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Occurrence and activity of *Bemisia tabaci* parasitoids on cassava in different agro-ecologies in Uganda

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Abstract. *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) is the vector of cassava mosaic geminiviruses that cause cassava mosaic disease (CMD), which in turn causes devastating yield losses. Surveys were conducted from October 2000 to November 2001 in four agro-ecologies in Uganda to enhance the understanding of parasitoid fauna and parasitism of *B. tabaci* in cassava fields. Such an understanding is an essential prerequisite for the development of biological control methods of *B. tabaci* to complement current CMD control practices. Parasitoid abundance and parasitism efficiency varied between locations and sampling dates within the locations; highest parasitoid densities were observed at Namulonge in the Lake Victoria crescent while the lowest was at Kalangala. In all locations, parasitism was mainly due to *Encarsia sophia* Dodd and Girault and *Eretmocerus mundus* Mercet (all Hymenoptera: Aphelinidae). Two occasionally observed species included *Encarsia mineoi* Viggiani (Hymenoptera: Aphelinidae), only observed at Namulonge, and blackhead *Encarsia* (Hymenoptera: Aphelinidae) observed at Bulisa, Namulonge and Lyantonde. Parasitism efficiency was highest at Bulisa (57.9%), but ranged from 40.2 to 46.9% at the other three sites. This paper discusses the possible causes of variations in parasitoid abundance and parasitism efficiency, and proposes further studies that might be carried out to assess the potential for augmentation of parasitoids to control *B. tabaci* populations and CMD.

Key words: Aleyrodidae, *Bemisia tabaci,* cassava, *Encarsia mineoi*, *Encarsia sophia*, *Eretmocerus mundus*, Homoptera, parasitism

Introduction

The whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) is a widespread pest of crops in the tropics and sub-tropics (Terry and

Hahn, 1980; Geddes, 1990). It is the vector of cassava mosaic geminiviruses (CMGs) that cause cassava mosaic disease (CMD) that leads to yield losses ranging from 15 to 27% in Africa (Thresh et al., 1997). Furthermore, *B. tabaci* has attained pest status on cassava in the East African sub-region (Legg et al., 2003). Biological control using parasitoids could offer opportunities for its control, but little is known about the parasitoid fauna of *B. tabaci* in Africa, and in Uganda in particular. Gerling (1986) indicated that Aphelinid parasitoids of the genera *Encarsia* and *Eretmocerus* occur in all whitefly-infested areas. In Uganda, Legg (1995) found that natural enemies give rise to mortality of more than half of all immature stages (eggs and nymphs) under field conditions, but never studied their distribution and variation over time. The study presented in this paper was initiated to determine the diversity of parasitoids that attack *B. tabaci*, the level of parasitism and their variation with time.

Materials and methods

Surveys were conducted at Bulisa (Masindi district), Namulonge (Wakiso district), Lyantonde (Rakai district) and Kalangala. The locations were chosen because of the need to compare *B. tabaci* parasitoid fauna and parasitism in a wet savannah (Bulisa and Lyantonde), transition forest (Namulonge) and tropical rain forest areas (Kalangala). Lyantonde was chosen because *Eretmocerus* was previously observed to be more common than *Encarsia* spp.

Each location was visited at three monthly intervals over a period of 1 year, making a total of five visits per location as indicated in Table 1.

At each location, five cassava fields, 3–7 months of age, were selected for sampling. In each field, variety, age of crop and cropping patterns (spacing and intercrops) were recorded, and thereafter five plants across a diagonal were selected for sampling for adult whitefly and nymph

Table 1. Sampling dates at the survey sites

Location			
Bulisa	Namulonge	Lyantonde	Kalangala
October 16, 2000	November 2, 2000	November 12, 2000	November 14, 2000
January 20, 2001	February 14, 2001	January 27, 2001	January 29, 2001
May 12, 2001	May 25, 2001	June 6, 2001	June 8, 2001
August 7, 2001	August 18, 2001	August 30, 2001	September 1, 2001
November 17, 2001	November 23, 2003	November 20, 2001	November 21, 2001

counts. For each of the five plants sampled, adult whiteflies were counted on the five top-most expanded leaves whereas for nymphs, leaves were examined for the presence of late fourth instars (pupae) of *B. tabaci*. The first pupa-bearing leaf and nine leaves below it were numbered and harvested. These were then placed in paper bags, which were placed in a cool box and taken to the laboratory.

