

Comparative evaluation of *Cotesia flavipes* and *C. sesamiae* (Hymenoptera: Braconidae) for the management of *Chilo partellus* (Lepidoptera: Pyralidae) in Kenya

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Abstract

Cotesia flavipes Cameron, a gregarious larval endoparasitoid native to the Indo-Australian region, was imported from Pakistan and released in Kenya in 1993 for management of the exotic stemborer, *Chilo partellus* (Swinhoe). Recent reports confirmed the successful establishment of the parasitoid in three locations in Kenya and in northern Tanzania. Functional response studies on this parasitoid and an indigenous congener, *Cotesia sesamiae* (Cameron), indicated that *C. flavipes* had a higher searching ability and attacked more larvae when *Chilo partellus* was the host. When a native stemborer, *Sesamia calamistis* Hampson, was the host, there was no significant difference between numbers attacked by both parasitoids. Numerical response studies showed that *Cotesia flavipes* produced more total progeny and female progeny per female parasitoid on *Chilo partellus* than did *Cotesia sesamiae*. No significant difference in progeny production was detected between the two parasitoids on *S. calamistis*. Functional and numerical responses tested in the laboratory gave the same ranking of the two parasitoids on the two hosts as in the field. This study suggests that *Cotesia flavipes* is a more efficient parasitoid and it is anticipated that it will contribute to the control of both exotic and native stemborers in Kenya.

Introduction

In sub-Saharan Africa, maize (*Zea mays*) and sorghum (*Sorghum bicolor*) production are severely reduced by the feeding of lepidopterous stemborers. In Kenya, all stemborers, with the exception of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae), are thought to be indigenous (Nye, 1960). In the southern coastal area of Kenya, two native stemborers, *Chilo orichalcociliellus* Strand (Lepidoptera: Pyralidae) and *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae), attack maize and sorghum coincidentally in

space and time with *C. partellus*. Among the three species, *C. partellus* is the most abundant and serious pest, and there is evidence that it may be displacing the indigenous stemborers (Overholt *et al.*, 1994).

Chilo partellus is indigenous to southeastern and southern parts of Asia. More than 40 parasitoid species are recorded from this pest in Africa (Bonhof *et al.*, 1997). The braconid, *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae), is the most common parasitoid of stemborers in most of East and southern Africa (Ingram, 1958; Mohyuddin & Greathead, 1970; Mathez, 1972; Kfir, 1992). However, in coastal Kenya, generational mortality of *Chilo partellus* due to *Cotesia sesamiae* during 1992 and 1993 was never greater than 3%, and was typically less than 0.5% (Overholt *et al.*, 1994).

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In an attempt to increase natural suppression of *Chilo partellus*, a classical biological control strategy has been initiated (Overholt *et al.*, 1994). *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), a gregarious larval endoparasitoid of *Chilo partellus* native to the Indo-Australian region (Mohyuddin, 1971), and ecologically similar to *Cotesia sesamiae*, was imported from Pakistan and released at the Kenya coast in 1993 (Overholt *et al.*, 1994). Recent evidence indicates that the parasitoid is firmly established in Kenya and northern Tanzania (Overholt *et al.*, 1997).

Studies were conducted on the host range of *Cotesia flavipes* before releases were made. *Cotesia flavipes* accepted and was able to develop in the three stemborer species that occur in coastal Kenya; *Chilo partellus*, *C. orichalcociliellus* and *S. calamistis* (Ngi-Song *et al.*, 1995). In comparative studies, more *Cotesia flavipes* progeny were obtained from *Chilo partellus* and *C. orichalcociliellus* than were progeny of *Cotesia sesamiae* (Ngi-Song *et al.*, 1995). *Cotesia flavipes* is a coevolved natural enemy of *Chilo partellus* whereas the African congener, *Cotesia sesamiae*, coevolved with *S. calamistis* and other indigenous stemborers. Reuniting the old-association parasitoid with its host in a new geographic area will result in new-association relationships with native stemborers. It is therefore useful to understand the performance of the two parasitoids on their new and old-association hosts to predict better their ability to suppress stemborer populations. An important aspect in evaluating the efficiency of a natural enemy is to study its performance as an individual by examining the attack rate on the host or prey. Knowledge of the functional response may provide some understanding of host-natural enemy interactions (Hughes *et al.*, 1992; Kidd & Jervis, 1996).

