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## **Functional Responses of *Cheilomenes propingua*, *C. lunata* and *C. sulphurea* (Coleoptera: Coccinellidae) to Predation on *Aphis gossypii* (Homoptera: Aphididae) in Eastern Tanzania**

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### **ABSTRACT**

Functional response is one of factors to know before considering use of predators in biocontrol programme. A study to determine type of functional responses of *Cheilomenes propingua*, *Cheilomenes lunata* and *Cheilomenes sulphurea* (predators) at different *Aphis gossypii* (prey) densities (i.e., 25, 50, 100, 200, 300, 400 and 500) were investigated in the laboratory using petri-dishes in ten replicates. Mean number of prey consumed were plotted against the initial density supplied which showed Type II Functional response to all three predators. The result was confirmed by using logistic regression model which showed negative linear parameter. The linear reciprocal transformation of the Holling's disc equation was used to determine handling time ( $T_h$ ) and search rate ('a'). The handling times 0.171, 0.196, 0.240 h for the females *C. lunata*, *C. sulphurea* and *C. propingua*, respectively were obtained of which were generally lower than that of the male coccinellids 0.217, 0.220 and 0.270 h. Female search rates were estimated as 1,258, 1,277 and 1,404 and males 1,312, 1,360, 1,489 for *C. lunata*, *C. sulphurea* and *C. propingua*, respectively. The above results indicate higher predation aggressiveness of females as compared to the males. Handling times for *C. lunata* and *C. sulphurea* females and males were lowest when compared to *C. propingua* suggesting to be more efficient in aphid consumption than *C. propingua*. It is concluded that the three coccinellid predators have type II Functional response and also *C. lunata* and *C. sulphurea* have a greater potential of eating aphids than *C. propingua*. Field studies are required to explore their potential under natural conditions.

**Key words:** Functional response, *Cheilomenes sulphurea*, *Cheilomenes lunata*, *Cheilomenes propingua*, *Aphis gossypii*

### **INTRODUCTION**

Cotton aphid, *Aphis gossypii* (Glover), is one of the most devastating insect pests of cotton in Eastern Cotton Growing Area (ECGA) of Tanzania (Kabissa, 1993; Nghoma, 1998; Mrosso and Kabissa, 2000). Control of aphids is mainly achieved by repeated application of insecticides (Jafari and Goldasteh, 2009). Organophosphates, carbamates and acetamiprid are the most common aphicides recommended for the effective control of cotton aphids (Treen, 1982). However, since 2004 Imidacloprid based insecticides have been shown to have very good efficacy in the control of the aphids (F.P.M., Unpublished data). Despite of being inefficient, pyrethroid based insecticides are being used continuously by cotton farmers in Tanzania because they are comparatively cheaper. The application of pyrethroids is often associated with irregular timing,

improper dosage and poor application techniques which might lead to reduced control of aphids and could also affect populations of natural enemies (Chimoga, 2002). In order continue conserving the natural enemies of cotton aphids, there should be an alternative or parallel management strategy.

Biological control could offer an alternative option for the control of aphids. Studies by Khan and Suhail (2001) revealed that ladybirds are the potential predators for controlling aphids in cotton fields.