In the laboratory, leaves were kept in paper bags in a refrigerator at 4 °C until whitefly immatures and parasitised nymphs could be counted. Counts were made on the underside of each leaf using a binocular microscope to determine the number of unparasitised and parasitised third and fourth instar nymphs. *Encarsia sophia* parasitised nymphs appeared as black pupal cases with meconia symmetrically located on both sides posteriorly, while *Eretmocerus* appeared orange with a shiny pupal skin (with the pupae having red eyes). The blackhead *Encarsia* pupa appeared black towards the anterior of the nymph. Immature parasitoids had displaced mycetomes or contained banana-shaped larvae as opposed to the unparasitised nymphs that were either translucent or mildly opaque and yellowish with yellow symmetrically located mycetomes. For parasitoid emergence, parasitoid pupae were put in petridishes and the dishes were sealed with parafilm. Emerged parasitoids were collected and identified using a binocular microscope and identification guides (Polaszek et al., 1992; Schauff et al., 1996; Rose and Zolnerowich, 1997) and kept in 70% ethanol. Samples were sent to the British Natural History Museum to confirm their identity, while others were kept in the laboratory at Namulonge Agricultural and Animal Production Research Institute as voucher specimens. Relative abundance was calculated for each parasitoid species based on the differentiated parasitoids, and expressed as a percentage of the total number of parasitoids of each species to the total number of differentiated parasitoids. Parasitism efficiency was calculated directly by expressing the number of parasitised nymphs as a proportion of total nymphs, which was calculated as a sum of parasitised and unparasitised nymphs.

In order to normalise parasitoid data, the individual values were square root transformed, while percent parasitism was transformed using arcsine square root transformation. The data were subjected to Analysis of Variance (ANOVA) using Genstat Release 3.2 (Lawes Agricultural Trust – IACR-Rothamsted) to assess the significance of differences between means in whitefly numbers, parasitoids' relative abundance and parasitism efficiency between locations and sampling dates. The age of the cassava crop was used as covariate and where it was significant, means were adjusted.

Results

Populations of B. tabaci

B. tabaci numbers differed significantly ($p < 0.001$; $F = 59.67$; sed = 5.6; $\bar{x} = 16.2$ adults per plant; n = 500 and $p < 0.001$; $F = 21.44$; sed = 26.9; $\bar{x} = 98.7$ nymphs per plant; n = 500) between locations. Significantly higher numbers were recorded at Namulonge (52 adults and 207 nymphs), followed by Bulisa (5.9 adults and 70.1 nymphs), Kalangala (4.6 adults and 59 nymphs) and Lyantonde (2.1 adults and 58.3 nymphs). There were significant location by date interactions for *B. tabaci* adults ($p < 0.001$; $F = 9.7$; sed = 12.6; n = 500) and nymphs ($p < 0.001$; $F = 6.14$; sed = 60.28; n = 500) where significantly higher numbers were recorded at Namulonge during January/February 2001 and August/September 2001 (Figure 1).

The incidence of parasitoids

Four species of parasitoids were reared from *B. tabaci* during the study, three of which were *Encarsia* species (*Encarsia sophia* Girault and Dodd, *Encarsia mineoi* Viggiani and an undescribed blackhead *Encarsia*) and *Eretmocerus mundus* Mercet (Table 2). *En. sophia* and *Er. mundus* occurred at all the locations surveyed, while the blackhead *Encarsia* was recovered at Bulisa, Namulonge and Lyantonde. Only 1 male *En. mineoi* was reared from *B. tabaci* picked from Namulonge. The numbers of the different parasitoids differed significantly between locations, but with generally higher numbers recorded at Namulonge (Table 2). *En. sophia* relative abundance was significantly ($p < 0.001$; $F = 16.54$; sed = 3.79; n = 400) higher at Kalangala (78%), but never differed significantly between Bulisa (61%) and Namulonge (59%); Lyantonde had a significantly lower *En. sophia* abundance (52%). The relative abundance of *Er. mundus* also differed significantly ($p < 0.001$; $F = 14$; sed = 3.8; n = 400) between locations and the highest abundance occurred at Lyantonde (46%), followed by Namulonge (40%) and Bulisa (39%), while the lowest *Er. mundus* relative abundance occurred at Kalangala (22%). The blackhead *Encarsia* had the highest abundance of 2.5% at Lyantonde, followed by Namulonge (1.6%) and least at Bulisa (0.2%). There were significant location by date interactions for the relative abundance of *En. sophia* ($p < 0.001$; $F = 6.09$; sed = 8.47; n = 400) and *Er. mundus* ($p < 0.001$; $F = 5.86$; sed = 8.49; n = 400) (Figure 1). The blackhead *Encarsia* was only recorded once at Bulisa (August/Septem-