The utilization of hosts for parasitoid population increase and host-finding efficiency have been the foci of host-parasitoid population models over the past half century (May & Hassell, 1988; Mills & Getz, 1996). Several functional response studies have mainly focused on the factors governing the upper asymptote of the response at high host densities where the number of hosts attacked reaches a plateau, such as foraging time, host handling time, parasitoid egg maturation rate or egg depletion (Fernando & Hassell, 1980; Flinn, 1991; Alebeek, 1996). However, the ability of a biological control agent to locate and maintain the host population at low densities is a main objective of biological control, therefore it is important to study the parasitoid's behaviour at densities characteristic of those encountered in the field. A typical type II functional response may be ideal for describing attack rates over a broad range of host densities. However, a linear response (type I) is not unexpected over a range of low host densities (Wiedenmann & Smith, 1993). In this study, we aim to compare the functional and numerical responses of an indigenous and an introduced parasitoid on the exotic pest, *Chilo partellus*, and on a native stemborer found in maize fields at the Kenya coast.

Materials and methods

Host rearing

Chilo partellus and *S. calamistis* colonies were maintained at the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi. Adult moths originated from immature stemborers collected at the Kenya coast. Adults were placed

in oviposition cages lined with folded wax papers and maintained at 25°C, 50–70% rh, and a light/dark regime of 12L:12D. Eggs were collected daily and transferred to Petri dishes with moist cotton wool, then transferred three to four days later to one litre plastic jars with 125 ml artificial diet (Ochieng *et al.*, 1985). Larvae used in this study were removed from the artificial diet as fourth instars and fed on natural diet (maize stems) for at least 24 h before any field or laboratory experiments.

Parasitoid rearing

A colony of *Cotesia flavipes* was initiated with founders collected from *Chilo partellus* larvae at Rawalpindi, Pakistan, by the International Institute of Biological Control (IIBC). A colony of *Cotesia sesamiae* was started from material reared from *Chilo partellus* collected at the Kenya coast. *Cotesia flavipes* and *C. sesamiae* colonies were maintained on *Chilo partellus* and *S. calamistis* fourth-instar larvae, respectively, using the method described by Overholt (1993). Fourth-instar host larvae were offered individually to one-day-old mated female parasitoids for oviposition. Parasitized larvae were then transferred to vials containing artificial diet until cocoon formation and kept at 28°C and 50–70% rh. Cocoons were collected one or two days prior to emergence and kept in vials containing a strip of cotton wool saturated with a 10% sugar/water solution to serve as a food source. Emerged parasitoids were given 24 h to mate before they were transferred to 50 cm³ perspex oviposition cages.

Laboratory functional response study

Early fourth-instar host larvae were placed individually in glass vials (7.5 × 2.5 cm) with small pieces of maize stems (2–2.5 cm long) for a period of 24 h. Stems with larvae were then removed from vials and transferred to 15 × 15 × 20 cm perspex containers. Stems were fixed vertically to the bottom of the containers with a small piece of masking tape. Host densities were two, four, six, and eight larvae per container. Three mated female parasitoids were introduced into each container. Ten containers (replicates) were used for each host density/parasitoid combination with *Chilo partellus*, while seven replicates were used for *S. calamistis* due to a limited supply of larvae. Containers were kept at 28°C for three days, which is the average adult parasitoid longevity at this temperature (Mbapila, 1996). Larvae were then removed and placed in glass vials with artificial diet until the emergence of parasitoids or pupation of the host. The number of progeny was recorded for each parasitized larva. Host larvae that did not pupate were dissected to determine parasitism.

Field functional response study

This study was conducted in the coastal area of Kenya, south of Mombasa. Maize was planted inside 2.5 × 2.5 × 2.5 m field cages with 24 plants per cage. Cages consisted of metal tubing covered with a 400-micron polyester screen mesh. Five weeks after planting, plants were artificially infested with 10, 20, 30 or 40 host larvae per cage. Larvae were inserted into holes made with a 5-mm cork borer about 30 cm above ground level. When two larvae were placed in the same stalk (≥30 per cage), they were placed 15 and 30 cm above ground level. For both parasitoids, *Chilo partellus*

Table 1. Linear regression equations of the functional responses of *Cotesia flavipes* and *C. sesamiae* attacking *Chilo partellus* and *Sesamia calamistis* in the field and laboratory.

