BioControl **46:** 289–310, 2001.

Predators of *Mesoplatys ochroptera* in sesbania planted-fallows in eastern Zambia

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Received 25 January 2000; accepted in revised form 30 November 2000

Abstract. *Mesoplatys ochroptera* Stål (Coleoptera: Chrysomelidae) is a serious pest of the tropical legume sesbania (*Sesbania sesban* (L.) Merrill) widely used for soil fertility improvement in southern Africa. Surveys were conducted between October 1997 and June 1999 in order to identify the predators of *M. ochroptera* in sesbania fallows in eastern Zambia. The Heteroptera *Afrius yolofa* (Guérin-Méneville), *Glypsus conspicuus* (Westwood), *Macrorhaphis acuta* Dallas, *Mecosoma mensor* (Germar), *Rhinocoris segmentarius* (Germar), and *Deraeocoris ostentans* (Stål), the carabid beetle *Cyaneodinodes fasciger* (Chaudoir), the ants *Tetramorium sericeiventre* Emery and *Pheidole* sp., and the lacewing *Mallada* sp. were recorded as predators of *M. ochroptera* for the first time. The pentatomid bugs *G. conspicuus*, *M. acuta* and *M. mensor* were the most common predators in sesbania fallows. Adults and the different nymphal stages of the three species preyed on larvae, adults and occasionally on eggs of the beetle. In the insectary, the adults of *G. conspicuus, M. acuta* and *M. mensor* consumed a significantly higher number of larvae ($p < 0.001$) compared to adults of *M. ochroptera* under both free-choice and no-choice conditions. The voracity of the three species showed a positive response to prey density. The fifth instar nymphs showed variation in daily consumption of larvae, the highest number of prey being consumed two to three days after the fourth molt. These predators also attacked other pests associated with sesbania and crop plants. The potential role of the predators in the natural control of pests in agroforestry systems is discussed, with a review of their prey species.

Key words: planted fallows, predators, soil fertility, Zambia, Coleoptera, *Mesoplatys ochroptera*, *Sesbania sesban*

Introduction

Sesbania (*Sesbania sesban* (L.) Merrill) is a legume used widely in farming systems in the tropics. It provides fodder, green manure, fuel wood and fixes nitrogen (Swinkels et al., 1997). Two to three year old planted fallows of sesbania have been demonstrated to replenish fertility in nitrogen-depleted soils, doubling or tripling maize yields compared to traditional fallows, and producing 15 to 21 t/ha fuel wood and poles (Swinkels et al., 1997; Kwesiga et al., 1999). In southern Africa, ICRAF (International Centre for Research in Agroforestry) and its partners are working with thousands of small-scale farmers planting sesbania fallows (Kwesiga et al., 1999).

With the widespread introduction of sesbania in agroforestry systems, the defoliating beetle, *Mesoplatys ochroptera* Stål (Coleoptera: Chrysomelidae), has become a widespread and serious pest of the tree (Mchowa and Ngugi, 1994; Wale et al., 1996; Kwesiga et al., 1999; Sileshi et al., 2000; Sileshi and Kenis, 2001). An extensive account of natural enemies of the Chrysomelidae was given by Cox (1994, 1996). However, there are no published records of the natural enemies of *M. ochroptera*. Recently, Sileshi et al. (2000) recorded some predators in naturally growing sesbania in Southern Malawi, but the distribution and impact of these predators on the beetle populations are not known in agroforestry systems. The objectives of this work were (1) to identify predators in sesbania-planted fallows and (2) to obtain data relating to their potential in integrated pest management of *M. ochroptera*.

Material and methods

Study sites and identification of the predator complex

The field study was conducted between October 1997 and June 1999 in sesbania planted fallows in Eastern Province of Zambia. Eastern Province is situated between latitudes 10–15° S and longitudes 30–33° E. The field study was conducted at Msekera Research Station and Kalunga (Chipata South District), Chadiza (Chadiza District) and Kagoro (Katete District). The altitude of all sites is between 600 m and 1200 m. The climate is sub-tropical with three distinct seasons: a warm-wet (November–April), a dry-cold (May–August) and a dry-hot season (September–October). The rainfall pattern is unimodal with an annual average ranging between 887 mm and 1000 mm. The average air temperature varies between 15 and 18 °C during the cool months of June and July and between 22 and 30 °C during the hot months of September and October.

The sesbania fields on which predators were sampled consisted of seedlings (0–2 m high) and one-year-old trees (2–4 m high). In all cases the spacing was 1 m between plants and 1 m between rows of sesbania. At Msekera, the experimental plots were 10 m $\times$ 10 m fallows consisting of ca. 100 plants whereas in farmers' fields, the plot size varied but was often larger than experimental plots. In both research and farmers' fields, less than one-year-old sesbania seedlings were kept weed free. One- or more years old plantations were usually not weeded because well-established sesbania fallows smother the weedy vegetation.

At Msekera, sampling was done during the daytime (9.00–14:00 h), 4–5 times per week during the rainy season but at irregular intervals during the winter and dry seasons. The fields in Kalunga were visited twice while those in Chadiza and Kagoro were visited only once during the peak population of *M. ochroptera* (March–April 1999). Seedlings and one-year-old plants were visually examined by walking through naturally infested sesbania fields and the species of predators attacking adults, larvae and eggs were recorded on randomly selected infested plants. Once a predator was spotted, its feeding activity was monitored and the kinds of prey eaten were recorded. Spider webs, trails of ants, and nests of wasps were examined for corpses of the different life stages of the beetle. Different stages of predator species were collected for studies in the insectary. Adult predators and parasitoids emerged from field-collected predator eggs were sent to taxonomists for identification.

Estimation of pest and predator densities

Density estimates of predators and *M. ochroptera* were obtained by sampling less than one-year old plants at monthly intervals at Msekera Research Station. Plants that were more than one-year old were not sampled because of the limitations of height. A protocol specifically developed for sampling *M. ochroptera* in one-year-old plants was used (Sileshi and Kenis, 2001). Enumerative and sequential sampling plans were developed incorporating distribution parameters of the beetle into Kuno's equation (1976). The protocols were developed using data collected using a two-stage stratified sampling procedure. The fields sampled were rectangular and consisted of 100 plants and these were divided into two rectangular blocks of 50 plants each; 50 plants in the middle formed a central block and the remaining 50 around the central plants formed a peripheral block. 15 trees (primary sampling units) were randomly selected from each block. The foliage canopy of each tree was divided into upper, middle and lower strata and 2 shoots (secondary sampling unit) were randomly selected from each stratum. Egg masses, larvae and adults were counted on each shoot. Using these data, parameters of the spatial distribution of *M. ochroptera* were obtained following Iwao's model (1968). Predator counts were taken on trees as *M. ochroptera* was being sampled.

The density of the beetle and its predators per shoot was converted into density per plant by multiplying the figures with the average number of shoots per plant. Since sesbania fallows consisted of one plant per square meter, the density per plant was equal to the density per square meter.

Predation of eggs by *Deraeocoris ostentans* was assessed fortnightly by counting the number of egg masses attacked, and the number of adult bugs and nymphs on three to four month old sesbania plants. Predation was recorded when eggs were punctured and their content sucked. Then, the percentage of eggs predated per egg mass was noted. Predation was attributed to *D. ostentans* when nymphs or adults were found feeding on eggs or when nymphs or adults were found on a seedling where the whole or part of an egg mass was damaged.