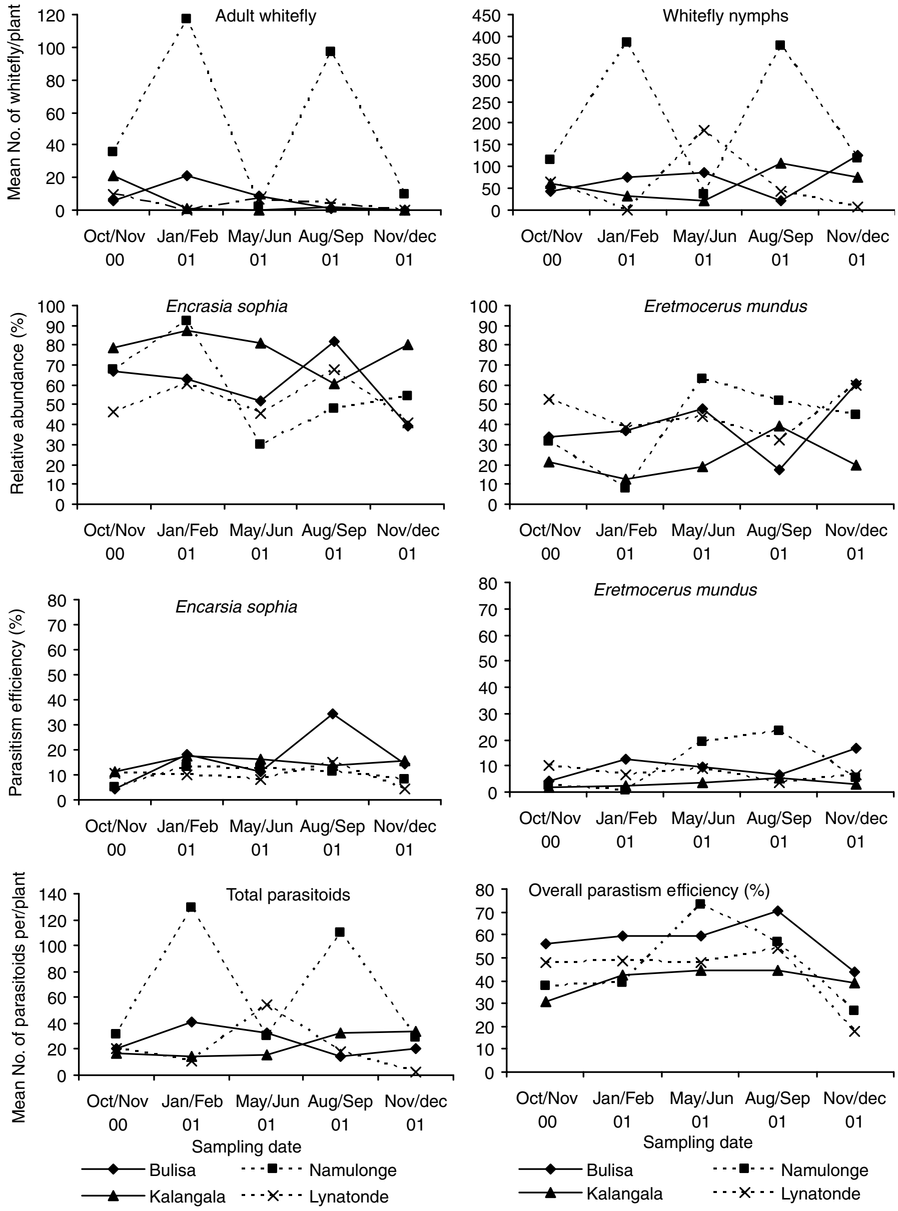

Figure 1. Variations in whitefly and parasitoid numbers, parasitoid relative abundance and parasitism efficiency at the four surveyed districts from October 2000 to December 2001.

ber 2001) and Lyantonde (May/June 2001). It was however, recorded twice at Namulonge during November/December 2000 and May/June 2001 period.

