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Evaluation of *Serangium* n. sp. (Col., Coccinellidae), a predator of *Bemisia tabaci* (Hom., Aleyrodidae) on cassava

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Abstract The potential of a new, previously unidentified *Serangium* species (Col., Coccinellidae) to control the high *Bemisia tabaci* (Gennadius) (Hom., Aleyrodidae) populations on cassava was evaluated. Field and laboratory studies were carried out to determine the abundance and feeding capacity of this *Serangium* species feeding on *B. tabaci* on cassava. *Serangium* nymphs and adults were most abundant in cassava fields late in the season, rising sharply from 5 months after planting (MAP) to a peak at 7–8 MAP. Pre-imaginal development averaged 21.2 days and was longest in eggs and shortest in the L_1 instar. Mean total prey consumption of immature *Serangium* increased with the stage of development with the lowest consumption in the L_1 instar and highest in the L_4 instar. Mean daily consumption was lowest on the first day after hatching in the L_1 instar and rose to a peak on the 13th day after hatching in the L_4 instar. Each *Serangium* larva consumed a mean of over 1000 nymphs during its entire development. These results have demonstrated the potential of this *Serangium* species to control *B. tabaci* populations on cassava.

Key words: biological control, pre-imaginal development, prey abundance, prey consumption

1 Introduction

Bemisia tabaci (Gennadius) (Hom., Aleyrodidae) is a widely distributed pest species colonizing many agricultural systems including greenhouses in both the tropics and subtropics (Oliveira et al. 2001). It is a major vector of viral plant diseases especially begomoviruses (Brown and Bird 1992), and in Africa, it transmits cassava mosaic geminiviruses, which cause cassava mosaic disease (CMD) (Bock and Woods 1983). This disease has resulted in devastating yield losses throughout cassava growing regions in Eastern and Central Africa with losses in Uganda estimated at several millions of US dollars at the height of the epidemic during the early 1990s (Legg and Ogwal 1998; Otim-Nape et al. 2000). The development of virus resistant cassava varieties resulted in alleviation of the CMD-caused damage. However, feeding of *B. tabaci* also results in direct damage, which is shown by leaf chlorosis, a mottled appearance, reduction in plant vigour, general plant stunting and induction of phytotoxic disorders (Bedford et al. 1994). In addition, *B. tabaci* also causes indirect damage through production of honeydew that results in growth of sooty mould on leaves, petioles and stems. The new virus resistant varieties are often very susceptible to both direct and indirect whitefly damage, which may result in crop reduction of up to 50% (Legg et al. 2003). This has led to a need to develop an integrated approach to the management of this pest, an predators are being explored as an option. Recent studies (Otim 2006) have identified a new species of *Serangium* (Col., Coccinellidae) consistently occurring wherever cassava is grown in Uganda.

Serangium spp. are widely distributed in the world and are known to be useful predators of many whitefly species. The most commonly studied *Serangium* species is *Serangium parcesetosum* Sicard. It has been recorded feeding on *B. tabaci* on cotton (Kapadia and Puri 1992) and *Aleurolobus barodensis* Mask (Shah et al. 1986). It has also been successfully used against the citrus whitefly, *Dialeurodes citri* Ashmead (Yigit 1992a,b; Uygun et al. 1997; Yigit et al. 2003) and the silverleaf whitefly, *Bemisia argentifolii* (= *B. tabaci*) (Legaspi et al. 1996, 2001; Ellis et al. 2001). Several studies to determine the biology of *S. parcesetosum* feeding on different whitefly species have been conducted. Timofeyeva and Nhuan (1979) determined its development, mortality and fecundity when feeding on *D. citri* on citrus at 20–23°C, Kapadia and Puri (1992) determined its biology with *B. tabaci* on eggplant and cotton at 23.7°C and Patel et al. (1996) studied its development and longevity with *A. barodensis* on

sugarcane at 27°C. Studies on prey consumption by Legaspi et al. (1996) showed that both larvae and adults of *S. parcesetosum* are voracious feeders of immature whiteflies capable of consuming up to 400 nymphs in a 24-h period. They also found the cumulative lifetime predation rate to be about 5000 nymphs per adult beetle. These studies, therefore, document the potential for use of *Serangium* spp. for controlling whiteflies.

Although it has been shown that all of the known coccinellids belonging to the tribe Seranginii are obligate predators of whiteflies (Gordon 1985), there is no documented evidence of their ability to feed on *B. tabaci* populations on cassava and therefore aid in controlling the super-abundant populations on CMD-resistant varieties. Also, nothing is known about their abundance relative to age of the plant in cassava fields. This study therefore aimed at determining the abundance, development duration and consumption rates of *Serangium* n. sp. (here after referred to as *Serangium*) on cassava in Uganda.