Insectary studies

Studies were conducted in an insectary at Msekera between February and May 1998 and 1999. The inside temperature of the insectary was recorded at 08:00, 12:00 and 17:00 h. The average (mean $\pm$ SE) monthly temperature was found to be 26.2 $\pm$ 0.2, 25.5 $\pm$ 0.2, 24.5 $\pm$ 0.3 and 24.7 $\pm$ 0.3 in February, March, April and May, respectively. The life history of the three most common predators was studied in the insectary. The adult predators were collected from the field, maintained in petri-dishes containing excised leaves of *S. sesban*, and were daily supplied with last (third) instar larvae of the beetle. When eggs were laid, the development from egg to adult was monitored and the duration of each stage recorded.

The voracity of last instar (fifth) nymphs and adults of *G. conspicuus, M. acuta* and *M. mensor* was tested after preconditioning to standardize their hunger level. Healthy last instar nymphs and adults reared in the insectary were selected and starved for 24 hours. These were then offered separately 5, 10, 15, 20, 25, 30 and 35 last instar larvae feeding on excised *S. sesban* leaves. Predators were transferred to fresh petri-dishes and offered the respective numbers of healthy prey supplied every 24 hours. Ten individuals were used as replicates for each treatment and these were observed for 7 to 9 days. Records on any predator that died or looked unhealthy during the course of observation were discarded. Since the consumption rates of nymphs were variable, this was recorded separately for each day and plotted against days after the fourth molt. To elucidate the functional response of adults, the daily (based on 24 hours) consumption by adults of each species was plotted against the number supplied.

To test prey preference of adult *G. conspicuus, M. acuta* and *M. mensor*, free- and no-choice tests were made. In the no-choice condition, each adult predator was supplied with 5 larvae, 10 larvae, 5 adults and 10 adults of *M. ochroptera* separately. In the free-choice test, a mixture of 5 larvae + 5 adults and 10 larvae + 10 adults *M. ochroptera* were supplied. *M. ochroptera* larvae and adults were provided with freshly excised *S. sesban* leaves. The same numbers of prey were provided every day. For all treatments, healthy adults reared in the insectary were used. Eight such adults were confined in petri dishes with the prey and the number of larvae and adults consumed was recorded for two consecutive days, making 16 observations per treatment. Paired and unpaired t-tests were made to compare the daily consumption in the free-choice and no-choice tests, respectively.

Results

Afrius yolofa (Guérin-Méneville), *Glypsus conspicuus* Westwood, *Macrorhaphis acuta* Dallas, *Mecosoma mensor* Germar (Heteroptera: Pentatomidae), *Rhinocoris segmentarius* (Germar) (Heteroptera: Reduviidae), *Deraeocoris ostentans* (Stål) (Heteroptera: Miridae), *Cyaneodinodes fasciger* (Chaudoir) (Coleoptera: Carabidae), *Tetramorium sericeiventre* Emery, *Pheidole* sp. (Hymenoptera: Formicidae) and *Mallada* sp. (Neuroptera: Chrysopidae) were recorded for the first time as predators of *M. ochroptera* in southern Africa. All pentatomid and reduviid bugs attacked the beetles and larvae by inserting the proboscis into the body of the prey and sucking out the body fluid, leaving only the exoskeleton. In all observed cases, no prey escaped once in the grip of the predator; the prey became passive after a few escape attempts.

Glypsus conspicuus *Westwood*

G. conspicuus was the commonest predator of *M. ochroptera* in the study area (Table 1). Its population built up during the rainy season and peaks were observed in April–May. This generally overlapped with the phenology of *M. ochroptera*, but there was a delay in the build up of the predator population (Figure 1).

In the insectary, eggs were laid in masses of 35 to 121 (Mean: 77.5; SE: 3.8) on sesbania leaves or the surface of the petri-dishes. Eggs were dark brown with 9–10 micropylar projections. The average incubation period was 12.4 days (SE: 0.2). The nymphal development passed through five instars. The duration of the different life stages is given in Table 2.

Second to fifth nymphal instars and adult *G. conspicuus* preyed on eggs, larvae and adult *M. ochroptera*. In the field, second to fourth instar nymphs attacked their prey in groups while fifth instar nymphs were solitary. First instar nymphs were not observed feeding. In the insectary, adult *G. conspicuus* consumed more larvae ($p < 0.001$) than adults as indicated by the paired

Table 1. Distribution and occurrence of heteropteran predators of *Mesoplatys ochroptera* in sesbania fallows sampled at 4 different localities in eastern Zambia, 1999

Locality:	Msekera			Kalunga		Chadiza	Kagoro
Sample date:	29.3.99	25.4.99	25.5.99	26.2.99	28.4.99	17.5.99	3.5.99
(Sample size)	(734)	(1293)	(1556)	(132)	(478)	(680)	(872)
Glypsus conspicuus	58.1	68.8	62.3	60.1	51.1	39.7	63.8
Macrorhaphis acuta	31.5	21.7	28.6	31.3	25.5	52.9	19.6
Mecosoma mensor	6.3	4.4	3.9	5.2	10.6	4.4	9.1
Afrius yolofa	2.9	3.1	2.2	3.4	10.7	0.7	4.2
Rhinocoris segmentarius	1.2	2.0	3.0	0.0	2.1	2.2	3.3

Numbers indicate the percentage of each species in the sample.

t-test (Table 3). Under both free-choice and no-choice conditions, about 80% of the larvae and only 10% of the adults were consumed.

The number of prey larvae consumed by adult *G. conspicuus* depended on the density of the prey supplied. At lower prey densities, the proportion of larvae consumed was found to be higher. The maximum number consumed per day was 30 larvae. Predators failed to respond to further increases in prey density and a plateau was reached at about 20 third instar larvae consumed per day (Figure 2). The daily consumption by last instar nymphs was highly variable and depended on the number of days from the last molt. The largest number of prey was consumed two to three days after the fourth molt and then voracity declined to zero one day before molting into the adult stage (Figure 3a). Maximum consumption (20 larvae/24 hours) was recorded three days after the fourth molt. In the field, *G. conspicuus* was observed preying on caterpillars of three lepidopteran species (Table 4).

Macrorhaphis acuta *Dallas*

M. acuta was the second most common heteropteran predator of the beetle (Table 1). Populations of this bug increased from February to May, but peaks were reached in April (Figure 1). In the insectary, females laid eggs in masses of 15 to 83 (mean: 39.3; SE: 3.2) on leaves and the surface of the petri-dishes. *M. acuta* eggs had aculei on the chorion surface and a pseudoperculum surrounded by a crown of 7–10 white transparent micropylar processes, giving it a silvery appearance. Rearing out of field-collected eggs *M. acuta* showed heavy egg parasitism by *Telonomus* sp. and *Trisolcus sipiodes* Johnson (Hymenoptera: Scelionidae) that together caused over 60%

