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IMPACT OF PARASITOIDS ON LEPIDOPTERAN STEM BORER INFESTATION LEVELS AND MAIZE YIELD AT THE KENYAN COAST

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Abstract: **Chilo partellus is an important stem borer pest in East Africa. To manage it's infestation, the parasitoid, Cotesia flavipes Cameron was introduced in Kenya and post release surveys showed that parasitism was steadily rising. However, due to lack of quantitative data on the parasitoid's impact, there are doubts on whether this parasitoid is an important mortality factor in stem borer management. This experiment was thus undertaken at the Kenyan coast to estimate the impact of C. flavipes on stem borers and maize yield. Using insecticide exclusion method, maize subplots were subjected to three treatments: treatment A (sprayed with Bulldock), treatment B (sprayed with Dimethoate) and treatment C (controls). Percentage infestation and parasitism were estimated at three maize growth stages. At the end of the experiment, maize was harvested, dried and weighed. Chilo spp dominated the stem borer community followed by S. calamistis. Stem borer infestation levels varied among treatments ($F_{2,87}$=6.92; p<0.05) and low infestation was recorded in treatment A compared to B and C. Infestation levels also varied with maize growth stages ($F_{2,87}$=11.07; p<0.001). The main parasitoid species recovered were Cotesia flavipes and Cotesia sesamiae (Cameron). Parasitism in treatments A, B and C were 16.2±7.4, 20.9±4.9 and 20.7±6.9% respectively with no significant difference among treatments (χ^2 =3.56; p>0.05). Parasitism varied significantly among maize growth stages (χ^2 =21.6; p<0.05). Maize yield did not vary among treatments A (20.8±2.1), B (24.1±2.0) and C (20.5±1.6) ($F_{2,27}$ =1.148; p>0.05) showing that the rise in parasitoid action has not translated into significant maize yield increase.**

Keywords: **Moist lowland tropics, Chilo partellus, Cotesia flavipes, impact, parasitism, insecticide exclusion method, maize yield.**

I. INTRODUCTION

In Sub-Saharan Africa, farmers mainly grow maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* Moench.) for both domestic consumption and income (Seshu Reddy, 1989; Odindo, 1991; Overholt, 1992; Chamberlain *et al.*, 2006). Production of these crops is however constrained by several factors key among them being field pest infestations (Seshu Reddy, 1983; Saxena *et al*., 1991; Brownbridge and Onyango, 1992; Bosque-Perez and Schulthess, 1998; Overholt,

1998). In Eastern and Southern Africa (ESA), there are five important stem borer pests of maize and sorghum. These are *Busseola fusca* Fuller and *Sesamia calamistis* Hampson (Family: Noctuidae), *Chilo partellus* (Swinhoe) and *Chilo orichalcociliellus* Strand (Family: Crambidae) and *Eldana saccharina* Walker (Family: Pyralidae) (Polaszek and Khan, 1998; Seshu Reddy, 1998; Overholt *et al.*, 2001). *Busseola fusca* and *C. partellus* are major pests in the region, while *S. calamistis*, C. *orichalcociliellus* and *E. saccharina* are minor pests (Bonhof *et al*., 1997; Songa *et al*., 2001; Zhou *et al*., 2001). In Kenya, *C. partellus* and *B. fusca* constitute the major proportion of stem borer pest community (Seshu Reddy, 1983; Khan *et al.*, 1997). In Kenya, a country where production of sufficient food for a rapidly increasing population is a challenge, 73% yield losses caused by *C. partellus* in small farmers'fields is of great concern (Seshu Reddy and Walker, 1990). Due to such high losses, various management strategies have been initiated to reduce *C. partellus* population in cereal crops.

The koinobiont larval parasitoid, *Cotesia flavipes* Cameron, from Sindh region of Pakistan was imported and released in Kenya to suppress *C. partellus* population (Overholt *et al*., 1994). Since the release in 1993, various post release surveys have been carried out and these showed a steady increase in parasitism levels (Overholt *et al*., 1994, 1997; Omwega *et al.*, 1997; Zhou *et al*., 2001). However, information regarding impact of the parasitoid on stem borer pest population and associated maize yield is lacking. Various methods for evaluation of parasitoid impact on pest populations have been developed. These include introduction and augmentation, cages and other barriers, removal of natural enemies, prey enrichment, direct observations and evidence of feeding (Luck *et al*., 1988). Removal of natural enemies with insecticides, first described as the insecticidal check method by DeBach (1946) is considered a good experimental technique for evaluating efficacy of natural enemies (Jones, 1982; Kenmore *et al*., 1984; DeBach and Rosen, 1991; Luck *et al*., 1999). Using insecticidal check technique, this study was undertaken to provide quantitative data on the impact of parasitoids on stem borer pest population and the associated maize yield in moist lowland agro-ecological zone (AEZ) of Kenya.