The efficacy of a predator is one of the essential factors to be investigated before implementation of any biological control programme (Jafari and Goldasteh, 2009). One of the components of predator efficiency is the type of functional response which varies according to species (Pervez and Omkar, 2005). The reaction of a predator to a density of a prey is reflected in functional response types (Isikber, 2004). Ecologists and entomologists delimit 3 major types of functional response when the number of prey killed is plotted against the number of prey available (Isikber, 2004; Hassell *et al.*, 1977; Pervez and Omkar, 2005). Functional response can determine if the predator is capable of regulating a certain population of prey or not (Livdahl and Stiven, 1983). A linear relationship between prey density and the number of prey killed is considered to be Type I functional response (Holling 1959, 1966). Type II Functional response is curvilinear and the saturation level is gradually reached (Jafari and Goldasteh, 2009). Hassell (1978) and many authors considered Type III having sigmoid structure to be the most efficient relationship between pest and natural enemy. Functional response models can determine search rate ('a') which is a rate of the predator to search a prey and handling time ( $T_h$ ) which is the time a prey and predator exposed together. Isikber (2004) pointed out that coccinellids show Type II functional response. However, according to Hassell *et al.* (1977) not all coccinellids show type II functional response. In this study investigation was carried out on the Functional responses of three species of aphidophagus coccinellids of the genus *Cheilomenes*, namely *Cheilomenes lunata*, *Cheilomenes sulphurea* and *Cheilomenes propingua* to their prey, *Aphis gossypii* in cotton crop in eastern Tanzania.

## **MATERIALS AND METHODS**

**Cultures of coccinellids and aphids:** Cotton (Variety Mkombozi) was planted in 2 L by volume plastic containers filled with loamy soil, placed in 50×50×50 cm cages and watered manually (Sapkota, 2004). When plants germinated and were three weeks old, they were infested with cotton aphids collected from cotton fields free from insecticide sprays. Initial population of coccinellids was obtained from the same unsprayed cotton field and introduced on the cotton plants in the cages at a sex ratio of 1:1. Each of the three species had two cages making a total of six cages. The coccinellids ate aphids in the cages which were the sole source of food. Moisturized filter papers were placed inside the cages for egg laying (Pervez and Omkar, 2005).

**Functional response:** Functional response studies were conducted from February to August 2011 in an insectary at Ilonga Agricultural Research Institute (IARI), (520 m.a.s.l.) (S 06°46': E 037° 02') at ambient temperature (range 23.8±0.21 to 28.2±0.28°C) and humidity (range 81.7±1.49 to 87.1±0.94 % RH). The coccinellid eggs laid on the moisturized filter paper were removed and reared individually from egg hatch to adult enclosed in petri dishes (9 cm diameter and 1.5 cm height) (63.6 cm<sup>2</sup>) on apterae aphid prey until they were 10 days old adults (Isikber, 2004). The adults with known sex were introduced individually in fresh petri dishes and left to starve for 24 h (Pervez and Omkar, 2005) to standardize their appetite. Different densities of mature apterae aphids (25, 50, 100, 200, 300, 400 and 500), were introduced in separate petri dishes with ten replications (Timms *et al.*, 2008; Pervez and Omkar, 2005).

After 24 h, the numbers of aphids eaten by the individual coccinellid adults were recorded daily by counting remaining aphids in each petri dish. The mean number of aphids consumed by coccinellids was calculated at each density level. To obtain body sizes of the coccinellids, a sample of twenty adults of each sex and species were killed using anaesthetic ether, left to dry for one month in the laboratory then the width and length of individual insects were measured using caliper.

**Data analysis:** Mean numbers of prey consumed per day ( $H_a$ ) were plotted against the initial prey density supplied ( $H$ ) and shapes of curves were estimated using 2007 Microsoft Excel Programme. After plotting this graph, the functional response type was determined.

Estimated parameters (search rates ('a')) for male and female *Cheilomenes* spp were derived from the type II Hollings disc equation modified by reciprocal linear transformation (Saleh *et al.*, 2010) equation using *Aphis gossypii* as prey. ANOVA was done by using SAS Institute, 1999 Software.

