CAPABILITY OF *Forficula auricularia* LINNAEUS (DERMAPTERA: FORFICULIDAE) TO PREY ON *Aphis craccivora* KOCH (HOMOPTERA : APHIDIDAE) IN EASTERN AND CENTRAL AFRICA

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ABSTRACT

Aphis craccivora Koch (Homoptera : Aphididae) is an economic pest of cowpea in eastern Uganda and in eastern Democratic Republic of the Congo (DRC). The earwig *Forficula auricularia* (Dermaptera : Forficulidae) is a predatory species frequently observed on farms in eastern and central Africa. To determine the predation capability of *F. auricularia* on *A. craccivora*, laboratory and field cage experiments were set up in Uganda and the DRC during the rainy seasons of 2004 and 2005, with various predator-prey ratios as treatments. In the laboratory, *F. auricularia* consumed a range of 1.27 to 7.82 *A. craccivora* per day, while in the field the range was 3.66 to 7.24. Although this earwig did not demonstrate high predation levels, it is contributing to natural control of insect pests and therefore its populations should be encouraged.

Keywords : Predation capability, *Forficula auricularia, Aphis craccivora,* Uganda, D. R. Congo.

RESUME

PREDATION DES PUCERONS, Aphis craccivora *KOCH (HOMOPTERA : APHIDIDAE) PAR LES PERCE-OREILLES,* Forficula auricularia *LINNAEUS (DERMAPTERA : FORFICULIDAE) EN AFRIQUE CENTRALE ET ORIENTALE*

Les pucerons, Aphis craccivora *Koch (Homoptera : Aphididae) compte parmi les ravageurs d'importance économique du niébé à l'Est de l'Uganda et à l'Est de la République Démocratique du Congo. Le perce-oreille commun,* Forficula auricularia *(Dermaptera : Forficulidae) est un prédateur fréquemment rencontré dans les agro-écosystèmes intégrant le niébé en Afrique centrale et orientale. L'action prédatrice (la capacité de prédation) exercée sur les pucerons par le perce-oreille commun, a été évaluée en conditions de laboratoire et de champs. Les essais de cage en champs ont été installés dans les terrains expérimentaux en Uganda et en République Démocratique du Congo, durant la petite et la grande saison pluvieuses des années 2004 et 2005. Dans ces essais, différents traitements de prédateur-proie ont été évalués. Les résultats montrent que* F. auricularia *est capable de consommer environs 1,27 à 7,82 pucerons par jour en conditions de laboratoire. En milieu réel (champ),* F.auricularia *consomme 3,66 à 7,24 pucerons par jour. Malgré le fait que l'insecte n'a pas démontré un taux élevé de consommation journalière des pucerons, il pourrait néanmoins contribuer à la réduction de l'augmentation des colonies du ravageur (*Aphis craccivora*) en milieu paysan. Les perce-oreilles peuvent jouer un rôle important en lutte biologique contre les pucerons puisque ils sont potentiellement important agents de contrôle naturel de ces ravageurs. Ainsi, une forte densité, de ce prédateur dans les agro-écosystèmes intégrant le niébé et cultures céréalières, est à encourager en Afrique centrale et orientale.*

Mots-clés : *Capacité de prédation,* Forficula auricularia, Aphis craccivora, *Uganda, R D Congo.*

INTRODUCTION

Earwigs (Dermaptera) are widely distributed throughout the world and are generally polyphagous predators (Milne and Bishop, 1987 ; Buxton and Madge, 1976). However, they are reported to be primarily aphidophagous (Anderson *et al.,* 1983), occuring in many agricultural ecosystems (Tawfik *et al.,* 1972 ; Kharboutli and Mack, 1993).These insects belong to a small order of insects distributed over 1800 species (Philips, 1981 ; Behura, 1996 ; Mols, 2000 ; Mueller *et al.*, 1988 ; Carillo, 1985 ; Helsen *et al.,* 1998), throughout the world (except the Polar Regions), with greatest diversity in the tropics (L'Enfant *et al.,* 1994 ; Syamsudin-Subahar *et al.,* 1990 ; Buxton, 1974). For example, of the 60 species that have been described from Australia (Gobin *et al.,* 2006 ; Burnip *et al.,* 2002), only 10 are predactors (Mols, 2000). Also, about 22 species are found in the US, and a few of them are predators of crop pests (Epstein, 1998). Few species of these insects are known as pests for crops in Sub-Sahara Africa (Heinrichs and Barrion, 2004).