Treatment	Regression equation	R ²	F-value	P
Field				
<i>C. flavipes</i> × <i>C. partellus</i>	$y = 0.89 + 0.18x$	0.63	43.17	<0.001
<i>C. sesamiae</i> × <i>C. partellus</i>	$y = 0.58 + 0.08x$	0.16	4.90	0.04
<i>C. flavipes</i> × <i>S. calamistis</i>	$y = 0.02 + 0.11x$	0.46	15.60	0.001
<i>C. sesamiae</i> × <i>S. calamistis</i>	$y = 0.16 + 0.10x$	0.45	17.43	<0.001
Laboratory				
<i>C. flavipes</i> × <i>C. partellus</i>	$y = -0.10 + 0.44x$	0.43	28.92	<0.001
<i>C. sesamiae</i> × <i>C. partellus</i>	$y = 0.02 + 0.20x$	0.34	19.66	<0.001
<i>C. flavipes</i> × <i>S. calamistis</i>	$y = 0.45 + 0.16x$	0.11	3.13	0.09
<i>C. sesamiae</i> × <i>S. calamistis</i>	$y = 0.63 + 0.21x$	0.33	9.87	0.005

densities of 10, 20 and 30 were replicated seven times and the density of 40 was replicated six times. Each *S. calamistis* density was replicated six times. For *Chilo partellus*, densities of 10, 20 and 30 *S. calamistis* larvae were replicated five times and the density of 40 was replicated six times. For *Cotesia sesamiae*, densities of 10, 20 and 30 *S. calamistis* larvae were replicated six times and the density of 40 was replicated five times due to a shortage of larvae. In each cage, 20 mated females were released 48 h after larval infestation. Plants were excised and dissected after three days. Recovered larvae were kept individually in vials with artificial diet until emergence of parasitoids or an adult moth. Host larvae that did not pupate were dissected to determine parasitism.

Data analysis

A linear regression analysis was used to relate host densities to the total number of hosts attacked. The total number of hosts attacked was the number of hosts that produced progeny plus the number of larvae that were found to be parasitized after dissection. Data from cages where no or a very low proportion of host larvae were recovered were not included in the analysis. Slopes were compared for the two parasitoids on the two hosts using indicator variables (dummy variables) in which the interaction between host density and parasitoid species was regressed against the number of hosts attacked by the two parasitoids (Montgomery & Peck, 1982). The numerical response for each parasitoid on each host was estimated by calculating the means of total progeny and female progeny/female parasitoid. For the two measurements, a two-way ANOVA was performed with parasitoid species and host species as factors to test for significant interaction between hosts and parasitoids. Differences between the two parasitoids were tested separately for each host and host density using a t-test procedure (SAS institute, 1988).

Results

Table 1 shows the functional response regression equations of the two parasitoids on the two hosts as predicted by a linear regression. In the field, *Cotesia flavipes* had a significantly higher slope than *C. sesamiae* when *Chilo partellus* was the host ($F = 21.4$; $df = 1,50$; $P = 0.036$). However, the regression slopes for the two parasitoids were not different when *S. calamistis* was the host ($F = 11.9$; $df = 1,40$;

$P = 0.84$). A similar trend was observed in the laboratory, as the slope for *Cotesia flavipes* was two times greater than the slope for *C. sesamiae* against *Chilo partellus* ($F = 26.1$; $df = 1,75$; $P = 0.014$), while no difference was found on *S. calamistis* ($F = 4.5$; $df = 1,45$; $P = 0.68$). In the laboratory, *Cotesia flavipes* attacked more *Chilo partellus* than *S. calamistis* ($F = 17.6$; $df = 1,63$; $P = 0.044$), while *Cotesia sesamiae* attacked similar numbers of the two hosts ($F = 12.3$; $df = 1,57$; $P = 0.91$) (fig. 1).

Cotesia flavipes produced progeny from 95% and 71% of the total number of *Chilo partellus* host larvae attacked in the field and the laboratory, respectively. When *S. calamistis* was the host, 90% and 46% of attacked larvae produced adult progeny in the field and the laboratory, respectively. For *Cotesia sesamiae*, the percentage of successfully parasitised *Chilo partellus* was 62% in both the field and the laboratory, while on *S. calamistis*, 72% and 78% of attacked hosts produced adult progeny in the field and the laboratory, respectively.