Since it is difficult to distinguish critically between type II and type III shapes of functional responses, a logistic regression model was used (Eq. 1) before fitting the data to a particular Hollings equation (Jafari and Goldasteh, 2009). The logistic regression model is frequently used by Ecologists and entomologists to confirm the shape and type of functional response of a predator against a prey by taking the proportion of prey consumed ( $H_a / H$ ) as function of initial prey density supplied (Eq. 1) (Juliano, 2001):

$$H_a/H = (\exp (q_0+q_1H+q_2H^2+q_3H^3))/(1+\exp (q_0+q_1H+q_2H^2+q_3H^3)) \quad (1)$$

where,  $q_0, q_1, q_2, q_3$  are the intercepts, linear, quadratic and cubic coefficients, respectively. These were estimated using maximum likelihood with PROC LOGISTIC software (SAS Institute, 1999). If  $q_1 < 0$ , it means the proportion of prey consumed declines monotonically with the initial number of prey density supplied, this trend reflects type II Functional response and if  $q_1 > 0$  and  $q_2 < 0$ , it means the prey eaten is positively density dependent thus reflecting type III Functional response (Juliano, 2001).

After establishing the type of Functional response and shape of the curve, the handling time ( $T_h$ ) and search rate ('a') coefficients of type II Functional response were determined using Hollings disc (Eq. 2) modified by reciprocal linear transformation (Livdahl and Stiven, 1983) Eq. 3 which is inform of Eq. 4 (linear) as follows:

$$[(H)]_a = \frac{a.H.T}{1+a.H.T_h} \quad (2)$$

$$= \left( \frac{1}{H_a} \frac{1}{a} * \frac{1}{H.T} + \frac{T_h}{T} \right) \quad (3)$$

$$= y = ax + \beta \quad (4)$$

Equation 2-4, where  $H_a$  is the number of prey consumed by the predator,  $H$  is the initial prey density, 'a' is the search rate,  $T$  is the time of a predator and prey exposed together, in this case  $T$

is one day (24 h),  $T_h$  is handling time for each prey eaten. The parameters were obtained by plotting  $\frac{1}{H_a}$  against  $\frac{1}{H.T}$ . Differences in body sizes were subjected to t test.

**RESULTS**

The Functional response curves show that *C. lunata* was the most vigorous predatory species in consuming aphid followed by *C. sulphurea* and *C. propingua* for both males (Fig. 1) and females (Fig. 2). At lower densities female and male responses were almost similar. Every tested species revealed decline in consumption rate at higher densities which corresponds to type II Functional response (Pervez and Omkar, 2005).

The logistic regression revealed negative linear parameter ( $q_1 < 1$ ) (Table 1) in all three coccinellids (*Cheilomenes propingua*, *C. lunata* and *C. sulphurea*). The obtained linear parameters for females and males are: -0.00764 (*C. propingua*), -0.00473 (*C. lunata*), -0.00623 (*C. sulphurea*) and -0.0100 (*C. propingua*), -0.00733 (*C. lunata*), -0.00727 (*C. sulphurea*), respectively. The negative signs of the above linear parameters reflects Type II functional response (Juliano, 2001; Jafari and Goldasteh, 2009). The proportion of prey eaten declined at high densities of prey for both males (Fig. 1) and females (Fig. 2) of the three species tested which is also a characteristic of Type II Functional response.

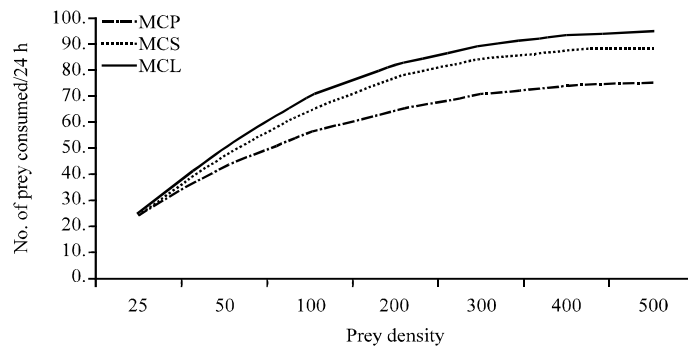


Fig. 1: Functional response Type II of male *Cheilomenes propingua* (MCP), *C. lunata* (MCL) and *C. sulphurea* (MCS) at different densities of *A. gossypii*