The European earwig, *F. auricularia*, which is native to Europe, is currently found in all continents (Morris, 1971 ; Lamb and Wellington, 1975 ; Zihibin, 1997). The species occurs in North, West, East and Central Africa where it is found to be associated with agro-ecosystems integrating pulse and cereal crops or tuber-root and horticultural crops (Baoua Boukary *et al.,* 1997 ; El Shafie, 2001 ; Munyuli *et al.,* 2007 ; Munyuli *et al.,* 2006).

A few numbers of earwig species have been reported to be effective predators of different crop pests. Laboratory studies have demonstrated that *F. auricularia* and *F. riparia* were potential predators of several insect pests of economical importance (noctuid larvae, *Spodoptera littoralis*, dipteran pest pupae, and others) in Egypt, Canada and USA (Philip, 1981 ; Tawfik *et al.,* 1972).

Forficula auricularia has been reported to feed on a wide range of preys (in Europe, Asia, America and Australia), including aphids, thrips, mites, and others (Milne and Bishop, 1987 ; Behura, 1950 ; Behura, 1996 ; Philips, 1981 ; Carillo, 1985 ; Lamb *et al.,* 1975 ; Fernanzez *et al.,* 2007).

For instance, in USA, *F. auricularia* was reported to play significant role in controlling apple aphids on non bearing apple trees (Epstein, 1998). The species are also considered as an important predator of *Cydia pomonella* (codling moth), (Nuessly *et al.,* 2004) in Canada. *Forficula auricularia* was shown to be a useful agent in the biological control of aphids (*Aphis spiraecola, A. gossypii* and *Toxoptera aurantii*) in ecologically managed citrus orchards in Spain, where the feeding behaviour of these generalist predators closely followed the seasonal fluctuations of aphid populations (Canellas *et al.,* 2005).

However, African earwig species are not well-known taxonomically and their potential as biological control agents of tropical crop pests is largely unknown.

Groundnut (*Arachis hypogea* L.), Beans (*Phaseolus vulgaris* L.) and Cowpea (*Vigna unguiculata* L.) are important food crops and source of proteins. They are grown by 90 % of farmers in Eastern Uganda (Munyuli, 2005 ; Munyuli, 2003a) and in Eastern, Central and Western Democratic Republic of the Congo (Munyuli, 2001, Munyuli *et al.,* 2008). Yields of up to 3.8 t/ha have been reported from countries with developed agriculture (Munyuli *et al.,* 2007) but only 0.1 to 0.8 t/ha are normally recorded at farmer level in Uganda and in DRC (Munyuli *et al.,* 2007). The low yields at the farmer level are attributed to a number of abiotic and biotic factors, with heavy biotic pressure from insect pests being particularly important (Munyuli, 2002b). Pests of economic importance in tropical regions and in eastern Uganda and DRC include aphids (*Aphis craccivora* Koch ; Homoptera Aphidae), (Munyuli *et al.,* 2008). Yield losses due to this pest have been estimated to exceed 45 % occurence in eastern and central Africa (Kyamanywa, personal communication).

The main techniques for controlling these economic pests, of pulse crops cultivated in the region, has been chemical pesticides use. However, these pesticides have negative effects on the environment. There is a great challenge of divising sustainable management strategies for pulse crops such as cowpea in eastern and central Africa. Thus, it is needed to investigate more environmentally friendly alternatives (Munyuli *et al.,* 2007). Consequently, integrated pest management (IPM) is being promoted in eastern and central Africa as an alternative to minimizing pesticide use and encouraging environmentally safe pest control tactics. A key component of IPM is biological control, or it is often recommended as the first line of defense in IPM programs (Munyuli *et al.,* 2006a).

Occurrence and abundances of arthropod predators of pulse crop pests have been documented in eastern and central Africa. In a previous study, Munyuli *et al.* (2007) found that earwigs were among the most abundant predators associated with cowpea agro-ecosystems in the region. However, it was not clear if high abundances were associated with high efficiency in terms of field pest population control. Therefore, the need to investigate the effectiveness of earwig against economic pest of pulse crops in the region, with hope that findings of this study may be useful in implementing integrated pest management in eastern and central Africa.