In the laboratory, the interactions between hosts and parasitoids for total progeny/female were significant for the host densities of four ($F = 9.5$; $df = 1,30$; $P = 0.004$), six ($F = 10.1$; $df = 1,23$; $P = 0.004$) and eight ($F = 7.3$; $df = 1,31$; $P = 0.01$) host larvae per container. However, the interaction was not significant at the lowest host density of two ($F = 0.4$; $df = 1,29$; $P = 0.56$). A similar trend was observed in the field as interactions between host and parasitoids for total progeny/female were significant at the densities of 20 ($F = 4.4$, $df = 1,18$; $P = 0.05$), 30 ($F = 8.1$; $df = 1,21$; $P = 0.009$) and 40 ($F = 5.8$, $df = 1,22$; $P = 0.025$), but not significant at the density of 10 ($F = 1.4$; $df = 1,22$; $P = 0.25$). For female progeny/female, the interactions between hosts and parasitoids were only significant at the host density of four ($F = 9.2$; $df = 1,30$; $P = 0.004$) in the laboratory, and the host density of 30 ($F = 8.4$; $df = 1,21$; $P = 0.008$) in the field. No significant interaction was shown at the host densities of two ($F = 1.5$; $df = 1,29$; $P = 0.23$), six ($F = 0.6$; $df = 1,23$; $P = 0.44$) or eight ($F = 3.7$; $df = 1,31$; $P = 0.06$) in the laboratory, and the host densities of 10 ($F = 1.2$; $df = 1,22$; $P = 0.28$), 20 ($F = 3.7$, $df = 1,18$; $P = 0.06$) or 40 ($F = 3.6$; $df = 1,22$; $P = 0.06$) in the field.

The numerical response of *Cotesia flavipes* was markedly higher than *C. sesamiae* on *Chilo partellus* in field and laboratory studies. In the laboratory, *Cotesia flavipes* produced more females and total progeny than did *C. sesamiae* on *Chilo partellus* at the densities of four, six and eight hosts per container. On *S. calamistis*, there were no differences in the total progeny or female progeny per introduced female by either parasitoid at any host density