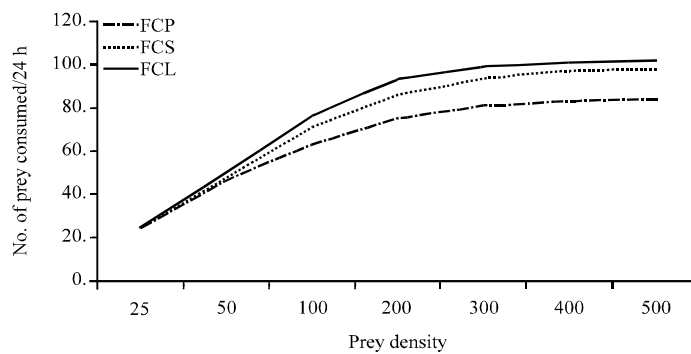


Fig. 2: Functional response Type II of female *Cheilomenes propingua* (FCP), *C. lunata* (FCL) and *C. sulphurea* (FCS) at different densities of *A. gossypii*

Table 1: Parameter estimates for logistic regressions of the proportion of prey eaten ( $H_a$ ) against the number of prey supplied (H) for *Cheilomenes propingua*, *C. lunata* and *C. sulphurea* in 24 h

Parameter	Female			Male		
	<i>C. propingua</i>	<i>C. lunata</i>	<i>C. sulphurea</i>	<i>C. propingua</i>	<i>C. lunata</i>	<i>C. sulphurea</i>
Intercept ( $q_0$ )	-1.97420	-2.0348	-2.0261	-0.19679	-1.9577	-2.0174
Linear ( $q_1$ )	-0.00764	-0.00473	-0.00623	-0.0100	-0.00733	-0.00727
Quadratic ( $q_2$ )	8.001EE-6	-2.23E-6	5.242E-6	1.869E-6	8.74E-6	7.997E-6
Cubic ( $q_3$ )	-2.06E-9	8.898E-9	-5.72E-12	6.306E-9	-2.81E-9	-2.78E-9
$r^2$	0.9500	0.82000	0.97000	0.92000	0.97000	0.97000

$r^2$  denotes regression value

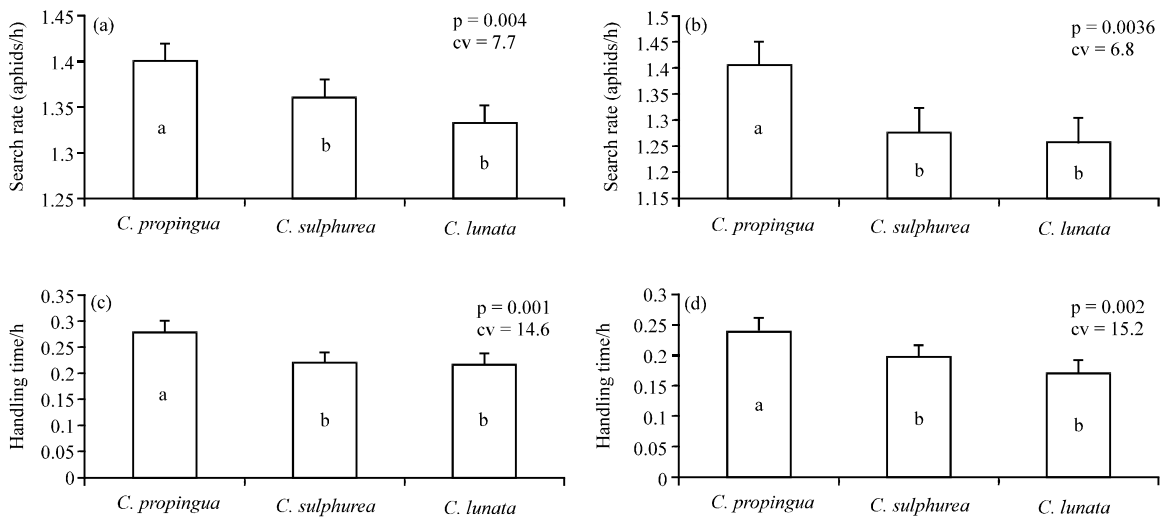


Fig. 3(a-d): Search rates of male *Cheilomenes* spp. and female *Cheilomenes* spp. (c-d): Handling time of M.C and F.C derived from the type II Hollings disc equation modified by reciprocal linear transformation. In the graph bars with the same letter are not significantly different