2 Materials and Methods

2.1 Field studies

A field experiment was set up at National Crops Resources Research Institute (NACRRI), Namulonge to determine the variation in *Serangium* populations with age of the cassava plant. The field measured 10 m by 10 m with cassava plants spaced at 1-m intervals. The experiment was planted in August 2003, which coincided with the end of the short rains. The time of planting was chosen based on the usual cassava-planting season in Uganda, where farmers take advantage of the drought resistant nature of the crop by planting during the short rainy season and allowing the crop to go through most of its growth period during the dry season.

At 3 months after planting (MAP), 10 plants were randomly selected from the trial plot. Each plant was then observed from the top to bottom including all leaves (both the top and underside), petioles and the stem. A count of all *Serangium* larvae and adults was made. Data were collected once a week for a period of 6 months, i.e. from 3–8 MAP which is the active growth period of cassava and also the period when *B. tabaci* populations are highest on cassava (Fishpool et al. 1995). Each plant was sampled once and was only sampled again when all the plants in a particular trial had been sampled. This gave an average of two samplings per plant over the 6-month trial period, with a 10-week interval for each plant between samplings.

The field counts were compared statistically by using regression analysis (SIGMASTAT 3.0, SYSTAT software) to determine relationship between *Serangium* abundance and age of the crop.

2.2 Laboratory studies

Adult *Serangium* were collected daily from already established cassava fields at the National Crops Resources Research Institute, Namulonge, by using an aspirator and were immediately transferred to the laboratory. All collections were performed in the morning hours between 9 AM and 11 AM. Leaves containing all whitefly nymph developmental stages were excised from whole plants in the field and transferred to the laboratory. Female *Serangium* were placed on the leaves and allowed to feed and oviposit on the leaf for 24 h. Following oviposition, the females were removed from the Petri dish and the eggs were allowed to hatch.

Each newly emerged first instar larva was placed in a single Petri dish containing a fresh leaf with all nymphal stages of *B. tabaci* except the pharate adults, as preliminary observations revealed a tendency of the larvae to avoid these stages. The leaf was placed on a filter paper at the bottom of the Petri dish, which was punctured with five small holes at the top to allow ventilation. The sides were sealed with parafilm to hold the lid and base of the Petri dish together, and to prevent escape of the predators. The number of healthy nymphs prior to introducing the larva was counted. The first and second larval instar predators were provided with >200 nymphs each, while the third and fourth instars had >400 nymphs. At 24-h intervals, the Petri dishes were checked to determine the number of nymphs consumed. The stage of the larva was also recorded and a new larval instar was determined based on the presence of an exo-skeleton in the Petri dish. Using a fine brush, the predator larva was moved to a new leaf containing prey and the old leaf was discarded. Glabrous leaves were used to allow free movement of the predators as they oviposited and foraged for prey. A total of 15 larvae of both sexes were monitored from hatching time to adulthood. No adults were used for the consumption studies because preliminary observations indicated a tendency for the adults to walk on the lid, probably looking for an exit point, and avoid the leaf containing prey, when placed in a Petri dish.

The number of prey consumed daily was determined by counting the number of predated nymphs, which appeared translucent and flat with all or most of the haemolymph sucked out. The temperature during the entire study was monitored by using a wall thermometer and was 25 ± 2°C, a 12L:12D photoperiod and ambient relative humidity. The data obtained were subjected to ANOVA by using SIGMASTAT 3.0. Holm-sidak multiple (Hochberg and Tamhane, 1987) comparisons were done to compare prey consumption between instars.

3 Results

3.1 *Serangium* abundance

Serangium larvae were generally more abundant than adults although both stages showed the same pattern in population build-up throughout the sampling period. Very low numbers (<5) of both stages were observed during the first three sampling months (3–5 MAP). There was a sharp increase in numbers of *Serangium* larvae from 5 to 7 MAP, before declining at 8 MAP. *Serangium* adults increased from 5 MAP peaking at 8 MAP (fig. 1). Regression analyses showed significant differences between *Serangium* larvae ($P = 0.034$, $R^2 = 0.71$) and adults ($P = 0.011$, $R^2 = 0.83$), with age of the plant.

