher on *Talinum* than on the other treatments, but there were no significant differences among *Manihot* plants. Between the two cassava varieties, our

Table 1. Female development time (days), immature mortality (%), oviposition time (days), total fecundity (eggs/female) and, daily and total mean number of adult mealybugs eaten by one female and two males, of *E. flaviventris* fed on cassava mealybug reared on four different host plants

	lncoza $n = 11$	Zanaga $n = 10$	Faux Caoutchouc $n = 11$	Talinum $n = 11$
Female development time (days)	25.4 ± 0.6 c	26.3 ± 0.9 b	28.4 ± 1.1 a	25.0 ± 1.1 c
Immature mortality (%)	24.4 ± 8.4 a	15.9 ± 3.8 b	23.1 ± 6.0 a	14.8 ± 5.9 b
Oviposition time (days)	28.9 ± 11.2 b	47.4 ± 19.7 a	25.8 ± 12.5 b	38.6 ± 16.6 ab
Total fecundity (eggs/female)	265.1 ± 118.4 b	384.5 ± 108.5 a	199.5 ± 73.1 b	269.0 ± 109.5 b
Daily consumption (adult mealybugs)	8.1 ± 1.4 a	4.7 ± 0.9 c	5.9 ± 0.9 b	8.5 ± 0.7 a
Total consumption (adult mealybugs)	284.3 ± 100.8 b	273.5 ± 76.8 b	207.4 ± 84.6 b	381.4 ± 142.8 a

*Values in the same row followed by the same letter do not differ significantly from each other at $P = 0.05$ (one way ANOVA and Fisher's PLSD).

results indicate that daily consumption was nearly two times greater on Incoza than on Zanaga. Nevertheless, longevity was nearly two times shorter on Incoza than on Zanaga, whereas total consumption was comparable on the two plants. These results suggest that prey quality leads to two consumption patterns for the ladybird: a high daily consumption, associated with a short imaginal time, and a low daily consumption associated with a long one. Faux-Caoutchouc and *Talinum* consumption patterns seem to be close to Incoza and Zanaga patterns respectively. A decrease in the body size of the herbivore may increase the functional response of the predator because the predator satiates more slowly (Price, 1986). In our study, the strong functional response of *E. flaviventris* observed on Incoza and *Talinum* might not be related to the body size of the herbivore [i.e., body size of the mealybug differ significantly between the two host plants, (A. Mitsipa, unpubl.)] but rather to prey trophic characteristics and their by-products (mainly honeydew).

The total fecundity was affected by the host plant ($P \leq 0.003$); it was higher on Zanaga than on Incoza, Faux-Caoutchouc and *Talinum* by 119, 185 and 115 eggs per female, respectively. It was related to the mean oviposition time ($n = 43$, $r^2 = 0.852$, $F = 13.50$, $P = 0.04$). Our study shows that the main factor that determined ladybird total fecundity was the mean oviposition time, indicating that female *E. flaviventris* will oviposit as far as they have a long life span. Nevertheless, the lengthening of the oviposition period and the increase of total fecundity were not related to an increase of the total mean consumption among cassava varieties. This result suggests that mealybugs fed on Zanaga were more suitable prey for female *E. flaviventris* since they oviposited more eggs on it than on Incoza with the same quantity of prey.

In conclusion, our study has shown that most life-history parameters of this generalist predator *E. flaviventris* were greatly affected by the host plant of the cassava mealybug. When foraging for prey, predators prefer those that maximise larval development and reproduction. Our results suggest that cassava mealybugs fed on Faux-Caoutchouc and Incoza were less suitable prey for *E. flaviventris* than those fed on *Talinum* and Zanaga. Whether or not low quality food of mealybugs reared on Incoza or Faux-Caoutchouc is a consequence of chemical (flavonoid compounds) and/or morphological (waxy leaf surface, leaf toughness) plant attributes has to be clarified. However, among cassava varieties, ladybird voracity was two times greater on the most antibiotic cassava variety Incoza than on the less antibiotic Zanaga, showing that the use of cassava varieties such as Incoza might synergistically interact with *E. flaviventris* to provide a significant cassava mealybug control.

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