II. MATERIALS AND METHODS

Description of the study area

The study was undertaken at Kenya Agricultural and Livestock Research Organisation (KALRO), Mtwapa station (S 03°55.897′; E 039°43.918′; Elevation 17m), located in moist lowland tropics. Moist lowland AEZ is characterized by temperatures ranging from 22-32°C and an average precipitation of 500-1000mm/year (Corbett, 1998). During this study, Hybrid 4 (PH4) maize variety was planted in an experimental plot measuring 127 by 37.25m during the long rains of 2014 (May-September).

Experimental layout

Randomized Complete Block Design (RCBD) approach was adopted for this study. The experimental plot was divided into 30 subplots each measuring 35.25 by 3m with buffer zones left between each subplot. Each subplot had five rows with 48 hills in each row and two plants per hill giving a total of 480 plants per subplot. Buffer zones had two rows with 48 hills in each row and two plants per hill giving a total of 192 plants per buffer zone. Maize grown subplots were subjected to three different treatments (A, B and C). Treatments A and B were treated with Bulldock® 262.5 EC (*Beta cyfluthrin*) and Dimethoate 40 EC respectively. Treatment C was not treated with any insecticide and served as a control. This layout design took care of differences associated with both experimental and replication errors.

Study design and insecticide treatment

The stem borer pesticide, Bulldock® 262.5 EC, was mixed with water at a ratio of 2ml/litre and sprayed onto pre-selected subplots to exclude stem borers from maize plants. Bulldock® is a synthetic pyrethroid, acting through contact and as stomach poison. Dimethoate 40 EC, was mixed with water at a ratio of 2ml/litre and applied to exclude parasitoids in pre-selected subplots. Dimethoate is a selective organophosphate compound with both systemic and contact action. The first Bulldock spraying was done three weeks after germination and two subsequent applications were done after every three weeks. The first dimethoate application was done six weeks after germination and two subsequent applications done after every three weeks.

Sampling protocol

Estimation of stem borer infestation, densities and parasitism was done at three different maize growth stages. Stem borer larvae were also collected from maize cobs during harvest. During each sampling session, all plants in each treatment subplots were inspected for stem borer infestation. The number of infested plants were expressed as a percentage of the

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total plants inspected in respective subplots to compute percentage infestation. In each treatment subplot, five infested plants were dissected and all immature stem borer stages collected, identified and categorized (as small {1st and 2nd instars}, medium, {3rd and 4th instars} and large {5th instars}). Identified larvae were placed individually in glass vials containing artificial diet (Onyango and Ochieng-Odero, 1994) and transported to the laboratory at *icipe* where they were reared at ambient temperatures of 24-25°C and relative humidity of 55-65%, with a 12:12 light: dark photoperiod. Samples were inspected daily for parasitoid cocoons, pupal development, pupal parasitoid and adult moth emergence. Pupae were transferred into plastic jars lined with wet paper towels. Humidity in the jars was maintained by moistening the soft paper towels once every 2 days using a few drops of distilled water. Larval parasitoids and adult stem borer moths were identified and recorded. At the end of the experiment maize was harvested, cobs dried for one week, shelled and weighed (kg).

Statistical analyses

Data on percentage infestation, stem borer density, stem borer parasitism and yield (kg) from individual subplots were pooled in respective treatments and used as replicates during analysis. Percentage infestation, stem borer density and stem borer parasitism were also estimated at three maize growth stages; vegetative, early maturity and mature stages. Before analysis, aforementioned parameters were tested for normality using Shapiro-Wilk's test. Percentage infestation and yield data were normal. Percentage stem borer parasitism was arcsine transformed while larval density was square root transformed. Two-way Analysis of Variance (ANOVA) was used to compare variations in stem borer pest infestations and maize yield among the three maize growth stages in the three insecticide treatments. Tukey's pairwise comparison test was performed to separate means where treatments were found to be significantly different ($p<0.05$). Two-way ANOVA was used to assess the effect of interaction between maize stage and treatment on the maize yield. Generalized Linear Model (GLM) was used to find stages of infestation and parasitism that significantly affected yield. Stem borer parasitism was subjected to Friedman rank sum test to compare the means. Wilcoxon test was used to compare means between *Chilo spp* and *S. calamistis* parasitism.