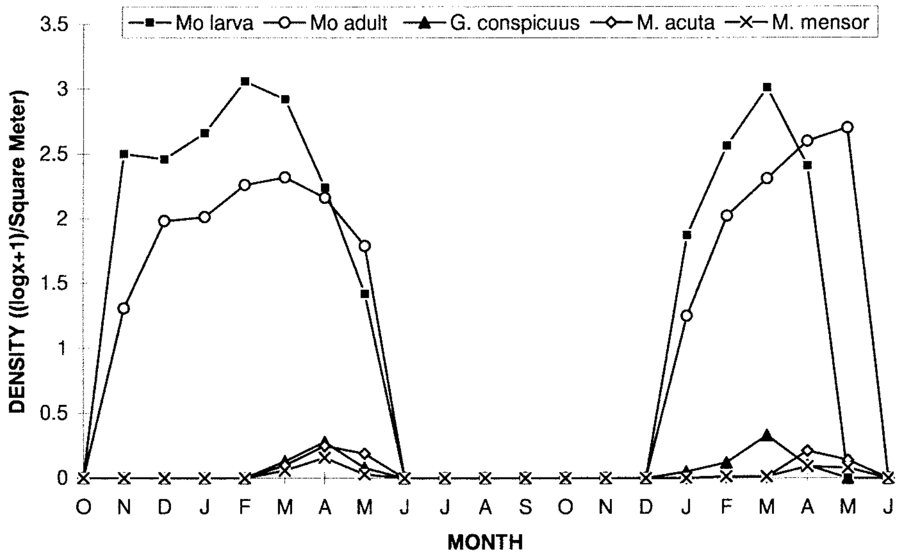

Figure 1. Seasonal population fluctuations of *Mesoplatys ochroptera* (Mo) and its predators *Glypsus conspicuus, Macrorhaphis acuta* and *Mecosoma mensor* in sesbania fallows at Msekera, Eastern Zambia, from October 1997 to June 1999. Absolute numbers of insects and SE of means are presented in Appendix 1.

Table 2. Duration of the developmental stages of the three most common pentatomid predators of *Mesoplatys ochroptera* in the insectary at Msekera, eastern Zambia

Developmental stages	*Glypsus conspicuus*	*Macrorhaphis acuta*	*Mecosoma mensor*
Eggs	12.4 ± 0.2 (11–13)	9.3 ± 0.2 (8–11)	9.4 ± 0.2 (7–12)
Nymphal instars			
First	3.3 ± 0.2 (2–6)	2.2 ± 0.1 (1–3)	3.0 ± 0.2 (2–5)
Second	4.3 ± 0.2 (3–7)	5.6 ± 0.2 (4–8)	2.7 ± 0.1 (2–4)
Third	5.8 ± 0.2 (5–8)	3.2 ± 0.2 (2–4)	3.4 ± 0.1 (2–5)
Fourth	6.3 ± 0.2 (4–9)	6.5 ± 0.2 (5–8)	5.4 ± 0.2 (4–8)
Fifth	9.1 ± 0.2 (6–10)	8.6 ± 0.2 (7–11)	8.0 ± 0.2 (6–11)
Egg to adult	43.2 ± 0.5 (38–47)	35.4 ± 0.4 (30–40)	31.9 ± 0.6 (26–39)
Adult life span	29.9 ± 1.1 (15–41)	26.9 ± 1.3 (14–36)	21.0 ± 1.4 (10–35)

Numbers represent the mean number of days ± SE (range). N = 30 for each measurement.

Table 3. Mean number of adults and larvae of *Mesoplatys ochroptera* consumed by adults of *Glypsus conspicuus, Macrorhaphis acuta* and *Mecosoma mensor* under free-choice and no-choice conditions in the insectary at Msekera

Test condition	*Glypsus conspicuus*		T value[b]	*Macrorhaphis acuta*		T value[b]	*Mecosoma mensor*		T value[b]
and prey supplied	Adults	Larvae		Adults	Larvae		Adults	Larvae	
Free-choice condition									
5 adults + 5 larvae	0.6 ± 0.2[a]	4.1 ± 0.4	–8.7***	0.3 ± 0.1	4.3 ± 0.3	–16.1***	0.8 ± 0.3	3.4 ± 0.2	–6.6***
10 adults + 10 larvae	0.3 ± 0.1	7.8 ± 0.6	–13.0***	0.5 ± 0.2	9.4 ± 0.2	–34.0***	1.8 ± 0.6	7.7 ± 0.5	–8.0***
No-choice condition									
5 adults or 5 larvae	1.1 ± 0.3	4.4 ± 0.2	–8.1***	1.1 ± 0.3	4.7 ± 0.2	–11.5***	1.1 ± 0.3	3.6 ± 0.3	–6.2***
5 adults or 10 larvae	1.1 ± 0.3	8.6 ± 0.4	–15.2***	1.1 ± 0.3	9.4 ± 0.2	–24.5***	1.1 ± 0.3	6.8 ± 0.4	–10.8***
10 adults or 5 larvae	1.2 ± 0.3	4.4 ± 0.2	–7.9***	1.4 ± 0.4	4.7 ± 0.2	–7.6***	1.6 ± 0.5	3.6 ± 0.3	–3.4**
10 larvae or 10 adults	1.2 ± 0.3	8.6 ± 0.4	–15.0***	1.4 ± 0.4	9.4 ± 0.2	–17.9***	1.6 ± 0.5	6.8 ± 0.4	–7.7***

[a]Mean number of prey consumed per individual per day ± SE, N = 16 for each measurement. [b]** Significant at 0.01 level; *** significant at 0.001 level.

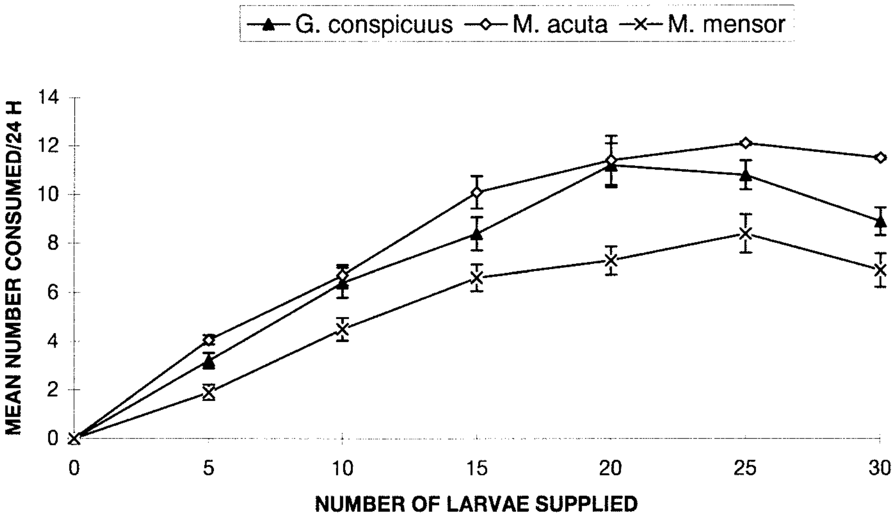

Figure 2. Mean (± SE) daily consumption of third instar larvae of *Mesoplatys ochroptera* by adult *Glypsus conspicuus, Macrorhaphis acuta* and *Mecosoma mensor* at different prey densities in the insectary at Msekera, Eastern Zambia.

parasitism in May and June. The nymphal development passed through five instars. The duration of the different life stages is given in Table 2.

Adults and nymphs attacked eggs, larvae or adults of *M. ochroptera*. In the insectary, adult *M. acuta* consumed many more larvae ($p < 0.001$) than adults under both free-choice and no-choice conditions (Table 3). The daily consumption of larvae by adult *M. acuta* followed the same pattern as that of *G. conspicuus*, but had a higher upper threshold before the response curve plateau (Figure 2). The daily consumption of last instar nymphs was variable and peak consumption (ca 20 larvae/24 hours) was observed four to five days after the fourth molt (Figure 3b). In addition to *M. ochroptera, M. acuta* preyed on many species of Lepidoptera attacking various plants at Msekera (Table 4).