3.2 Development duration

Pre-imaginal development time ranged 18–27 days with a mean of 21.2 days from egg to adult. Mean within stage duration was highest in eggs (4.2 ± 0.09 days) (mean ± SE) and lowest in the L_1 instar (2.3 ± 0.11 days). There was little variation in

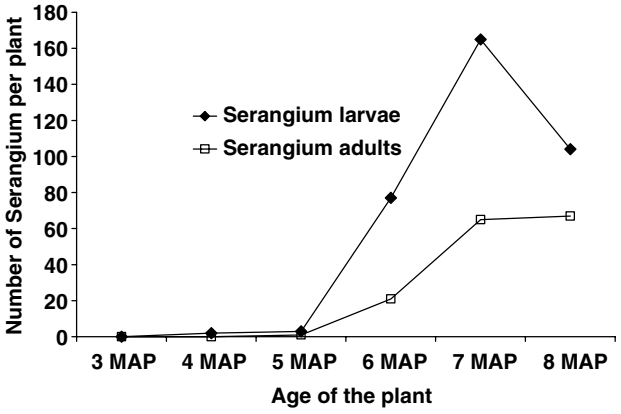

Fig. 1. Variation in populations of Serangium *larvae and adults with age of cassava in Uganda*

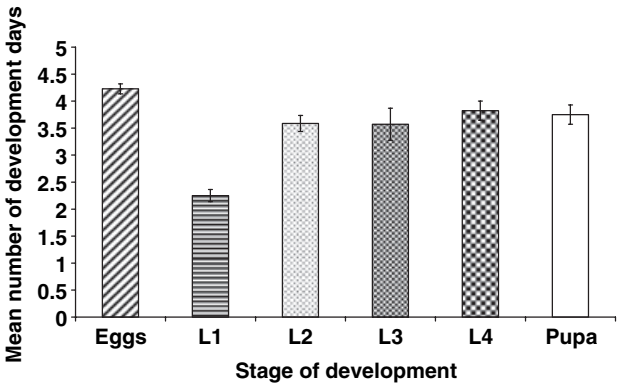

Fig. 2. Mean development time of immature stages of Serangium *by feeding* Bemisia tabaci *nymphs as prey on cassava in Uganda at 25 ± 2°C*

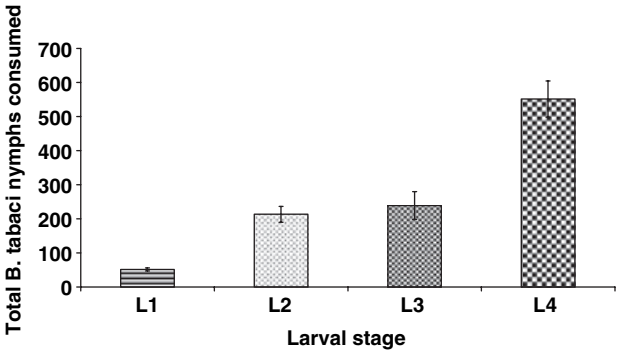

Fig. 3. Mean total prey consumption by Serangium *larval instars feeding on Bemisia tabaci nymphs on cassava leaves at 25 ± 2°C*

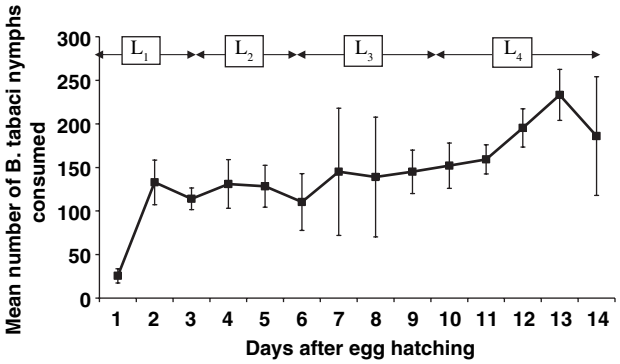

Fig. 4. Variation in mean number of prey consumed by Serangium *on different days after hatching, when fed on* Bemisia tabaci *nymphs on cassava leaves at 25 ± 2°C*

mean development time among L_2, L_3 and L_4 instars with L_2 instars taking 3.6 ± 0.15 days, L_3 instar took 3.6 ± 0.30 days, L_4 instar took 3.8 ± 0.17 days, and the pupa took 3.8 ± 0.18 days (fig. 2). There were significant differences in mean number of development days across the stages ($P < 0.001$, $n = 90$), although no differences were observed within the stages.

3.3 Prey consumption

The mean total prey consumption by the separate larval instars of *Serangium* feeding on *B. tabaci* nymphs increased with stage of larval development with the least, L_1 instar consuming 51.4 ± 4.68 nymphs and the highest L_4 instar consuming 551.3 ± 52.88 nymphs (fig. 3). In total, *Serangium* larvae consumed a mean of 1055.1 nymphs. Holm-sidak multiple pairwise comparisons revealed significant differences ($P < 0.001$, $n = 60$) in total numbers of *B. tabaci* nymphs consumed between larval instars except between L_2 and L_3, however no significant differences were found in total prey consumed within larval instars.

The mean daily consumption of nymphs was lowest on the first day after hatching in the L_1 instar 25.6 ± 8.19 nymphs, but rose to a peak of 233.3 ± 29.19 nymphs on the 13th day after hatching, in the L_4 instar. There was a sharp increase in number of nymphs consumed on the second day, rising to a mean of 132.9 from 25.6 on the first day after hatching (fig. 4).