III. RESULTS

Stem borer species composition and abundance

A total of 632 immature stem borers (larvae (622) and pupae (10) were collected during the experiment. Majority of immature stem borers (71.5%) were collected during the vegetative stage, followed by early maturity (23.7%) and mature stage (4.7%). However, sizes of sampled stem borers varied among maize growth stages (Table 1). At vegetative stage, 34, 50 and 16% of collected immatures could be grouped as small, medium and large respectively. Similar variations were observed at early maturity in which 20, 19 and 61% of collected immatures were categorised as small, medium and large respectively, while at mature stage, 18, 9 and 73% of total collection constituted small, medium and large stages respectively (Table 1). Immature stem borers were found on different maize plant parts during sampling. At vegetative stage, 74 and 26% of total collection were found on stems and tassels respectively contrary to what was observed at early maturity in which 84% of the total collection were found on stems and 16% on the cobs. At maturity, immature stem borers were found on cobs (54%) and stems (46%) (Table 1).

On rearing, three stem borer species, *C. partellus*, *C. orichalcociliellus* and *S. calamistis* were identified from collected immature stages. *Chilo partellus* constituted 43, 52 and 25% while *C. orichalcociliellus* constituted 30, 35 and 8% of the total collections during the vegetative, early maturity and mature maize growth stages respectively. *Sesamia calamistis* constituted 27, 14 and 67% of all stem borers collected at vegetative, early maturity and mature maize stages respectively (Table 1).

TABLE 1: Percentage (%) stem borer stages, plant parts and community composition at different maize growth stages

	Vegetative	Early maturity	Mature
	Stem borer size (%)		
Small	33.9	20.0	18.2
Medium	50.7	19.2	9.1
Large	15.5	60.8	72.7
	Plant part (%)		
Tassel	25.9	0.0	0.0
Stem	74.1	84.1	46.2
Cob	0.0	15.9	53.8

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	Community composition (%)		
C. partellus	43.1	51.7	25.0
C. orichalcociliellus	29.7	34.5	8.3
S. calamistis	27.2	13.8	66.7

Stem borer infestation levels

Stem borer infestation levels varied among treatments (A, B and C) during the study ($F_{2,87}$ = 6.92; p<0.05 (Table 2). Infestation was significantly low in treatment A (1.4±0.2%) compared to treatments B (2.4±0.2%) and C (2.2±0.2%). In addition to treatment differences, there was evidence that infestation levels varied with maize growth stages ($F_{2,87}$= 11.07; p<0.001). Infestation was significantly higher at vegetative stage (2.7±0.5%) compared to early maturity (1.9±0.3%) and mature maize stages (1.5±0.3%) (Table 2).

TABLE 2: Overall stem borer infestation across treatments and maize growth stages

Overall infestation ($\bar{x} \pm SE$)			
Treatment		**Crop stage**	
A	1.4 ± 0.2^{b}	Vegetative	2.7 ± 0.5^{a}
B	2.4 ± 0.2^{a}	Early maturity	1.9 ± 0.3^{b}
C	2.2 ± 0.2^{a}	Mature	1.5 ± 0.3^{b}
$F_{2,87}$	6.92	$F_{2,87}$	11.07
p value	0.00162**	p value	$5.208e^{-05***}$

Mean (± *SE*) within columns followed by the same lower case superscripts respectively are not significantly different (p>0.05)

Interaction between maize stage sampled and treatment had a significant effect on infestation ($F_{2,81}$ = 3.383; p = 0.013). At the vegetative stage, mean stem borer infestation levels varied among treatments ($F_{2,27}$=7.04; p<0.05). Infestation was relatively high in both treatment B (3.1±1.5%) and C (3.3 0.6%) which were not significantly different, but significantly higher than in treatment A (1.6±0.9%) (Table 3). Mean infestation levels by the pest during early maturity also varied among treatments ($F_{2,27}$=5.4; p<0.05). Infestation was significantly higher in treatment B (2.6±1.0%) compared to treatments A (1.2±1.1%) and C (1.8±0.7%), which were not significantly different. Mean stem borer infestation levels on maize at mature stage did not vary among treatments ($F_{2,27}$=0.2; p>0.05).