Mecosoma mensor *Germar*

M. mensor was the third most common predator of the beetle (Table 1). Populations of this bug followed the same pattern as those of *G. conspicuus* and *M. acuta* (Figure 1). The eggs were laid in masses of 14–52 (mean: 30.7; SE: 1.9) in the insectary and the incubation period was 9.4 days (SE: 0.2). *M. mensor* eggs had 7–10 long micropylar processes bending inwards. Field-collected *M. mensor* eggs were heavily parasitized (up to 75%) and the scelionid *Trisolcus*

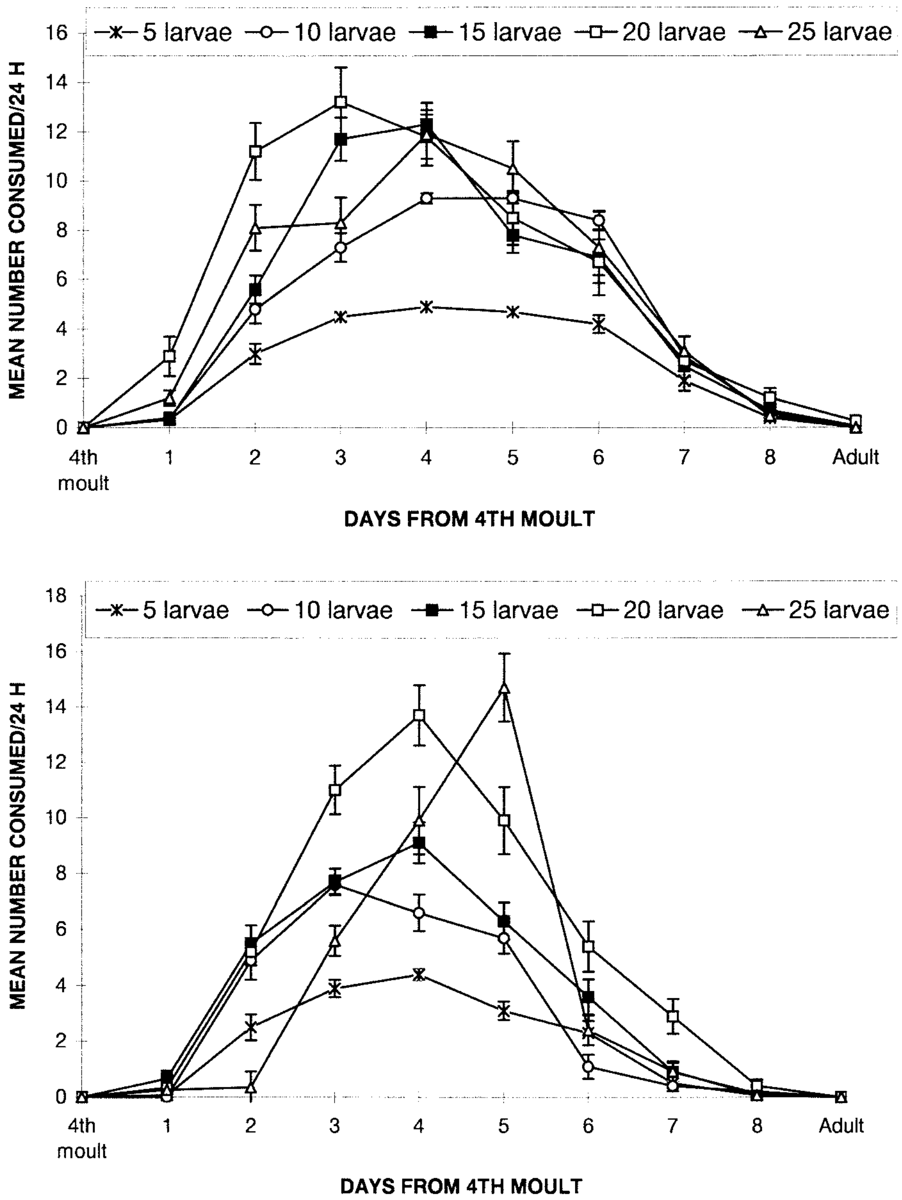

Figure 3. Mean (± SE) daily consumption of third instar larvae of *M. ochroptera* by fifth instar nymphs of *Glypsus conspicuus* (A, above) and *Macrorhaphis acuta* (B, below) at different prey densities the insectary at Msekera, Eastern Zambia.

Table 4. Additional prey species of the predators of *Mesoplatys ochroptera* observed in the field at Msekera, eastern Zambia

Predator	Prey species	Plant species
Afrius yolofa	*Euproctis rubricosta* Fawc. (Lepidoptera: Lymantriidae) larvae	*S. sesban*
	Helicoverpa armigera F. (Lepidoptera: Noctuidae) larvae	*S. sesban*
Glypsus conspicuus	*Euproctis rubricosta* Fawc. (Lepidoptera: Lymantriidae) larvae	*S. sesban*
	Helicoverpa armigera (Hub.) (Lepidoptera: Noctuidae) larvae	*S. sesban*
	Plusia. orichalcea F. (Lepidoptera: Noctuidae) larvae	*S. sesban*
Macrorhaphis acuta	*Euproctis rubricosta* Fawc. (Lepidoptera: Lymantriidae) larvae	*S. sesban*, Castor
	Helicoverpa armigera (Hub.) (Lepidoptera: Noctuidae) larvae	*S. sesban*, cotton, pigeon pea
	Plusia orichalcea F. (Lepidoptera: Noctuidae) larvae	*S. sesban*
	Cosmophila flava (F.) (Lepidoptera: Noctuidae) larvae	Cotton
	Spodoptera littoralis (Boisd.) (Lepidoptera: Noctuidae) larvae	Cotton
Mecosoma mensor	*Euproctis rubricosta* Fawc. (Lepidoptera: Lymantriidae) larvae	*S. sesban*
	Helicoverpa armigera (Hub.) (Lepidoptera: Noctuidae) larvae	*S. sesban*
	Plusia orichalcea F. (Lepidoptera: Noctuidae) larvae	*S. sesban*
Deraeocoris ostentans	*Lipaleyrodes* sp. (Homoptera: Aleyrodidae) nymphs	*S. sesban*
	Heteropsylla cubana Craw. (Homoptera: Psyllidae) nymphs	*Leucaena leucocephala*
	Sitobion nigrinectaria (Homoptera: Aphididae) all stages	Pigeon pea
Mallada sp.	*Lipaleyrodes* sp. (Homoptera: Aleyrodidae: Homoptera) nymphs	*S. sesban*
Rhinocoris segmentarius	*Euproctis rubricosta* Fawc. (Lepidoptera: Lymantriidae) larvae	*S. sesban*, cotton, pigeon pea
	Helicoverpa armigera (Hub.) (Lepidoptera: Noctuidae) larvae	Cotton
	Cosmophila flava F. (Lepidoptera: Noctuidae) larvae	Cotton
	Spodoptera littoralis (Boisd.) (Lepidoptera: Noctuidae) larvae	Cotton

sipiodes was reared out from eggs. The nymphal development passed through five instars. The duration of the different life stages is given in Table 2.