Male and female Search rate (a) coefficients of the three predatory species are presented in Fig. 3a and b, respectively. Search rates did not differ significantly between species except for *C. propingua* female and male which were the highest ( $p < 0.01$ ). The predatory coccinellid *C. lunata* and *C. sulphurea* males and females (Fig. 3a, b) were found to have similar search rates.

Handling times ( $T_h$ ) for the males and female coccinellids are presented in Fig. 3 and d, respectively. Handling times for the females were generally lower than that of males (Fig. 3c, d). There were significant differences ( $p < 0.01$ ) between *Cheilomenes propingua* males handling time (0.279 h) and that of *C. sulphurea* (0.220 h) and *C. lunata* (0.2170 h). Likewise the females handling time for *C. propingua* (0.240 h) was significantly higher ( $p = 0.0002$ ) than that for females of *C. sulphurea* (0.196 h) and that for *C. lunata* (0.171 h). The handling times of *C. sulphurea* and *C. lunata* in both sexes did not differ significantly ( $p > 0.05$ ) between species (Fig. 3c, d).

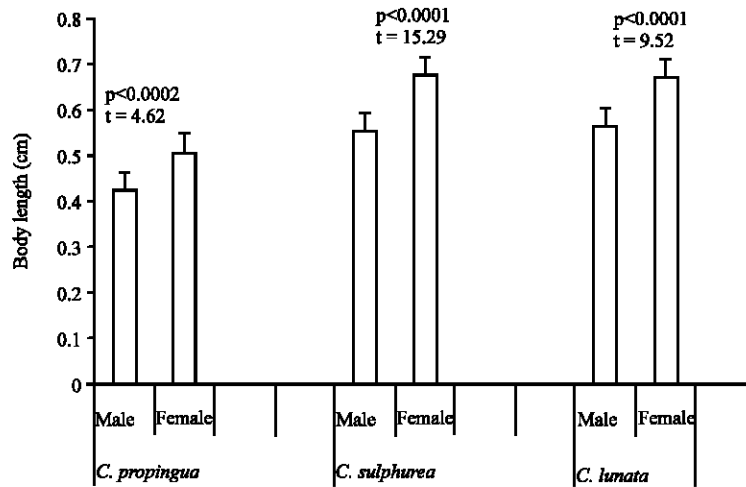


Fig. 4: Body size (length, cm) comparisons between males and females of predatory coccinellids, *Cheilomenes propingua*, *C. sulphurea* and *C. lunata*

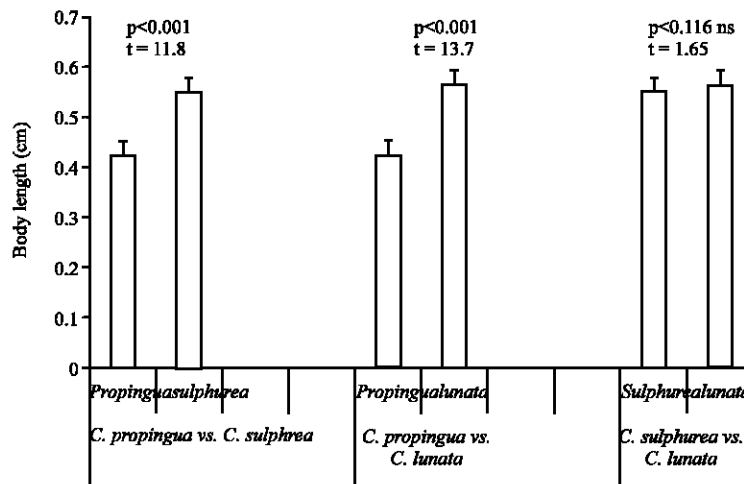


Fig. 5: Male body size (length, cm) comparisons of *Cheilomenes propingua*, *C. sulphurea* and *C. lunata*