One of the approaches to select a predator as good biological control agent is the determination of its prey capability, both under natural and confined local laboratory conditions (Munyuli *et al.,* 2006b). Such basic information once collected, is a step ahead in the planning and implementation of appropriate biological programs in the region (Munyuli *et al.,* 2006c).

Worldwide, information on the feeding capacity of *F. auricularia* in the laboratory suggests that this predator possesses the potential to substantially reduce populations of pests, such as *Aphis craccivora* (Zihibin, 1997 ; Philip, 1998 ; Weiss and MacDonald, 1998 ; Anderson *et al.,* 1993 ; Buxton and Madge, 1976 ; Behura, 1950 ; Bourez, 1984 ; Morris, 1971 ; Lamb and Wellington, 1974).

While it has been demonstrated clearly that earwigs are efficient predators of pests of economical importance such as apple aphids, woolly aphids and scale insects (Gobin *et al.,* 2006 ; Helsen *et al.,* 1998 ; Peusens and Gobin, 2007 ; Gobin *et al.,* 2007 ; Symondson *et al.,* 2000) in temperate regions (Helsen *et al.,* 2006 ; Hansen *et al.,* 2006 ; Caroll, 1984 ; Burni *et al.,* 2002) ; in Sub-Sahara Africa, such information is very limited although very important for the advancement of biological control technologies in the continent. The appreciation of common earwigs as effective and important predators of crop pests in Sub-Sahara Africa has not received attention from scientists, probably because of their nocturnal activities.

As previously highlighted, *F. auricularia* is among the abundant predators commonly associated with aphid infestations in eastern Uganda (Nampala *et al.,* 1999) and in eastern DRC (Munyuli *et al.,* 2007 ; Munyuli *et al.,* 2008). However, its effectiveness as good predator is unknown in the region. Based on earwigs' abundance in the field, there is reason to believe that they may be exerting natural control over some pests of economical importance such as aphids in eastern and central Africa.

Therefore the objective of this study was to evaluate the predation potential of earwigs on aphids, which are pests to crops.

MATERIALS AND METHODS

LABORATORY STUDIES

Predation effects of *F. auricularia* on *A. craccivora* were studied under laboratory conditions at Makerere University, Uganda, in June and November 2004. The study was repeated at Lwiro Research Center, DRC, in December 2004 and May 2005.

To assess the predation rate, seven predator-prey ratios were studied. The number of aphids was kept constant at 200 per container, while the predator number was varied. The numbers of earwigs per container were 5, 10, 15, 20, 25, 30 and 35 ; resulting in predator-prey ratios of 1 : 40, 1 : 20, 1 : 13, 1 : 10, 1 : 8, 1 : 7 and 1 : 6, respectively. Each predator-prey ratio was replicated eleven times.

Adult earwigs and adult aphids were collected from farmers fields. Earwigs were first starved for 24 h, and then placed in containers of 12 cm diameter and 6 cm height. The aphids were transferred into fresh cowpea leaves using a fine camel hair brush ; these infested leaves were subsequently inserted into the same containers. The experiments were conducted at room temperature and humidity. Moistened filter paper in each container prevented early wilting of leaflets. The containers were examined daily, and all aphids and earwigs (dead or alive) were counted until all the aphids were either consumed or dead. The numbers of aphids killed by the earwigs but not infested were also recorded and combined with the numbers of those consumed by earwigs for analysis.

Due to limited resources and published information about the food resources of the earwigs in the region, this study did not use «standard» controls treatment, although it would be better to have it in order to compare the feeding behaviour of the predator in the presence of other alternative food resources.

FIELD EXPERIMENTS

To study the effect of predation on aphids of *F. auricularia* on *A. craccivora* under field conditions, field cage experiments were conducted both at the Mulungu Agricultural Research Center of the INERA, South-Kivu province, eastern of DRC, during long (September-February) and short rains (March-May) of 2005 (Munyuli, 2002a ; Munyuli, 2003b) and at Bukeddea (Kumi District, Uganda) during the long (March-June) and short (September-February) rain saisons of 2004 (Figure 1). These cage studies were designed to minimize dispersal of earwigs and aphids and facilitate easy assessment of the daily consumption of immature and adult aphids by earwigs.