Mean stem borer infestation in treatment A did not vary across maize growth stages ($F_{2,27}$ = 0.403; p>0.05). Contrary to this, in treatment B and C, stem borer infestation varied significantly ($F_{2,27}$=5.962; p<0.05 and $F_{2,27}$=28.21; p<0.05 respectively) (Table 3).

TABLE 3: Mean stem borer infestation among treatments at different maize growth stages

Mean infestation ($\bar{x} \pm SE$)				**Statistics**	
	Vegetative	Early maturity	Mature	F value	p value
A	1.6 ± 0.3^{bA}	1.24 ± 0.3^{bA}	1.4 ± 0.2^{aA}	0.403	0.672
B	3.1 ± 0.5^{aB}	2.6 ± 0.3^{aAB}	1.4 ± 0.2^{aA}	5.962	0.007**
C	3.3 ± 0.2^{aB}	1.8 ± 0.2^{bA}	1.6 ± 0.1^{aA}	28.21	$2.436e^{-07***}$
$F_{2,87}$	7.04	5.4	0.21		
p value	0.003**	0.011*	0.82		

Mean (± *SE*) within columns and rows followed by the same lower case and upper case superscripts respectively are not significantly different (p>0.05).

Parasitoid species composition and abundance

A total of 98 cocoon masses were recovered from parasitized stem borers during the experiment. Emerging parasitoids were identified as *C. flavipes* and *C. sesamiae*. *Cotesia flavipes* was the most abundant parasitoid species constituting 90.43 and 94.89% of parasitoids collected during the vegetative and early maturity plant growth stages respectively (Table 4). No parasitoids were recovered from stem borer larvae sampled on mature maize plants despite the presence of parasitized larvae and parasitoid cocoons, as depicted in mean parasitism. Parasitoids were recovered from all three stem borer species.

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TABLE 4: Abundance and percentage composition of parasitoid community at different maize growth stages

Parasitoid species	% Composition (*n*)		
	Vegetative	Early maturity	Mature
Cotesia flavipes	90.4 (1342)	94.9 (446)	0
Cotesia sesamiae	9.6 (142)	5.1 (24)	0

Stem borer pest parasitism

Mean stem borer pest parasitism in treatment A, B and C were 16.2±7.4, 20.9±4.9 and 20.7±6.9% respectively (Table 5). Pest parasitism levels did not vary among treatments (C_2^2=3.558; p>0.05). However, there was evidence of variation in pest parasitism levels among different maize growth stages (C_2^2=21.6; p<0.05). Significantly higher parasitism was recorded in both vegetative (22.4±5.2%) and early maturity stage (34.6±8.9%) compared to mature maize (0.8±0.8%) (Table 5).

TABLE 5: Mean stem borer parasitism $(\bar{x} \pm SE)$ among treatments in different maize growth stages

Treatment	Parasitism (%)	Maize stage	Parasitism (%)
A	16.2±7.4^a	Vegetative	22.4±5.2^a
B	20.9±4.9^a	Early maturity	34.6±8.9^a
C	20.7±6.9^a	Mature	00.8±0.8^b
C_2^2 value	3.558	C_2^2 value	21.6
df	2	*df*	2
p value	0.169	*p* value	2.05E-05

Mean (± *SE*) within columns and rows followed by the same lower case superscripts are not significantly different (p>0.05).

At the vegetative stage, mean parasitism did not vary among treatments (C_2^2=3.84; p>0.05). Parasitism was relatively high in treatment C (35.5±13.7%) compared to A (13.2±4.4%) and B (18.5±4.8%) (Table 6). Mean parasitism during early maturity stage varied among treatments (C_2^2=6.22; p<0.05). Parasitism was significantly higher in treatment B (41.5±11.25%) compared to treatment A (35.5 ± 20.8%) and C (26.67±13.9%). Mean parasitism at mature stage did not vary among treatments (C_2^2 = 2; p>0.05) (Table 6).