Table 2. Mean number of parasitoids per plant at the survey sites for the period October 2000–November 2001

Location	*Eretmocerus mundus*	*Encarsia sophia*	Blackhead *Encarsia*	Immature parasitoids	Total parasitoids
Bulisa	4.66 (1.89)	6.75 (2.25)	0.02 (0.72)	13.10 (3.21)	26.0 (4.50)
Namulonge	9.48 (2.46)	17.1 (3.24)	0.30 (0.82)	39.20 (5.19)	65.0 (6.84)
Lyantonde	3.92 (1.60)	3.11 (1.59)	0.16 (0.77)	13.60 (2.92)	21.2 (3.66)
Kalangala	1.76 (1.26)	8.24 (2.29)	0 (0.71)	13.90 (3.07)	22.6 (3.96)
Mean	4.96 (1.80)	8.81 (2.34)	0.12 (0.8)	20 (3.60)	33.9 (4.74)
F-value	21.75	16.96	8.55	26.69	24.99
p-value	<0.001	<0.001	<0.001	<0.001	<0.001
Sed	0.15	0.24	0.02	0.29	0.41

Figures in parentheses are square root transformed values.

Table 3. Parasitism efficiency of *B. tabaci* at the survey sites for the period October 2000 to November 2001

Location	*Eretmocerus mundus*	*Encarsia sophia*	Blackhead *Encarsia*	Immature parasitoids	Total
Bulisa	9.94 (21.51)	16.57 (28.16)	0.15 (0.58)	30.0 (41.4)	57.9 (62.13)
Namulonge	10.18 (20.29)	9.99 (22.11)	0.51 (0.69)	26.5 (40.4)	46.9 (55.42)
Lyantonde	7.12 (17.45)	9.69 (20.49)	0.68 (0.66)	25.9 (37.1)	43.5 (51.37)
Kalangala	3.29 (11.79)	14.93 (26.26)	0 (0.56)	22.9 (35.5)	40.2 (48.81)
Mean	7.63 (17.76)	12.79 (24.25)	0.33 (0.62)	26.3 (38.6)	47.1 (54.43)
F-value	14.21	6.10	4.21	2.77	10.32
p-value	<0.001	<0.001	0.006	0.048	<0.001
Sed	1.63	2.04	0.04	2.47	2.56

Figure in parentheses are arcsine square root transformed values.

Parasitism efficiency by *Er. mundus* was greatest at Namulonge, while that by *En. sophia* was highest at both Bulisa and Kalangala (Table 3). The blackhead *Encarsia* contributed relatively lower and negligible parasitism efficiency, averaging less than 1% of the total parasitism at all the three locations where it was recovered. The combined parasitism efficiency was significantly higher at Bulisa, followed by Namulonge, Lyantonde and Kalangala (Table 3). Parasitism efficiency of *B. tabaci* by *Er. mundus* rarely exceeded 10% except in the January/February 2001 and November/December 2001 periods at Bulisa, and between May/June 2001 and August/September 2001 at Namulonge. Parasitism efficiency by *En. sophia* did not differ markedly between the locations except during the August/September 2001 period when it had a significantly higher peak at Bulisa (Figure 1).

Discussion

The study revealed the presence of four parasitoid species attacking *B. tabaci* on cassava in the surveyed locations. *En. sophia* was the most common species at Bulisa, Kalangala and Namulonge, while *Er. mundus* was more abundant at Lyantonde. Blackhead *Encarsia* occurred at Bulisa, Namulonge and Lyantonde, while *En. mineoi* was only recovered from *B. tabaci* at Namulonge. Previous studies by Gerling (1984) found *En. sophia* (as *En. sublutea*) and *Er. mundus* attacking *B. tabaci* in Kenya, Malawi and Zimbabwe, while Nyirenda et al. (1993) found *En. sophia* (as *En. transvena*) attacking *B. tabaci* on cassava in Malawi. The greater abundance of *En. sophia* at most sites compared to *Er. mundus* may be due to the differences in the biology of the two parasitoids. *Encarsia* species are oligophagous and their females develop on whiteflies or armored scales, while the males may develop on the same hosts as the females or develop as secondary parasitoids of other aphelinids, or parasitoids of the eggs of Lepidoptera or other hosts (Walter, 1983; Gerling, 1990; Hunter et al., 1996). *Eretmocerus* species on the other hand only attack whiteflies (Gerling, 1990).

During the present study, there were differences in parasitism efficiency; Bulisa had the highest parasitism efficiency of *B. tabaci*, followed by Namulonge, while parasitism at Lyantonde and Kalangala were similar. Differences in parasitism levels may be due differences in cropping systems, cassava varieties grown and climatic conditions. For instance at Bulisa, all the fields sampled had one major cassava variety (Nase 3), and intercropped with maize. At Namulonge, Nase 4 was the main cassava variety and was mainly intercropped with maize, banana, beans, groundnuts, coffee and green pepper. At Lyantonde, different local varieties were intercropped with banana, maize, beans, potato, tomatoes and sweetpotato, while at Kalangala, cassava was mainly intercropped with banana, maize, sweetpotato, yams, coffee and groundnuts. There could have also been differences in rainfall and temperature that may have affected parasitoid abundance and parasitism between locations and in the different sampling dates, but no data were available. It is apparent from the above that no single factor can be pointed out as the sole cause of variation in parasitoid abundance and activity between and within locations. But, additional studies will be required to assess the influence of climate and crop associations on parasitoid activity.