4 Discussion

The study showed that *Serangium* is present in cassava fields and is able to prey on immature *B. tabaci*. In the field, *Serangium* numbers are generally low in the early part of the season and only become abundant later in the season. This is in contrast to their prey where studies by Legg (1995) showed that *B. tabaci* populations on cassava are abundant in the early part of the season with highest nymph and adult numbers at 4–6 MAP. This indicates that there is a delayed response of the predator to the presence and abundance of its prey. At 7 MAP when *Serangium* populations are highest, the *B. tabaci* population is only beginning to decline but is still relatively high; therefore, the peak *Serangium* numbers observed in this study corresponded with a relatively high number of their prey. The 2-month delay between the peaks in *B. tabaci* and *Serangium* populations is probably due to a combination of prey density and suitable canopy, preferring plants that are older and with denser canopy than the young ones.

The ability of a natural enemy to oviposit successfully and develop on the host plant on which its prey lives is one of the major factors in determining its ability to successfully control the pest. The preimaginal development period was studied and showed that the egg stage had the longest mean development period, which is similar to studies on development of other *Serangium* species. Vatanesever et al. (2003) found that mean development of eggs of *Serangium montazerii* Fursch was 5.5 days on both cotton and egg plant. This hatching period was, however, slightly higher than the 4.2 days observed in our study and could have been due to differences in the predator species, nature of the host plant and prey species. The overall mean developmental period of the *Serangium* on cassava was also much shorter (21.2 days) compared with other species carried out by using whiteflies on cotton (28.8 days) and eggplant (28 days) at similar temperatures (Yigit 1992b; Vatanesever et al. 2003). The development period of *Serangium* on cassava is much shorter than that of its prey, *B. tabaci*, in Uganda which was found to be 33.3 days at similar temperatures in the same location (Legg 1995). This is a favorable attribute of *Serangium* as a predator of *B. tabaci*. However, additional factors such as fecundity, survival rates, adult longevity and prey consumption have an important bearing on the predator–prey balance and may limit its usefulness.

The mean total prey consumption by the larvae increased with their developmental maturity, with much less numbers consumed by L_1 instars compared with the L_4 instars. These results are comparable with those of Sengonca et al. (2005) on *S. parcesetosum* where similar consumption trends were reported albeit with slightly higher numbers, with the L_1 instar consuming up to 78.9 nymphs and the L_4 instar consuming 675.9 nymphs, although at 30°C. Studies on total prey consumption have revealed widely variable results. Kapadia and Puri (1992) found that *S. parcesetosum* larvae consumed a mean total of 89.2 nymphs of *B. tabaci* on cotton and 105.7 nymphs on eggplant at 27 ± 2°C. Also, Patel et al. (1996) reported that *S. parcesetosum* consumed a mean total of 671 nymphs of *A. barodensis* on sugarcane at 27 ± 1°C.

However, Sengonca et al. (2005) found that *S. parcesetosum* consumed up to 1119.1 nymphs, at 30°C, during its entire larval development on cotton. This is similar to results from this study which showed total consumption of 1055.1 nymphs, at 25 ± 2°C. The mean daily prey consumption of nymphs also increased with number of days after hatching. The lowest numbers were observed on the first day after hatching, peaking on the 13th day after egg hatch. These results are similar to the study by Sengonca et al. (2005) which found that the mean daily consumption of nymphs was up to 22.7 nymphs on the first day after hatching and increased to a peak of 161 nymphs on the 20th day after hatching, in the L_4 instar.

This study indicated that *Serangium* is abundant at a time when its prey is still in high numbers. This together with its shorter development duration compared with the prey and its ability to oviposit successfully and feed on the sessile stage of its otherwise mobile prey, make *Serangium* a promising agent for biological control. The study also provided new information in understanding the biology of this predator on cassava. Successful biological control of a pest depends on the ability of the natural enemy to destroy a sufficient level of the pest to keep its density from increasing. In an agro-ecosystem, the prey population will never be constant and will always fluctuate in response to many factors, the ability of the predator to adapt to such fluctuations in prey availability is important if it is to be considered as an efficient natural enemy. Studies by Legg et al. (2003) showed that the cassava variety Nase 4 supported up to 100 *B. tabaci* adults per leaf at 4–5 MAP, therefore *Serangium*, though abundant at relatively the same time as its prey, still does not occur in sufficiently high numbers to control the ever increasing *B. tabaci* populations on cassava. Effective use of these predators as control agents would aim at having them in high numbers at 2–4 MAP when their prey population is still low and only beginning to build-up. Therefore, timing of introduction and/or augmentation should aim at having high numbers of the most voracious stage, L_4 instar, at 2–4 MAP.

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