One week after emergence of the crop, a cage was placed in the middle of each plot to cover 10 cowpea plants. The cages (Figure 2), measuring 2 x 1.5 x 1.5 m each, were constructed from iron frame and covered with white fine nylon mesh (2 mm size). Before placing the cages, the plants were inspected to ensure that no arthropods remained inside the delineated surface-area of the cage. Each cage had an entrance door to allow introduction and counting of the insects inside. The aphids and earwigs were collected from farmers' fields and introduced into the cages at 2 weeks post-emergence of the crops.

The caged plants were artificially infested with 200 aphids per cage. Predation was studied under population densities of 0, 10, 15, and 20 earwigs per cage. Therefore, four predator-prey ratios of 0 : 200 (T1), 1 : 20 (T2), 1 : 13 (T3) and 1 : 10 (T4) were studied. The treatments were replicated three times in a randomized complete block design. The numbers of *F. auricularia* and *A. craccivora* were recorded at 2-days interval for two weeks.

DATA ANALYSIS

The data were subjected to analysis of variance (ANOVA) after checking the validity of assumptions underlying this analysis. Treatment means were separated using the Fisher's protected least significant difference test at 5 % probability level. Regression analyses were used to examine the relationships between predator density and prey consumption rates. All analyses were conducted with the Genstat computer package programme (Genstat 5 release 3.2 PC/Windows 95).

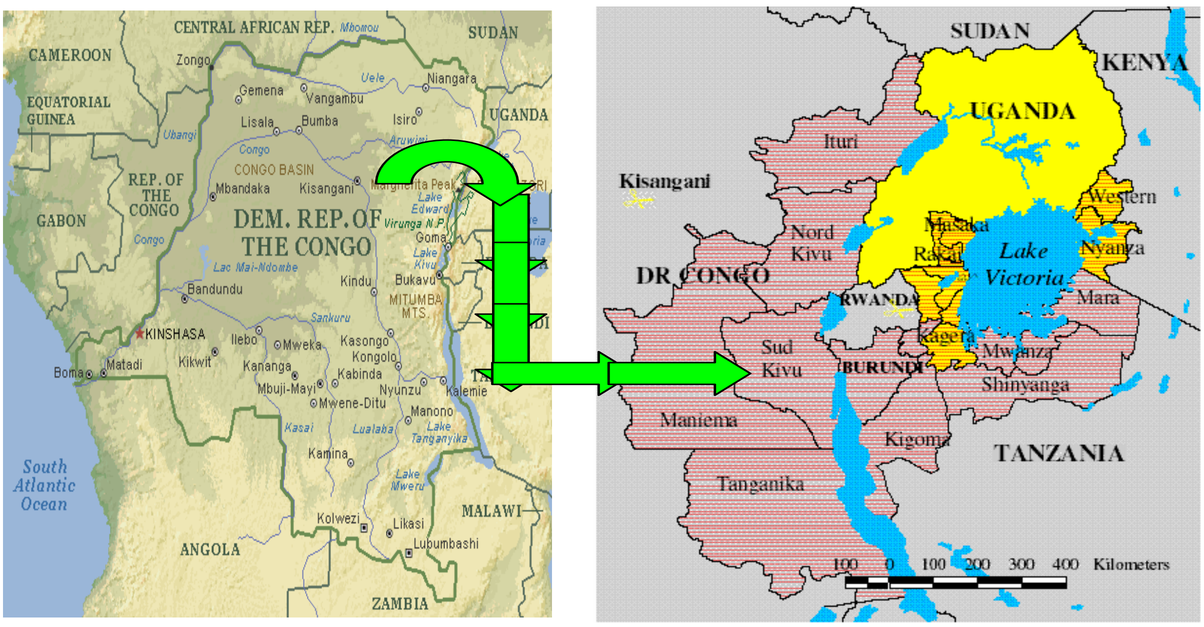

Figure 1 : Study sites.

Sites d'essai de champs.