M. mensor nymphs and adults preyed on eggs, larvae and adults of *M. ochroptera*. As for the two other pentatomid bugs, adult *M. acuta* consumed significantly higher numbers of larvae ($p < 0.001$) compared to adults under both free-choice and no choice conditions (Table 3). The daily consumption pattern of adults was similar to those of *G. conspicuus* and *M. acuta*, but had a lower plateau (Figure 2). In addition to *M. ochroptera, M. mensor* preyed on various caterpillars in sesbania fallows (Table 4).

Afrius yolofa *(Guérin-Méneville)*

This was a morphologically variable pentatomid species observed less frequently in the sesbania fallows and its life cycle was not known. *A. yolopha* eggs were characterized by their dark brown colour and a rough pseudoperculum with 11–13 micropylar processes. Nymphs and adults attacked larvae and adults of *M. ochroptera*, and larvae of *Euproctis rubricosta* Fawc. and *Helicoverpa armigera* (Hubn.) in the fallows (Table 4).

Deraeocoris ostentans *(Stål)*

Adults and nymphs of the mirid bug *D. ostentans* preyed on only eggs of *M. ochroptera*. They also attacked various Hemiptera on different crop and tree species at Msekera (Table 4). The population of *D. ostentans* was generally higher during the 1997–1998 rainy season compared to the 1999 rainy season. During the 1997–1998 rainy season, the numbers built up rapidly beginning from the last week of March and the peak was recorded in May. The percentage egg loss due to predation was 15.2% in mid-March and rose to 73.2% in mid-May 1998. At that time, high numbers of *D. ostentans* nymphs and larvae were found on, or in the vicinity of damaged eggs, suggesting that this bug was the main predator responsible for the high level of predation. During the 1998–1999 rainy season, large numbers were observed from May onwards. By this time *M. ochroptera* populations had drastically declined and predation of eggs could not be assessed.

Rhinocoris segmentarius *(Germar)*

In the field both adults and nymphs of the reduviid bug *R. segmentarius* preyed on adults and larvae of *M. ochroptera*. This species was found throughout the rainy season in small numbers. In addition to *M. ochroptera*, it was seen to attack larvae of *E. rubricosta, H. armigera* on sesbania, and *Spodoptera litoralis* and *Cosmophila flava* on cotton.

Cyaneodinodes fasciger *(Chaudoir)*

All larval stages and adults of the carabid *C. fasciger* preyed on larvae and eggs of *M. ochroptera*. The adult beetles dwell in the soil and these were seen frequently in weed infested sesbania fallows. The larvae were black and could easily be mistaken for *M. ochroptera* larvae except for their fast movement. Both adults and larvae of this species were found to be active climbers and were seen attacking *M. ochroptera* larvae on tree branches as well as in the soil. Though this was one of the commonest predators in weedy fields, its impact could not be assessed in the conventional clean-weeded fallows because most of the attack occurred in weedy fallows.

Tetramorium sericeiventre *Emery and* Pheidole *sp.*

The ant species *Tetramorium sericeiventre* Emery and *Pheidole* sp. were observed to attack larvae and adults of *M. ochroptera*. Both species collected larvae crawling on the soil surface and carried them to the nest. We have not attempted to quantify their impact on *M. ochroptera* populations, but qualitative observations on ant nest sites confirmed heavy predation of the small larvae of the beetle. These species were abundant towards the end of the rainy season (March–April) in sesbania fallows.

Mallada *sp.*

The larvae of the lacewing *Mallada* sp. were frequently observed preying on larvae and eggs of *M. ochroptera*. Assessment of their population could not be made reliably because of the concealing habit of the larvae that cover themselves with pieces of dry leaves and could not be readily distinguished from weathered sesbania leaves. Preliminary data showed that their population was higher during the 1998–1999 rainy season compared to the 1997–1998.

Discussion

M. ochroptera was found to be attacked by many predators in sesbania-planted fallows in Eastern Zambia. The most common predators were *G. conspicuus* and *M. acuta* that accounted for over 80% of the heteropteran predators. These species were found in the fallows only during the rainy season. It is not yet known how they survive during the dry season (May–November). It is probable that the adults hibernate during the winter (Mossop, 1927).

Although *G. conspicuus, M. acuta*, and *M. mensor* could prey on eggs, larvae and adults of *M. ochroptera*, the biggest proportion (> 65%) of their diet consisted of larvae. These bugs were reported to attack other pest species on different kinds of plants in Africa (Table 5). However, little was known about their biology except the descriptions of stages of *G. conspicuus* (Mossop, 1927). According to him, *G. conspicuus* lays eggs in masses of 12 to 59 and one female laid 119 eggs in four masses during two and half months in captivity. This was fewer than eggs laid in just one large mass in the insectary at Msekera. The incubation period of eggs was also much shorter than the 18 to 20 days in South Africa (Mossop, 1927).

Nymphs of *G. conspicuus, M. acuta* and *M. mensor* appeared not to feed during the first instar development. Mossop (1927) reported similar observations on *G. conspicuus*. The second to fourth instar nymphs attacked prey in groups, so it was difficult to determine voracity of individual nymphs. The fifth instar nymphs also showed variations in daily consumption, the peak voracity being 3 to 4 days after the fourth molt and feeding very little 2 to 3 days before molting into adulthood. This behavior, termed the 'developmental response' has also been reported in other predatory insects (Murdoch, 1971; Hassell et al., 1976).

D. ostentans has been reported as a pest on cotton in Uganda (Hargreaves, 1924) and coffee in Kenya (Anderson, 1934). However, this bug was not observed feeding on sesbania. Most of the *Deraeocoris* spp. are well known predators of many insects (Villacarlos, 1993; Ulubilir et al., 1997) and their potential as sap-sucking pests has been experimentally disproved at least in one species (Chinajariyawong and Harris, 1987).

Since monitoring of all predation events was conducted during daytime, mainly on foliage, it is likely that predators that are active at night or foraging on or in the ground have been missed or underestimated. This may be the case for the carabid *C. fasciger*. The biology of *C. fasciger* is largely unknown. Generally, *Cyaneodinodes* (= *Chlaenius*) spp. are known to lay their eggs singly in the soil (David et al., 1973). The larvae move up and down the plant in search of prey and feed on insects, e.g. noctuid larvae (Katiyar et al., 1976). Whereas most predators found during this study are polyphagous, the mimicry shown by larvae of *C. fasciger* suggests that this species may be specific to *M. ochroptera*. Another carabid, *Cyaneodinodes ammon* Fab. was similarly reported to mimic *Mesoplatys cincta* in West Africa (Jolivet and Van Parys, 1977).

Implications for the control of M. ochroptera

Parallel studies on parasitism in *M. ochroptera* showed that, in eastern Zambia, parasitism is limited to the wasp *Perilitus larvicida* van Achterberg (Hymenoptera: Braconidae) and the nematode *Hexamermis* sp. (Nematoda: Mermithidae), both parasitizing larvae and adults of *M. ochroptera* (Achterberg et al., 2000). Although their impact on *M. ochroptera* populations was not fully assessed, observations during two seasons in eastern Zambia showed a very low level of apparent parasitism (< 10%) (Kenis and Sileshi, unpublished). In contrast, the predator guild is more furnished. Our results suggest that predators may play an important role in limiting beetle populations, particularly at the end of the rainy season before the beetles reach their overwintering sites. The same predators may also exert some control of other pests of sesbania and crop plants and agroforestry species such as pigeon pea. This may be particularly relevant to areas like southern Malawi where sesbania is relay intercropped with pigeon pea and maize. Polyphagous predators can feed on any pest that is in abundance, acting as a balancing factor in the ecosystem. Although biological control strategies are more often linked to the use of specific natural enemies, generalist predators undoubtedly play a role in limiting pest populations, particularly at low prey density (DeBach, 1951). Such predators are sometimes used as augmentative biological control agents, and their conservation and enhancement is often recommended in IPM programmes (Van Driesche and Bellows, 1996).