The low parasitism efficiency implies a need to conserve and/or augment the activity of the natural enemies through identification and manipulation of potential refuges that would act as bridging gaps for whitefly parasitoids. The introduction of additional natural enemies may also be important to increase the diversity and efficiency of parasitoids in maintaining whitefly populations at low levels. There is also an urgent need for information on whitefly life history, sources of mortality, and predators suspected to play an important role in controlling whitefly populations. Such studies should provide valuable information that will enable scientists to develop and optimise the use of natural enemies in controlling *B. tabaci* and through this reduce the incidence of CMD.

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References

Geddes, A.M.W., 1990. The relative importance of crop pests in sub-Saharan Africa. *Nat. Resour. Inst. Bull. Chathan* 36: 69.

Gerling, D., 1984. The overwintering mode of *Bemisia tabaci* and its parasitoids in Israel. *Phytoparasitica* 12: 109–118.

Gerling, D., 1986. Natural enemies of *Bemisia tabaci*. Biological characteristics and potential as biological control agents. *Agric. Ecosyst. Environ.* 17: 99–110.

Gerling, D., 1990. Natural enemies of whiteflies: predators and parasitoids. In: D. Gerling (ed), *Whiteflies: Their Bionomics, Pest Status and Management*, Intercept, Andover, Hants, UK. pp. 147–185.

Hunter, M.S., M. Rose and A. Polaszek, 1996. Divergent host relationships between males and females in the parasitoid *Encarsia porteri* (Hymenoptera: Aphelinidae). *Ann. Entomol. Soc. Am.* 89: 667–675.

Legg, J.P., 1995. The ecology of *Bemisia tabaci* (Gennadius)(Homoptera: Aleyrodidae) vector of cassava mosaic viruses in Uganda. PhD thesis, University of Reading, 183 pp.

Legg, J.P., S. Mallowa and P. Sseruwagi, 2003. First report of physical damage to cassava caused by the whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Sternorrhyncha: Aleyrodidae). In: *Book of Abstracts, 3rd International Bemisia Workshop. Barcelona 17–20 March, 2003.*

Nyirenda, G.K.C., D.C. Munthuli, G.S.N. Phiri, R.F.N. Sauti and D. Gerling, 1993. Integrated Pest Management of *Bemisia* spp. whiteflies in Malawi. Report Makoka Research Station, Thondwe Malawi, 12 pp.

Polaszek, A., G.A. Evans and F.D. Bennet, 1992. *Encarsia* parasitoids of *Bemisia tabaci* (Hymenoptera: Aphelinidae, Homoptera: Aleyrodidae); a preliminary guide to identification. *Bull. Entomol. Res.* 82: 375–392.

Rose, M. and G. Zolnerowich, 1997. *Eretmocerus* Haldeman (Hymenoptera: Aphelinidae) in the United States, with descriptions of new species attacking *Bemisia* (*tabaci* complex) (Homoptera: Aleyrodidae). *Proc. Entomol. Soc. Washington* 99(1): 1–27.

Schauff, M.E., G.A. Evans and J.M. Heraty, 1996. A pictorial guide to the species of *Encarsia* (Hymenoptera: Aphelinidae) parasitic on whiteflies (Homoptera: Aleyrodidae) in North America. *Proc. Entomol. Soc. Washington* 98(1): 1–35.

Terry, E.R. and S.K. Hahn, 1980. The effect of cassava mosaic disease on growth and yield of a local and an improved variety of cassava. *Trop. Pest Manage.* 26: 34–37.

Thresh, J.M., G.W. Otim-Nape, J.P. Legg and D. Fargette, 1997. African cassava mosaic disease: the magnitude of the problem? *Afr. J. Root Tuber Crops*. Special Issue: Contributions of Biotechnology to Cassava for Africa. In: A.M. Thro and M.O. Akoroda (eds), *Proceedings of the Cassava Biotechnology Network*, *Third International Scientific Meeting* 13–19, 26–31 August 1996, Kampala, Uganda.

Walter, G.H., 1983. Divergent male ontogenies in Aphelinidae (Hymenoptera: Chalcidoidea): a simplified classification and a suggested evolutionary sequence. *Biol. J. Linn. Soc.* 19: 63–82.