Body lengths of *Cheilomenes lunata* (0.565±0.008 cm) males and females (0.668±0.006 cm) didn't differ significantly ( $p > 0.05$ ) with that of *C. sulphurea* (0.551±0.006 cm) males (Fig. 4) and females (0.675±0.006 cm) (Fig. 4) ( $p = 0.116$ ,  $t = 1.65$  and  $p = 0.455$ ,  $t = 0.76$  for males and females, respectively). Both Male (Fig. 5) and female (Fig. 6) *Cheilomenes lunata* and *C. sulphurea* body lengths were similar but significantly larger than that of *C. propingua* ( $p < 0.0001$ ); this trend suggests that *C. lunata* and *C. sulphurea* have similar prey consumption rate but higher than that of *C. propingua* probably because of their small body sizes. Similar findings were obtained by Sabaghi *et al.* (2011) from *Scymnus syriacus* (Coleoptera: Coccinellidae) studies on functional response. Females in all three species were found to have significantly larger body lengths than the males ( $p < 0.0001$ ) (Fig. 4) indicating high vigorousness for the females in reducing populations of *Aphis gossypii*.

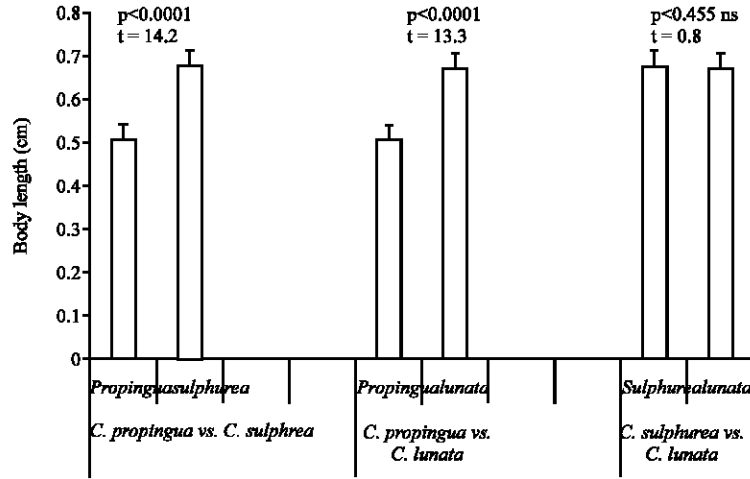


Fig. 6: Female body size (length, mm) comparisons between *Cheilomenes propingua*, *C. sulphurea* and *C. lunata*

## DISCUSSION

Figure 1 shows the estimated functional response (Type II) curves for males of the three predatory coccinellids, *Cheilomenes propingua*, *C. lunata* and *C. sulphurea*. The proportion of prey eaten in all predators declined monotonically with increasing number of prey supplied, this is sufficient to justify a Type II functional response (Isikber, 2004). *Cheilomenes lunata* male curve has the highest elevated curve followed by *C. Sulphurea* and *C. propingua*, which suggests that *C. lunata* is more vigorous in consuming the prey followed by *C. Sulphurea* and *C. Propingua*. This is supported by Pervez and Omkar (2005) and Sabaghi *et al.* (2011) that the higher the elevation of Functional response curves the more vigorous the predator. A similar trend was observed for the females (Fig. 2). The point of maximum consumption of aphids by the predatory coccinellids is shown by the asymptotes in the curves Fig. 1 for males and Fig. 2 for females with *C. lunata* having the highest asymptote followed by *C. sulphurea* and *C. propingua* of which imply their potential in reducing the prey populations.