The role of *Mallada* and *Deraeocoris* species in the biological control of serious pests such as *H. armigera*, aphids, psyllids and whiteflies has been demonstrated elsewhere (Villacarlos, 1993; Mani and Krishnamoorthy, 1995; Kabissa et al., 1996; Ulubilir et al., 1997). Artificial diets and methods for mass rearing of *Mallada* species have been developed (Yazlovetskii et al., 1992; Gautam, 1994; Lee et al., 1994). However, in the present situation, it is practically (but probably not economically) feasible to mass-produce and release these predators in sesbania fallows. However, there are opportunities for manipulation of predator activity and augmentation of their populations. For instance, naturally occurring populations of predators have been successfully concentrated and their egg deposition increased by spraying solutions of attractants such as sucrose, molasses (Schiefelbein and Chiang, 1966; Carlson and Chiang, 1973; Ben Saad and Bishop, 1976), caryophyllene (Flint et al., 1979), brewers yeast and tryptophan (Hagen et al., 1976; Liber and Niccoli, 1988) in the field. Where the habitat preferences of the predators are known, cultural practices may also be manipulated to favor the activity of predators such as *C. fasciger*. Most Carabidae, including the genus *Cyaneodinodes* (= *Chlaenius*), are known to show affinity for thick vegetation and forests

Table 5. Prey species of *Afrius yolofa, Glypsus conspicuus, Macrorhaphis acuta, Rhinocoris segmentarius*, and *Pheidole* spp. reported from elsewhere in Africa

Predator	Prey species	Country of Report (References)
A. yolofa	*Acreae eponina* (Cram.) (Lepidoptera: Nymphalidae)	Nigeria (Matanmi and Hassan, 1987)
	Mesoplatys cincta Oliv. (Coleoptera: Chrysomelidae)	Nigeria (Golding, 1931)
G. conspicuus	*Achaea lienardi* Boisd. (Lepidoptera: Noctuidae)	South Africa (Taylor, 1965)
	Argyrostagma niobe (W.) (Lepidoptera: Lymantriidae)	Kenya (Bullock and Smith, 1968)
	Dasychira georgiana Fawc. (Lepidoptera: Lymantriidae)	Kenya (Bullock and Smith, 1968)
	Earias biplaga Walk. (Lepidoptera: Noctuidae)	Uganda (Nyiira, 1970)
	Earias insulana Boisd. (Lepidoptera: Noctuidae)	Uganda (Nyiira, 1970)
	Epicerura pulverulenta H. (Lepidoptera: Noctuidae)	Nigeria (Akanbi and Ashiru, 1991)
	Helicoverpa armigera (Hub.) (Lepidoptera: Noctuidae)	Uganda (Nyiira, 1970)
	Diparopsis castanea Hamps. (Lepidoptera: Noctuidae)	S. Africa (Smith, 1933)
	Bombycomorpha pallida Dist. (Lepidoptera: Lasiocampidae)	S. Africa (Gunn, 1916)
	Gonipterus scutellatus Gyll. (Coleoptera: Curculionidae)	S. Africa (Mossop, 1927)
	Mesoplatys cincta Oliv. (Coleoptera: Chrysomelidae)	Nigeria (Golding, 1931)

M. acuta	*Achaea lienardi* Boisd. (Lepidoptera: Noctuidae)	S. Africa (Taylor, 1965)
	Acreae terpsicore (L.) (Lepidoptera: Nymphalidae)	Ghana (Duodu and Lawson, 1987)
	Ascotis selenaria reciprocaria Wlk (Lepidoptera: Geometridae)	Kenya (Abasa and Mathenge, 1974)
	Cassida jeanneli Spaeth. (Coleoptera: Chrysomelidae)	Kenya (Poulton, 1925)
	Diparopsis castanea Hamps. (Lepidoptera: Noctuidae)	Malawi (King, 1928)
	Earias biplaga Walk. (Lepidoptera: Noctuidae)	Malawi (King, 1928)
	Earias insulana Boisd. (Lepidoptera: Noctuidae)	Malawi (King, 1928)
	Epicampoptera andersoni (Tams) (Lepidoptera: Drepanidae)	Kenya (Abasa, 1975)
	Helicoverpa armigera (Hub.) (Lepidoptera: Noctuidae)	Uganda (Nyiira, 1970)
	Latoia vivida Walk. (Lepidoptera: Limacodidae)	Malawi (Lee, 1971)
	Leucoplema dohertyi (Warr.) (Lepidoptera: Epiplemidae)	Kenya (Abasa, 1975)
	Niphadolepis alianata Karsch. (Lepidoptera: Limacodidae)	Malawi (Lee, 1971)
	Mesoplatys cincta Oliv. (Coleoptera: Chrysomelidae)	Nigeria (Golding, 1931)
R. segmentarius	*Acreae eponina* (Cram.) (Lepidoptera: Nymphalidae)	Nigeria (Matanmi and Hassan, 1987)
	Bagrada hilaris (Burm.) (Heteroptera: Pentatomidae)	S. Africa (Gunn, 1919)
	Dysdercus spp. (Heteroptera: Pyrrhocoridae)	S. Africa (Ullyett, 1930)
	Earias biplaga Walk. (Lepidoptera: Noctuidae)	S. Africa (Taylor, 1932)
	Earias insulana Boisd. (Lepidoptera: Noctuidae)	S. Africa (Taylor, 1932)
	Helicoverpa armigera (Hub.) (Lepidoptera: Noctuidae)	S. Africa (Taylor, 1932)
Pheidole spp.	*Helicoverpa armigera* (Hub.) (Lepidoptera: Noctuidae)	Kenya (Berg et al., 1997)

(Bhat and Rajagopal, 1993). A better knowledge of the biology and ecology of this species should help in developing methods to enhance its activity in sesbania fallows. The current practice of spraying insecticides for control of *M. ochroptera*, in addition to being probably uneconomical in improved fallows, is likely to have adverse effects on the natural enemy fauna and, subsequently, the natural control of the pests.

Many biotic and abiotic factors are known to influence the activity of natural enemies. Parasitoids are probably the most important biotic factors that may reduce the efficiency of biocontrol agents (Sileshi, 1997). The heavy egg parasitism observed on *M. acuta* and *M. mensor* by *T. sipiodus* and *Telonomus* sp. during this study confirms other observations such as those of *Trisolcus basalis* (Woll.) on *M. acuta* (Lee, 1971), *Asolcus aloysiisabaudiae* (Foutts) and *Asolcus seychelensis* (Kieff) on *G. conspicuus* (Bullock and Smith, 1968) and most certainly limits effectiveness of the predators. Another limitation may be that predator populations build up much later than those of *M. ochroptera*. A third limitation of such generalist predators may be sudden changes in the predator's preference between various prey species, which may influence their efficiency in control of the target pest.