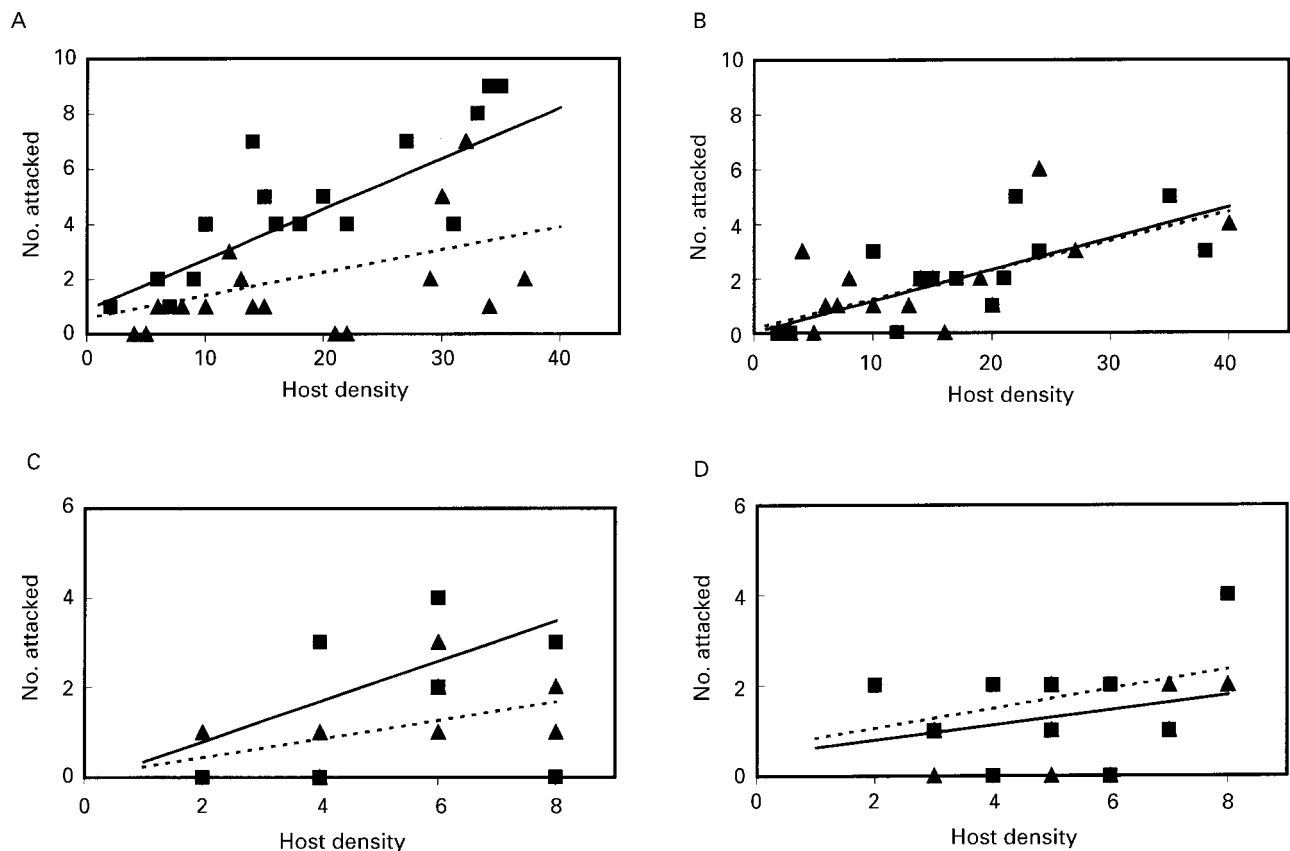


Fig 1. Functional responses of *Cotesia flavipes* and *C. sesamiae* attacking (A) *Chilo partellus* in the field; (B) *Sesamia calamistis* in the field; (C) *Chilo partellus* in the laboratory; (D) *Sesamia calamistis* in the laboratory. Predicted number of larvae attacked by *Cotesia flavipes* (—); predicted number of larvae attacked by *C. sesamiae* (---); actual number of hosts attacked by *C. flavipes* (■); actual number of hosts attacked by *C. sesamiae* (▲).

(table 2). Similar results were obtained from the field study, where *Cotesia flavipes* produced more female and total progeny per female parasitoid at the densities of 10, 30 and 40 *Chilo partellus* per cage, while no difference was found between the two parasitoids on *S. calamistis* at any host density (table 3).

Discussion

The release of *Cotesia flavipes* in maize fields at the Kenya coast has resulted in establishment, and it is now recovered beyond the areas where it was originally released (Overholt *et al.*, 1997). In the present study, *C. flavipes* proved to be a more efficient searcher of *Chilo partellus* than was *Cotesia sesamiae* in field and laboratory experiments. When *S. calamistis* was the host, no significant difference was found between the two parasitoids in the number of hosts attacked. Though a non-coevolved natural enemy of *S. calamistis*, *C. flavipes* was able to attack *S. calamistis* as efficiently as *C. sesamiae* at all host densities. Moreover, *C. flavipes* produced more female progeny than *C. sesamiae* at all densities of *Chilo partellus* in both field and laboratory studies. These findings agree with the higher intrinsic rate of increase of *Cotesia flavipes* over *C. sesamiae* found by Mbapila (1996), who also reported a higher percentage parasitism of *C. flavipes* than *C. sesamiae* in field cages when *Chilo partellus* was the host (Mbapila & Overholt,

1997). The poor performance of *Cotesia sesamiae* on *Chilo partellus* in the field was due to the low numbers of female progeny produced per female on that host.

Functional response studies have been criticised by several workers. For example, Kareiva (1990) argued that functional responses measured by confining a known number of hosts and parasitoids are unnatural because insects are forced to stay in a confined arena. The hosts used in our study, fourth instar stemborer larvae, are not highly mobile. In nature, the larvae reside in plant stems, so confinement in stems inside cages probably had little effect on their behaviour or accessibility to parasitoids. Once *Cotesia flavipes* females land on an infested plant, they crawl to an entrance to a stemborer feeding tunnel, directed by odours emanating from host frass, and then enter the tunnel to attack the host (Ngi-Song *et al.*, 1996; Potting *et al.*, 1997). After successfully parasitizing a host, Potting *et al.* (1997) found that females left the tunnel, but remained on the same plant for 27 to 88 min before beginning to search for additional hosts, sometimes resuming search on the same plant. Thus it did not appear that the parasitoid's behavioural response to successful parasitization was long distance dispersal. Confinement in a caged environment with infested plants, or plant stems, is likely to have had minimal effect on the searching behaviour of the parasitoids used in our study.