M = Mulungu agricultural research station, South-Kivu province (eastern DR Congo), K = Bukedea sub-county, Kumi district (eastern Uganda)

M = Station de recherché agronomique de Mulungu,Province du Sud-Kivu, Est de la République Démocratique du Congo ; K = Village de Bukedea , District de Kumi ,Est de l'Ouganda

Figure 2 : Type of cages used during field experiments conducted in eastern DRC and in eastern Uganda

Modèle de cage expérimentale utilisée lors de la conduite des essais de champs à l'Est de la RDC et à l'Est de l'Ouganda

RESULTS

IMPACT OF PREDATOR DENSITY ON THE RATE OF PREY CONSUMPTION

Laboratory observations revealed that one earwig consumed 1.27 to 7.82 aphids per day (Table 1), depending on the predator-prey ratio. The effect of predator density on the number of prey consumed was significant (P < 0.05). The highest number of aphids consumed per earwig was observed in the predator-prey ratio of 1 : 6 and the lowest in the 1 : 40 ratio. The number of aphids consumed per earwig per day increased as the predator-prey ratio increased (Table 1). Linear relationships were found between earwig densities and aphid consumption rates for all four-laboratory experiments (Figure 3).

Table 1 : Daily consumption of aphids by earwigs under laboratory conditions in Uganda and DR Congo. (Data are means from the first 6 days of observation)

Consommation journalière des pucerons par le perce-oreille en conditions de laboratoire en Uganda et en République Démocratique du Congo. (Les données sont les moyennes pour 6 jours d'observations).

Treatments (Predator-prey ratios)	Number of aphids consumed per earwig per day				
	Uganda		D R Congo		
	June 2004	November 2004	December 2004	May 2005	Mean
1:40	1.5 d	1.9 e	0.9 e	0.8 e	1.27
1:20	3.1 c	2.1 e	3.2 d	1.9 d	2.58
1:13	3.7 c	3.9 d	4.2 c	2.2 d	3.50
1:10	4.0 c	5.9 c	5.3 c	3.2 c	4.60
1:8	5.8 b	7.8 b	7.5 b	5.2 b	6.57
1:7	6.2 b	8.1 b	8.2 a	5.9 a	7.10
1:6	7.2 a	9.2 a	8.7 a	6.2 a	7.82
Mean	4.5	5.56	5.4	3.9	
CV(%)	7.91	3.78	5.89	5.81	

Within columns, means followed by the same letter are not significantly different at 5% probability level as determined with Fisher's protected least significant difference (LSD) test for mean separation. CV (%) = coefficient of variation.

Dans chaque colonne, les moyennes suivies par la même lettre ne sont pas significativement différentes à P=0,05 selon le test LSD de Fisher. CV (%) = Coefficient de variation