To sum up, predation must not be viewed as the ultimate solution to the beetle problem in fallows, but their conservation should be kept in mind when other control methods and cultural practices are being developed. Further research is needed on the biology, ecology and impact of some of the main predators, such as *C. fasciger, D. ostentans*, and *Mallada* sp. as well as on the influence of present cultural practices on predator populations.

Acknowledgments

We acknowledge the Identification Service, CABI Bioscience, in particular R.G. Booth, A. Polaszek (CABI Bioscience, UK), L.H. Triana, M.D. Webb (National History Museum, UK), and L. Masner (ECORC, Canada) for identification of our specimens, and David A. Rider (Department of Entomology, North Dakota State University) for supplying the up-to-date list of synonyms for the Pentatomidae. We also thank Fred Phiri for technical assistance and the two reviewers for their excellent comments on the first draft of the manuscript. This study was funded by the Canadian International Development Agency (CIDA) and a fellowship to the senior author from the Deutscher Akademischer Austauschdienst (DAAD). The involvement of M. Kenis in this project was supported by the UK Department for International Development (DFID-Project R6736).

Appendix 1. Density (mean numbers per square meter ± S.E.) of *Mesoplatys ochroptera, Glypsus conspicuus, Macrorhaphis acuta* and *Mecosoma mensor* at Msekera Research Station, eastern Zambia, between October 1997 and June 1999

Month	*M. ochroptera*		*G. conspicuus*	*M. acuta*	*M. mensor*
	Larva	Adult			
Oct. 1997	0	0	0	0	0
Nov.	324.3 ± 74.6	20.8 ± 4.0	0	0	0
Dec.	286.5 ± 55.0	96.0 ± 15.4	0	0	0
Jan. 1998	454.6 ± 75.92	51.5 ± 6.8	0	0	0
Feb.	1134.4 ± 136.1	183.5 ± 22.4	0	0	0
March	835.6 ± 85.2	211.4 ± 29.6	0.35 ± 0.12	0.26 ± 0.10	0.15 ± 0.06
April	173.8 ± 74.7	145.5 ± 20.7	0.89 ± 0.26	0.78 ± 0.24	0.43 ± 0.14
May	53.1 ± 12.7	62.8 ± 10.7	0.20 ± 0.04	0.56 ± 0.14	0.07 ± 0.02
June	0	0	0	0	0
July	0	0	0	0	0
Aug.	0	0	0	0	0
Sept.	0	0	0	0	0
Oct.	0	0	0	0	0
Nov.	0	0	0	0	0
Dec.	0	0	0	0	0
Jan. 1999	74.3 ± 16.4	17.8 ± 3.6	0	0	0
Feb.	361.1 ± 64.3	103.9 ± 16.3	0.13 ± 0.04	0.03 ± 0.01	0.03 ± 0.01
March	1017.9 ± 158.8	201.8 ± 28.3	0.31 ± 0.07	0.03 ± 0.01	0.03 ± 0.01
April	255.8 ± 46.0	396.2 ± 39.6	1.12 ± 0.28	0.64 ± 0.17	0.24 ± 0.02
May	0	498.8 ± 94.8	0.26 ± 0.06	0.38 ± 0.07	0.21 ± 0.06
June	0	0	0	0	0

References

Abasa, R.O., 1975. A review of the biological control of coffee insect pests in Kenya. *East Afr. Agric. For. J.* 40: 292–299.

Abasa, R.O. and W.M. Mathenge, 1974. Laboratory studies of the biology and food requirements of *Macrorhaphis acuta* Dallas. *Entomophaga* 19: 213–218.

Achterberg, C. van, M. Kenis and G. Sileshi, 2000. *Perilitus* (*Microctonus*) *larvicida* spec. nov. (Hymenoptera: Braconidae: Euphorinae) from Zambia. *Zool. Med. Leiden* 74: 57–62.

Akanbi, M.O. and M.O. Ashiru, 1991. Towards integrated pest management of forest defoliators: the Nigerian situation. *For. Ecol. Manage.* 39: 81–86.

Anderson, T.J., 1934. Entomological section. Report of the Department of Agriculture-Kenya, Nairobi, Kenya. pp. 137–145.

Ben Saad, A.A. and G.W. Bishop, 1976. Effect of artificial honeydew on insect communities in potato fields. *Environ. Entomol.* 5: 453–457.

Berg, H. van den, M.J.W. Cock and G.I. Odour, 1997. Natural control of *Helicoverpa armigera* in sunflower: assessment of the role of predation. *Biocontr. Sci. Tech.* 7: 613–629.

Bhat, P.S. and D. Rajagopal, 1993. A study on pitfall trapping of Carabid beetles (Coleoptera: Carabidae). *J. Soil Biol. Ecol*. 13: 44–49.

Bullock, J.A. and R.G. Smith, 1968. The bionomics and control of *Argyrostagma niobe* (Weym.) and *Dasychira georgiana* Fawc. (Lepidoptera: Lymantriidae) on black wattle in Kenya. *Bull. Entomol. Res.* 58: 255–277.

Carlson, R.E. and H.C. Chiang, 1973. Reduction of an *Ostrinia nubilalis* population by predatory insects attracted by sucrose sprays. *Entomophaga* 18: 205–211.

Chinajariyawong, A. and V.E. Harris, 1987. Inability of *Deraeocoris signatus* (Distant) (Hemiptera: Miridae) to survive and reproduce on cotton without prey. *J. Aust Entomol. Soc.* 26: 37–40.

Cox, M.L., 1994. The Hymenoptera and Diptera parsitoids of Chrysomelidae. In: P.H. Jolivet, M.L. Cox and E. Petitpierre (eds), *Novel aspects of the biology of Chrysomelidae*. Kluwer Academic Publishers, Dordrecht/Boston/London. pp. 419–467.

Cox, M.L., 1996. Insect predators of Chrysomelidae. In: P.H. Jolivet and M.L. Cox (eds), *Chrysomelida Biology*, Vol. 2. *Ecological Studies*. SPB Academic Publishing, Amsterdam. pp. 23–91.

David, H., D.K. Banergi and A.N. Kalra, 1973. Records of a carabid predator *Chlaenius bioculatus* Chaud. on the leaf roller, *Neomarasmaia supicalis* Wlk., a pest of sugarcane. *Indian J. Entomol.* 34: 175–177.

DeBach, P., 1951. The necessity for an ecological approach to pest control in citrus in California. *J. Econ. Entomol.* 44: 443–447.

Duodu, Y.A. and B.W.L. Lawson, 1987. Natural enemies of *Acreae terpsicore* (Lepidoptera: Nymphalidae) in Ghana, with particular reference to the parasite *Charops diversipes* (Hymenoptera: Ichneumonidae). *Entomophaga* 28: 271–276.

Flint, H.M., S.S. Salter and S. Walters, 1979. Caryophyllene: an attractant for the green lacewing. *Environ. Entomol.* 8: 1123–1125.

Gautam, R.D., 1994. Present status of rearing of chrysopids in India. *Bull. Entomol. New Delhi* 35: 31–39.

Golding, F.D., 1931. Further notes on the food plants of Nigerian insects. *Bull. Entomol. Res.* 22: 221–223.

Gunn, D., 1916. The pepper tree caterpillar, *Bombycomorpha pallida* Dist. Union of South Africa, Department of Agriculture, Pretoria, Division of Entomology Bulletin No. 5, 10 pp.