TABLE 6: Mean stem borer parasitism in different insecticide treatments at various maize growth stages

Mean parasitism (%)				Statistics	
Treatment	Vegetative	Early maturity	Mature	*F*	*p* value
A	13.2±4.4^a	35.5±20.8^b	0.0 ± 0.0^a	7.69	0.021
B	18.5±4.8^a	41.5±11.3^a	7.9±2.5^a	10.764	0.0046**
C	35.5±13.7^a	26.7±13.9^b	0.0 ± 0.0^a	10.137	0.0063**
Friedman χ^2	3.84	6.22	2		
p value	0.147	0.045*	0.368		

Mean (± *SE*) within columns and rows followed by the same lower case superscripts are not significantly different (p>0.05) (Tukey's/Friedman's rank sum test).

Maize yield

A total of 513.7kg of shelled dry maize was harvested from the experimental plot. On average, 20.8±2.1, 24.1±2.0 and 20.5±1.6kg were harvested from treatments A, B and C respectively. Statistical comparison did not reveal any significant difference in mean yield among treatments ($F_{2,27}$=1.148; p>0.05). Further analysis showed that stem borer density at early maturity stage had the greatest negative impact on maize yield (b=1.131; t=2.639; p>0.05). However, there was no evidence of impact of larval density at vegetative (b=0.062; t = 0.368; p>0.05) and mature stage (b=0.086; t=1.201; p>0.05) on yield (Table 7). Like larval density, stem borer infestation level at early maturity had the greatest impact on maize yield (b=2.185; t=2.363; p<0.05). However, this was not consistent at vegetative (b=-0.624; t =-0.849; p>0.05) and

mature stage (b=1.358; t=1.017; p>0.3186). Stem borer parasitism at early maturity had the greatest effect on maize yield (b=0.093; t=3.207; p<0.05). This however was not consistent for vegetative (b=0.059; t=0.702; p>0.05) and mature stages (b=0.037; t=1.357; p>0.05).

TABLE 7: Effect of stem borer larval density, infestation and parasitism on maize yield

Maize stage	Estimate	Std. Error	t value	Pr(>|t|)
Stem borer larval density				
Intercept	17.81432	1.71219	10.404	9.23e-11 ***
Vegetative	0.06221	0.16905	0.368	0.7158
Early maturity	1.13143	0.42875	2.639	0.0139*
Mature	0.86365	0.71904	1.201	0.2405
% infestation				
Intercept	15.7426	3.6103	4.361	0.000182***
Vegetative	-0.9853	0.9835	-1.002	0.325699
Early maturity	2.9848	1.2371	2.413	0.02318*
Mature	2.1402	1.7872	1.198	0.241907
% parasitism				
Intercept	18.0495	1.56297	11.548	9.77e-12 ***
Vegetative	0.08436	0.11212	0.752	0.45859
Early maturity	0.12226	0.03891	3.142	0.00415**
Mature	0.0565	0.0362	1.561	0.13069

IV. DISCUSSION

This study confirmed the presence of three stem borer pest species (*C. partellus*, *C. orichalcociliellus* and *S. calamistis*) in moist lowland AEZ corroborating findings by Mathez (1972), Seshu Reddy (1983), Overholt *et al*. (1994), Bonhof (2000) and Rwomushana *et al*. (2005). Among the three species, *C. partellus* (43.2%) was the most abundant followed by *C. orichalcociliellus* (29.2%) and *S. calamistis* (27.6%). Even though this study was conducted under controlled field conditions, similar patterns of community composition were reported by Bonhof (2000) and Midega *et al*. (2004).

Generally, infestation levels recorded were lower than levels reported in the mid-1990's. Low infestation was however not consistent among the treatments. Relatively low infestation was observed in Bulldock treated subplots suggesting that the insecticide killed majority of first instar larvae. Initial Bulldock spraying was done three weeks after germination of maize plants to coincide with oviposition period. Being a contact and stomach poison, first instar larvae were killed by insecticide action upon emergence thereby successfully suppressing the 1st generation of stem borer population.