Table 2. Mean number of total progeny and female progeny per female parasitoid (means±SD) at varying host densities in the laboratory.

Host		<i>Chilo partellus</i>		<i>Sesamia calamistis</i>	
Initial host density	Parasitoid	progeny/♀	♀♀/♀	progeny/♀	♀♀/♀
2	<i>Cotesia flavipes</i>	1.8 ± 2.7 a	1.1 ± 1.9 a	6.4 ± 10.7 a	3.2 ± 7.0 a
	<i>C. sesamiae</i>	1.7 ± 2.7 a	0.6 ± 1.3 a	8.9 ± 7.7 a	6.9 ± 6.0 a
4	<i>C. flavipes</i>	21.3 ± 13.8 a	13.9 ± 9.9 a	7.2 ± 9.1 a	3.2 ± 4.3 a
	<i>C. sesamiae</i>	2.9 ± 3.9 b	1.6 ± 2.3 b	9.3 ± 7.9 a	4.2 ± 4.9 a
6	<i>C. flavipes</i>	24.9 ± 8.2 a	15.4 ± 6.0 a	14.4 ± 12.5 a	10.4 ± 8.8 a
	<i>C. sesamiae</i>	3.9 ± 3.0 b	2.1 ± 2.3 b	19.6 ± 19.9 a	0.7 ± 0.9 a
8	<i>C. flavipes</i>	11.2 ± 8.0 a	7.7 ± 6.5 a	3.8 ± 7.6 a	2.9 ± 5.7 a
	<i>C. sesamiae</i>	3.1 ± 3.6 b	1.1 ± 1.8 b	9.2 ± 8.9 a	2.7 ± 4.2 a

Means with the same letter within the same column and host density are not significantly different.

Table 3. Mean number of total progeny and female progeny per female parasitoid (mean ± SD) at varying host densities in the field.

Host		<i>Chilo partellus</i>		<i>Sesamia calamistis</i>	
Initial host density	Parasitoid	progeny/♀	♀♀/♀	progeny/♀	♀♀/♀
10	<i>Cotesia flavipes</i>	3.2 ± 2.1 a	2.3 ± 1.5 a	1.6 ± 2.5 a	1.0 ± 1.7 a
	<i>C. sesamiae</i>	0.5 ± 0.7 b	0.4 ± 0.6 b	0.4 ± 0.7 a	0.2 ± 0.3 a
20	<i>C. flavipes</i>	8.5 ± 2.1 a	7.0 ± 1.5 a	1.1 ± 1.2 a	0.7 ± 0.8 a
	<i>C. sesamiae</i>	4.5 ± 3.7 a	3.8 ± 3.2 a	2.0 ± 2.1 a	1.1 ± 1.1 a
30	<i>C. flavipes</i>	8.3 ± 2.7 a	6.1 ± 1.9 a	1.2 ± 0.3 a	0.4 ± 0.3 a
	<i>C. sesamiae</i>	2.7 ± 3.8 b	2.0 ± 2.8 b	1.8 ± 1.6 a	0.5 ± 0.6 a
40	<i>C. flavipes</i>	13.5 ± 6.7 a	10.3 ± 5.4 a	4.2 ± 2.8 a	2.6 ± 2.2 a
	<i>C. sesamiae</i>	4.6 ± 4.0 b	3.7 ± 3.8 b	3.7 ± 1.7 a	1.5 ± 1.0 a

Means with the same letter within the same column and host density are not significantly different.

O'Neil (1989) suggested that functional response studies may be misleading because they usually involve prey densities that are far in excess of those encountered in natural situations. However, host densities used in our field study ranged from 0.41 to 1.7 borers per plant, which are representative of the average stemborer densities found in the field in Kenya (0.2 to 1.8) (Overholt *et al.*, 1994). The use of a linear regression rather than a non-linear model to describe the data is justified as attack rates never exceeded 9 per 20 females in the field and 6 per 3 females in the laboratory. Thus, a linear response may be more suitable to describe functional response data than a non-linear regression over a range of low host densities (Hopper & King, 1986; Wiedenmann & Smith, 1993). However, the response of *C. flavipes* on *S. calamistis* in the laboratory was highly variable and not well described by the model, which may have been due to the low number of host larvae recovered. *Sesamia calamistis* larvae are known to be cannibalistic, which may provide an explanation for their disappearance (Bosque-Perez & Dabrowski, 1989).