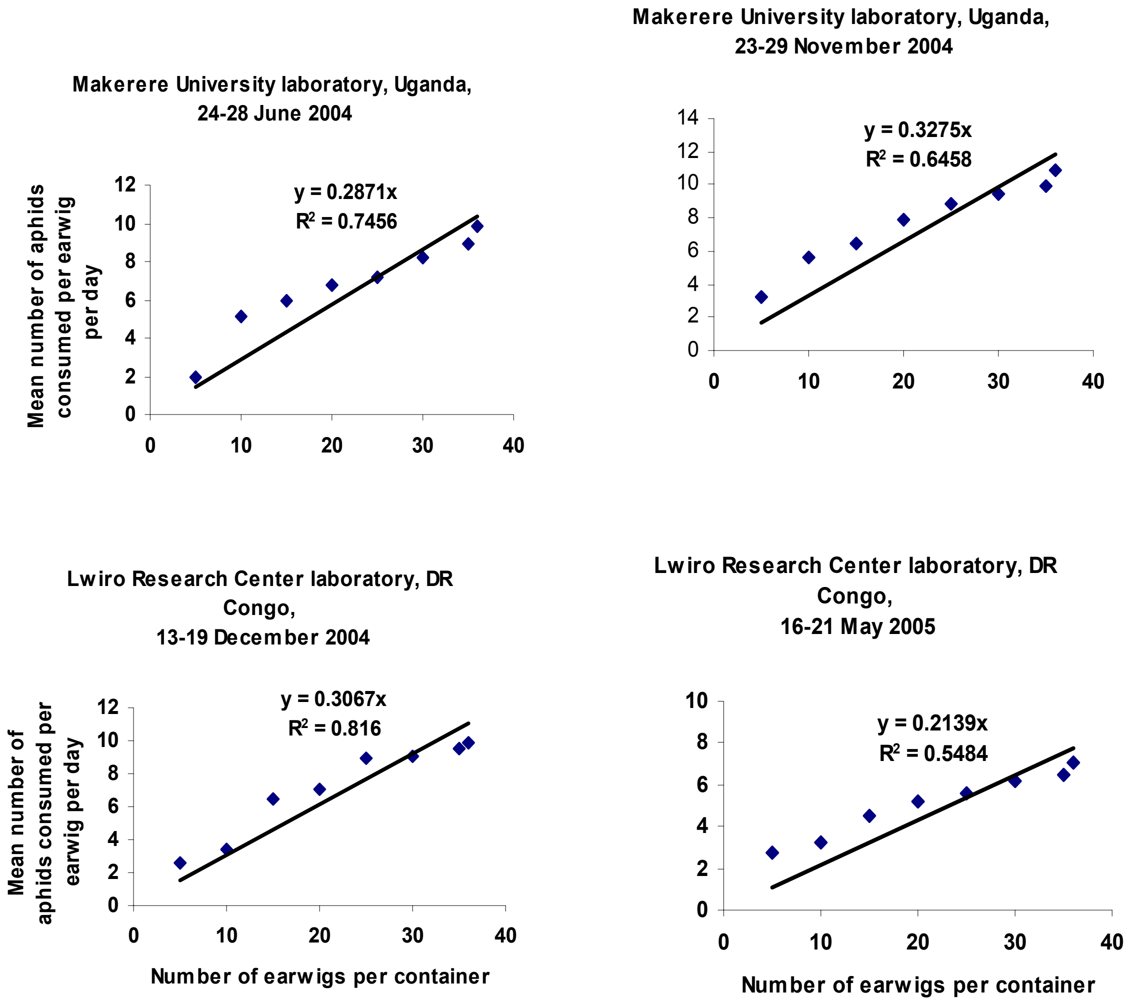

Figure 3 : The effect of predator population density on the rate of consumption of aphids, *Aphis craccivora*, Koch (Homoptera : Aphididae) by the earwig, *Forficula auricularia* (Dermaptera : Forficulidae).

*Effet de la densité du prédateur sur le taux de consommation des pucerons (*Aphis craccivora*, Koch (Homoptera : Aphididae) par le perce-oreille,* Forficula auricularia *(Dermaptera : Forficulidae)*

In separates containers (control containers), aphids (200 per container) were reared separately (data not shown) with the aim of observing the number of aphids that could die in the absence of earwigs. These control containers were also monitored for the same period at both study sites, and the number of aphids found dead in absence of predators was 0.28 % (Uganda) and 0.92 % (in D R Congo) only, (Munyuli, personal observation).

FIELD CAGE RESULTS

In the field cage experiments, significant differences ($P < 0.05$) were observed in the number of aphids consumed by earwigs for the different predator-prey ratios at all sites and for all seasons (Table 2). The mean number of aphids consumed per earwig per day varied between 3.66 and 7.24. The consumption rate rose with increased predator-prey ratios. The highest number of aphids consumed per earwig was observed at a predator-prey ratio of 1 : 10 (Table 2).

Table 2 : Daily consumption of aphids by earwigs in field cages in Uganda and the DR Congo.

Consommation journalière des pucerons par le perce-oreille en cages au champ en Uganda et en République Démocratique du Congo.

Treatments (predator-prey ratios per treatment)	Mean daily consumption of aphids by earwigs				Mean
	Kumi, Uganda		Mulungu, D R Congo		
	Long rains 2004	Short rains 2004	Long rains 2004	Short rains 2005	
T1 (0 : 200)[a]	0.00 c	0.00 d	0.00 c	0.00 c	0.00
T2 (1 : 20)	4.62 b	2.38 c	3.97 b	3.69 b	3.66
T3 (1 : 13)	7.72 a	5.94 b	4.19 b	6.93 a	6.19
T4 (1 : 10)	6.28 a	7.70 a	9.14 a	5.91 a	7.24
Mean	6.20	5.02	5.76	5.59	
CV(%)	45.3	39.9	45.67	29.92	-

[a] T1 : 0 earwigs/200 aphids ; T2 : 10 earwigs/200 aphids ; T3 : 15 earwigs/200 aphids ; T4 : 20 earwigs/200 aphids.