The logistic regression analyses performed in this study revealed negative linear parameter ( $q_1 < 0$ ) for all three aphidophagous predators tested (Table 1). These results confirm type II Functional responses for the three predatory coccinellids and is consistent with previous findings by Pervez and Omkar (2005) that it is rare to get a type II Functional response with a positive linear term. Similar observations were made by Saleh *et al.* (2010). The type II Functional response is characterized by having a curve which rises negatively and accelerated to attain plateau when the number of prey eaten is plotted against the initial prey density (Fernandez-Arhex and Corley, 2003; Saleh *et al.*, 2010; Isikber, 2004) (Fig.1-2). This implies that *C. propingua*, *C. lunata* and *C. sulphurea* are capable of reducing the cotton aphids more effectively at low than at high densities due to satiation. Similar results were obtained by Isikber (2004) on *Scymnus levaillanti* and *Cycloneda sanguinea* predatory coccinellids against the prey, *Aphis gossypii*. Hughes *et al.* (1992) pointed out that predators exhibiting type II Functional response have been successfully established and managed prey populations. This study shows that the three predatory coccinellid (*C. propingua*, *C. lunata* and *C. sulphurea*) can be used solely or as a component within strategic programmes for management of *A. gossypii* in the Eastern Cotton Growing Areas of Tanzania.



However, since *C. propingua* functional response curve has the lowest elevation, probably attributed to its small body size for both males (Fig. 5) and females (Fig. 6), it would not be the best choice compared to the *C. lunata* and *C. sulphurea*.

The coefficients of search rate ('a') did not differ significantly except for *C. propingua* females which was the highest, this indicates that the 'a' is least affected in change of predator species (Fig. 3a, b). A similar trend has been reported in *Cheilomenes sexmaculata* preying on *Aphis craccivora* (Pervez and Omkar, 2005). The handling times varied significantly both between sex and species with females showing generally shorter handling times, suggesting being more vigorous than the males. Females have larger body sizes (Fig. 4) than the males and therefore it could influence their handling time. Atlihan and Guldal, 2009 reported similar results in *Scymnus subvillosus* preying on mealy plum aphid *Hyalopterus pruni* and *Cosmoclopius nigoannulatus* preying on *Spartocera dentiventris nymphae* (Da Rocha and Redaelli, 2004). *Cheilomenes lunata* and *C. sulphurea* males and females had significantly shorter handling time ( $p < 0.001$ ) than *C. propingua* (Fig. 3c, d), indicating they were able to consume more aphids. Females take shorter time in chasing, catching, subduing and ingesting the prey, thus are able to consume more prey within shorter time than the males. This therefore suggests that they are ideal for biological control. However field populations cannot have females alone therefore they would tend to associate with males in the management of the prey population.

## CONCLUSION

*Cheilomenes lunata*, *C. sulphurea* and *C. propingua* have shown type II functional response and hence they are able to reduce populations of cotton aphids. *Cheilomenes lunata* and *C. sulphurea* have greater predatory potential than the *C. propingua*. Females for the three species have bigger body size and shorter handling time than their male counterparts of which influences their ability of consuming aphids. *Cheilomenes lunata* and *C. sulphurea* have similar search rates reflecting same magnitude of reducing aphid populations.

From the above view, the three predatory coccinellids, can be used as a component within strategic programmes for the management of *A. gossypii* in the Eastern Cotton Growing Areas of Tanzania.

It is hereby recommended to conduct further studies on life table parameters for the three coccinellids. The study was carried in insectary which does not reflect the actual field situation therefore it is recommended to conduct studies in the field to establish Functional responses under natural condition. Geographical mapping occurrences of the coccinellid species in the eastern zone of Tanzania is important for future recommending the use of the coccinellids as biocontrol agents.

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