Functional response studies may not explain the role of natural enemies in controlling pest populations (Varley & Gradwell, 1969). However, such studies may be useful for comparing the efficiency of different natural enemies (Overholt & Smith, 1990). The present study shows that functional and numerical responses found in the laboratory gave the same ranking of the two parasitoids on the two hosts as in the field. Laboratory studies in a simplified

environment may exaggerate the effect of natural enemies, but still provide a valid means of comparing the host finding abilities of candidate natural enemies.

There is obvious niche overlap between *C. flavipes* and *C. sesamiae* (Ngi-Song *et al.*, 1995). After the invasion of *Chilo partellus* into Africa, native stemborer parasitoids expanded their host ranges to include this exotic pest (Oloo & Ogedah, 1990; Kfir, 1992). However, recent surveys indicated that *C. partellus* was by far the most abundant species in maize, sorghum, *Sorghum arundinaceum* and *Panicum maximum* in the coastal area of Kenya, and typically accounted for >80% of the stemborer population (Overholt, unpublished; Overholt *et al.*, 1994). Thus, *Cotesia flavipes* may have an important advantage over *C. sesamiae* due to the dominance of its coevolved host.

The invasion of *Chilo partellus* may have led to partial displacement of some indigenous stemborers (Overholt *et al.*, 1994). If *Cotesia flavipes* attacked only the exotic stemborer, then it is likely that native stemborer populations would expand to fill a partially empty ecological niche. Thus, the ability of *C. flavipes* to utilize other stemborers may increase its colonizing ability and provide an overall suppression of the stemborer complex.

The ratio of successful attacks to the total number of attacks may provide a reliable estimate of physiological host-parasitoid compatibility. A higher number of hosts producing progeny relative to the total number attacked indicates a more compatible natural enemy. The proportion

of hosts successfully parasitized is a useful measure for estimating the long-term impact on the host (Wiedenmann & Smith, 1993). In our case, *C. flavipes* successfully parasitized a higher proportion of *Chilo partellus* than *Cotesia sesamiae*, while there was little difference in parasitism of *S. calamistis*.

Host-parasitoid physiological interactions can be predicted for old associations. However, they are less predictable in novel associations because of no coevolutionary history between the pest and the natural enemy (Wiedenmann & Smith, 1995). When a natural enemy is introduced into a new region, new associations can develop when a related host species occupies a niche similar to that of the original host species (Hokkanen & Pimentel, 1989). This seems to be the case with *C. flavipes* on *S. calamistis*. We anticipate that *C. flavipes* will contribute to the control of the indigenous stemborer as well as the exotic one. The results of this study suggest that *C. flavipes* is extrinsically superior to *C. sesamiae* when *Chilo partellus* is the host, and equally competitive when *S. calamistis* is the host. Current studies are investigating the competitiveness of the two parasitoids within the same host (multiple parasitism). If *Cotesia flavipes* proves to be intrinsically superior to *C. sesamiae*, then competitive displacement may eventually occur, particularly in areas where *Chilo partellus* is the dominant host.

A controversial question is: Would the displacement of *Cotesia sesamiae* by *C. flavipes* be considered a 'negative impact' on the environment? The present study suggests that *C. flavipes* is a more efficient parasitoid, and therefore is likely to result in increased suppression of stemborer populations. It is generally agreed that the displacement of a natural enemy by a second can only occur if the second one is more effective, and therefore should result in better host population regulation. *Cotesia flavipes*, though capable of parasitizing a fairly wide host range of noctuid and pyralid stemborers, does not produce progeny on the indigenous stemborer, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae), which is a suitable host for the development of *C. sesamiae* occurring in western Kenya (Ngi-Song *et al.*, 1995). Moreover, Mohyuddin (1971) found that *C. flavipes* is better adapted to drier climates than *C. sesamiae*. Thus, complete elimination of *C. sesamiae* is highly unlikely to happen as a result of the introduction of *C. flavipes*. Slight differences in niches may enhance stability of the stemborer parasitoid community in Kenya.

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