Within columns, means followed by the same letter are not significantly different at 5 % probability level as determined with Fisher's protected least significant difference (LSD) test for mean separation. CV (%) = coefficient of variation.

[a] T1 : 0 perce-oreilles/200 pucerons ; T2 : 10 perce-oreilles/200 pucerons ; T3 : 15 perce-oreilles /200 pucerons ; T4 : 20 perce-oreilles/ 200 pucerons.

Dans chaque colonne, les moyennes suivies par la même lettre ne sont pas significativement différentes à P=0,05 selon le test LSD de Fisher. CV (%) = Coefficient de variation

DISCUSSION

This study showed that under laboratory and field conditions, an earwig can consume approximately 7 aphids per day. Higher numbers of aphids were consumed with increases in predator-prey ratios.

The capability of earwigs as biological controlling agents has been tested world wide using different species (Helsen *et al.,* 1998 ; Fenoglio *et al.,* 2007 ; Asante, 1995 ; Carroll and Hoyt, 1984 ; Caroll *et al.,* 1985). Results show a wide range of consumption rates by different earwig species. The earwig *Doru taeniatum* (Dohrn) has been reported to be an effective predator of armyworms, aphids and other soft bodied insect pests in corn, sugarcane in USA.(Jones,1985) ; and as effective bio-control agent of faba bean pests in USA (Nuessly *et al.,* 2004). In Canada, Buxton and Madge (1976) observed that an adult earwig and its 3rd and 4th instars could consume 46-122 aphids (*Phorodon humili*) per day. In a study in the USA, Crumb and Bonn (1995) found that an earwig could consume 2.5-5.2 *Acyrthosiphum spartii* Koch, 3 *Aphis pomi* and 5.2 *Eriosoma lanigerum* Hauson.

In New Zealand the European earwig was reported to be an important predator of diaspidid scale insect pest of Kiwifruit. Here, earwigs were able to feed on around 83 % of the scale populations in 8 weeks after being released in Kiwifruit fields (Logan *et al.,* 2007). More over, Logan *et al.* (2007) found that up to 40 % of scale insects can be consumed prior to harvest in autumn, when high numbers of earwigs occur in the canopy of kiwifruit during summer.

Despite the difference in prey species, our results corroborated closely with those of Weiss and MacDonald (1998), who found that an adult earwigs could consume 8-9 *Aphis* sp. per day on wheat. Kharboutli and Mack (1993) also showed that under laboratory conditions, *F. auricularia* consumed 21.5 mites (*Halotydeus destructor,* Acarina : Penthaleidae) and 18 aphids (*P. humili*) in Australia. *A. craccivora* is a large and heavy aphid, as compared to *P. humili.* This may explain the lower feeding rate recorded in our study, as compared with other studies on various prey species in Australia, USA, Canada and other locations. In addition, the difference in earwig sizes played a significant role.

CONCLUSION AND RECOMMENDATIONS

This is the first study that provides basic information on the effectiveness of the insect species in controlling crop pests in eastern and central Africa. Although the study was conducted in cowpea agro-ecosystems, the predator may be effective in other type of cropping systems in Sub-Sahara Africa. Its potential as an effective predator for a large number of pest species should be explored further for the benefit of low in-put small scale farmer. This is possible since the natural enemy seems to occur abundantly in local agro-ecosystems.

This baseline data will only be applicable if other aspects are investigated in eastern and central Africa. Therefore, further studies are needed to assess the potential of earwigs as predators of other insect pests on food and cash crops in eastern and central Africa. At this early stage of research on earwig as biological controlling pest agents with high value in Sub-Sahara Africa, studies should be initiated to characterize and describe cropping systems associated with higher predator population densities.

Moreover, there is a need to undertake more studies aiming at better understanding the feeding behaviour of earwigs against a range of economic pests of food crops in Sub-Sahara Africa, in order to find out substitutes for pesticides that are expensive and not environmentally safe in African agricultural landscapes.

Further development of IPM systems in different ecological areas of Africa are still needed. There is also a need to understand and measure area requirements for all beneficial arthropod including earwigs to provide ecological services of high quality in terms of field pests control under local agro-ecosystem environments

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