Gunn, D., 1919. The bagrada bug (*Bagrada hilaris*). Union of South Africa, Department of Agriculture, Pretoria, Division of Entomology Bulletin No. 9, 16 pp.

Hagen, K.S., P. Greany, E.F. Sawall and R.L. Tassan, 1976. Tryptophan in artificial honeydew as a source of an attractant for adult *Chrysopa carnea. Environ. Entomol.* 5: 458–468.

Hargreaves, H., 1924. Annual report of the government entomologist. Annual Report of Department of Agriculture 1923, Entebbe, Uganda. pp. 15–21.

Hassell, M.P., J.H. Lawton and J.R. Beddington, 1976. The components of arthropod predation. I. The prey death rate. *J. Anim. Ecol.* 45: 135–164.

Iwao, S., 1968. A new regression method for analysing the aggregation pattern of animal populations. *Res. Pop. Ecol.* 10: 1–20.

Jolivet, P. and E. Van Parys, 1977. Un cas inédit de mimétisme agressif entre un chrysomelide (*Mesoplatys cincta* (Olivier) et un carabique (*Cyaneodinodes ammon Fabricius*) (Coleoptera). *Bull. Men. Soc. Linn. Lyon* 46: 168–180.

Kabissa, J.C.B., J.G. Yarro, H.Y. Kayumbo, and S.A. Juliano, 1996. Functional response of two chrysopid predators feeding on *Helicoverpa armigera* (Lepidoptera: Noctuidae) and *Aphis gossypii* (Homoptera: Aphididae). *Entomophaga* 41: 141–151.

Katiyar, R.R., B.P. Misra, K.D. Upadhyay and N. Prasad, 1976. Laboratory evaluation of a carabid larva *Chlaenius bioculatus* (Coleoptera: Carabidae) as predators of lepidopterous pests. *Entomophaga* 21: 349–351.

King, C.B.R., 1928. Some notes on the red (Sudan) bollworm (*Diparopsis castanea*, Hampson) in Nyasaland. *Empire Cotton Growers Rev.* 3(4): 354–364.

Kuno, E., 1976. Multistage sampling for population estimation. *Res. Pop. Ecol.* 18: 39–56.

Kwesiga, F., S. Franzel, F. Place, D. Phiri and C.P. Simwanza 1999. *Sesbania sesban* improved fallows: Their inception, development and farmer enthusiasm. *Agrofor. Sys.* 47: 49–66.

Lee, R.F., 1971. *A preliminary annotated list of Malawi forest insects*. Malawi Forest Research Institute Research Record No. 40, Zomba, 132 pp.

Lee, W. T., S.A. Hassan and K.S. Hagen, 1994. Technical development of microencapsulated artificial diets for *Mallada basalis* Walker. *Chin. J. Entomol.* 14: 47–52.

Liber, H. and A. Niccoli, 1988. Observations on the effectiveness of an attractant food spray in increasing chrysopid predation on *Prays oleae* (Bern.) *eggs. Redia* 71: 467–482.

Mani, M. and A. Krishnamoorthy, 1995. Natural enemies of the whitefly, *Lipaleyrodes euphorbiae* David and Subramaniam (Homoptera: Aleyrodidae). *J. Biol. Cont.* 9: 102–104.

Matanmi, B.A. and T.J. Hassan, 1987. The life history and habits of *Acreae eponina* (Cramer) (Lepidoptera: Nymphalidae). *Rev. Zool. Afr.* 101: 371–377.

Mchowa, J.W. and D.N. Ngugi, 1994. Pest complex in agroforestry systems: the Malawi experience. *For. Ecol. Manage.* 64: 277–284.

Mossop, M.C., 1927. Insect enemies of the eucalyptus snout-beetle. *Farm. South Afr.*, no. 11: 430–431.

Murdoch, W.W., 1971. The developmental response of predators to changes in prey density. *Ecology* 52: 132–137.

Nyiira, Z.M., 1970. A note on the natural enemies of lepidopterous larvae in cotton bolls in Uganda. *Ann. Entomol. Soc. Am.* 63: 146–162.

Poulton, E.B., 1925. A cassid beetle pest of a timber-tree in Kenya colony. *Trans. Entomol. Soc. London* 3–4: 63–64.

Schiefelbein, J.W. and H.C. Chiang, 1966. Effects of spray of sucrose solution in a corn field on the populations of predatory insects and their prey. *Entomophaga* 111: 333–339.

Sileshi, G., 1997. Potential biocontrol agents for the blue couch grass, *Digitaria abyssinica* (A. Risch.) Stapf. in East Africa. *Int. J. Pest Manage.* 43: 173–176.

Sileshi, G., and M. Kenis, 2001. Survival, longevity and fecundity of overwintering *Mesoplatys ochroptera* Stål (Coleoptera: Chrysomelidae) defoliating *Sesbania sesban* (Leguminosae) and implications for its management in southern Africa. *Agric. For. Entomol.* 3 (in press).

Sileshi, G., J.A. Maghembe, M.R. Rao, C.K.P.O. Ogol, and S. Sithanantham, 2000. Insects feeding on *Sesbania* species in natural stands and agroforestry systems in southern Malawi. *Agrofor. Sys.* 49: 41–52.

Smith, A.J., 1933. Report on cotton insects and diseases investigations, Part 3: Notes on the red bollworm (*Diparopsis castanea* Hampson) of cotton in South Africa. *Sci. Bull. South Afr.* No. 114, 29 pp.

Swinkels, R.A., S. Franzel., K.D. Shepherd, E. Ohlsson, and J.K. Ndufa, 1997. The economics of short rotation improved fallows: Evidence from areas of high population density in western Kenya. *Agric. Syst.* 55, 99–112.

Taylor, J.S., 1932. Report on cotton insect and disease investigations, Part II: Notes on the American bollworm (*Heliothis obsoleta*, Fabr.) on cotton, and on its parasite *Microbracon brevicornis* Wesm. *Sci. Bull. South. Afr.* 113: 18.

Taylor, J.S., 1965. The fruit-piercing moth, *Achaea lienardi* Boisduval (Lepidoptera: Noctuidae), in the Eastern Cape province. *J. Entomol. Soc. South. Afr.* 28: 50–56.

Ullyett, G.C., 1930. The life-history, bionomics and control of cotton stainers (*Dysdercus* spp.) in South Africa. *Sci. Bull. South Afr.* 94: 3–9.

Ulubilir, A., A. Yigit, S. Yucel and C. Yabas, 1997. Biological control of *Bemisia tabaci* Gen. (Homoptera: Aleyrodidae) by *Deraeocoris pallens* Reut (Hemiptera: Miridae) on eggplant in plastic houses in Adana. *Adv. Hort. Sci.* 11: 202–204.

Van Driesche, R.G. and T.S. Jr. Bellows, 1996. *Biological Control*. Chapman & Hall, New York.

Villacarlos, L.T., 1993. Natural enemies of *Heteropsylla cubana* (Homoptera: Psyillidae) in Philippines. *Philippines Tech. J.* 18: 57–71.

Wale, M. T. Abate, and A. Tesfaye, 1996. Getting to know the enemy-Mesoplatys beetles and sesbania. *Agrofor. Today* 8(3): 17–18.

Yazlovetskii, I.G., L. I. Ageeva and L.S. Keiser, 1992. Artificial nutrient medium for five species of chrysopids. *Zool. Zh.* 71: 123–129.