The first application of dimethoate five weeks after germination coincided with the presence of stem borer larval stages that are suitable for parasitization. Treatment with dimethoate was anticipated to suppress parasitoid action, while leaving stem borer infestation level unchanged. This explained why there was a very subtle difference in stem borer infestation levels observed in treatments B and C, where natural stem borer infestations and parasitoid action were not manipulated. Treatment B plots exhibited higher infestation level compared to treatments A and C, this was a direct effect of increased oviposition by stem borers. Similar results were documented by Kinzer *et al*. (1977) who showed an increase in lepidoptera that oviposited on maize crop as a result of spraying with dimethoate. In listing various possible limitations of insecticidal exclusion method DeBach (1946) stated that "Residues nontoxic to the host but toxic to its natural enemies may, entirely aside from the elimination of the natural enemies make conditions more favourable for host population increase". The above observed stem borer infestations was not consistent across maize growth stages in all treatments. High infestation levels observed during the vegetative stage was attributed to diaspore population that formed the first generation in the season. This initial population was assumed to have had limited natural enemies that suppressed their numbers unlike subsequent maize growth stages where parasitoids affected pest populations.

Natural enemies identified in this maize ecosystem included the larval parasitoids, *C. flavipes* and *C. sesamiae*. *Cotesia flavipes* dominated the parasitoid community, an observation attributed to the dominance of pest community by its old association host, *C. partellus*. *Cotesia flavipes* has been introduced into more than 40 countries in the tropics and subtropics for biological control of *Chilo sp*. (Polaszek and Walker, 1991). However, host suitability studies have indicated that *C. flavipes* has expanded its host range to include indigenous species (Ngi-Song *et al*., 1995; Overholt, *et al*., 1997; Zhou *et al*, 2003) findings that are upheld in this study. *Cotesia flavipes* was recovered from *C. partellus* and

the indigenous *C. orichalcociliellus* and *S. calamistis.* The ability of *C. flavipes* to parasitize three stem borer species is essential for success of the biological control programme. Use of a highly specific parasitoid that attacked only *C. partellus* would have probably had no effect on overall stem borer population. Suppression of *C. partellus* could have resulted in an ecological void that could have been filled by indigenous species (Overholt *et al*., 1994). Similar to *C. flavipes*, *C. sesamiae*, a native, gregarious larval endoparasitoid which fills an ecologically similar niche (Polaszek and Walker, 1991) was also recovered from *C. partellus*, *C. orichalcociliellus* and *S. calamistis* during the experiment. However, it was recovered at lower proportions and thus it would not be an important mortality factor. This finding emphasized on reports that *C. sesamiae* is an inferior competitor to *C. flavipes* on *C. partellus* (Mbapila and Overholt, 2001; Ngi-Song *et al*., 2001; Sallam *et al*., 2002).

Parasitism is a numerical response of parasitoids to host populations. Percentage parasitism is estimated from the number of parasitized hosts expressed as a percentage of the total hosts (of suitable developmental stage) collected in respective treatments. In addition to the presence of suitable hosts, parasitoids select only the suitable host stages (Russell, 1987). Though infestation was relatively high at vegetative stage across all treatments, majority of the larvae were in the 1st and 2nd instar and were unsuitable for parasitization. To the contrary, majority of larvae collected during early maturity were in the 3rd, 4th and 5th instars of their development thus highest parasitism was exhibited at this stage of maize growth. Observed differences in larval instars among maize stages explained the observed variations in parasitism levels. Low percentage parasitism observed in treatment A was as a result of suppression of the pest (and thus host) population. Higher parasitism in dimethoate-treated subplots resulted from numerical response to increased stem borer population.

Levels of infestation and parasitism at early maturity stage of maize growth had the greatest impact on maize yield as they induced compensation and reduced stem borer population respectively. Stem borer attack on mature maize has been known to result in less devastating damage (Seshu Reddy, 1988; Youdeowi, 1989; Bosque-Perez and Mareck, 1991) and grain yield loss inspite of the larval density (Reddy and Sum, 1991). Contrary to variations in infestation and parasitism, there was no difference in mean maize yield among treatments.

V. CONCLUSION

Levels of parasitism by *C. flavipes* on stem borers at the Kenyan coast have exhibited a steady rise but are still low compared to what is observed in the pest's native range. In India, 80% parasitism by *C. flavipes* is observed in maize (Singh *et al.*, 1975) with 0-43% being recorded in maize-sorghum intercrops (Subba Rao *et al*., 1969). The rising parasitoid action has not translated into maize yield increment. This is because of the *modus operandi* of the parasitoid. The parasitoid attacks late instars of the stem borer pest and thus interruption occurs when the pest is already at an advanced stage of causing damage. Optimum yield may be realised when biological control involving both egg and larval parasitoids is used since egg parasitoids would curb stem borer pest development into the most destructive larval stage.

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