

Species diversity and abundance of lepidopteran stem borer natural enemies in Botswana

Reyard Mutamiswa

Department of Biology and Biotechnological Sciences,
Botswana International University of Science and
Technology (BIUST)
Palapye, Botswana

Eva Moeng

Department of Biology and Biotechnological Sciences,
Botswana International University of Science and
Technology (BIUST)
Palapye, Botswana

Bruno Le Ru

Laboratoire Evolution, Génomes, Comportement et
Ecologie, Diversité, Ecologie et Evolution des Insectes
Tropicaux, CNRS, Gif-sur-Yvette
Paris, France

Des Conlong

South African Sugarcane Research Institute
(SASRI),
Mount Edgecombe, South Africa

Yoseph Assefa

Department of Crop Production,
Faculty of Agriculture, University of Swaziland,
Luyengo, Swaziland

Muluken Gofitshu

School of Plant Sciences,
Haramaya University,
Diredawa, Ethiopia

Casper Nyamukondiwa

Department of Biology and Biotechnological Sciences,
Botswana International University of Science and
Technology (BIUST)
Palapye, Botswana

Abstract— Africa hosts significant lepidopteran stem-borers which are attacked by a diversity of natural enemies in their natural and cultivated environments. To determine diversity, relative abundance of stem-borer natural enemies and associated host plants, field surveys were conducted during 2014/15 and 2015/16 austral summer on natural and cultivated habitats across Botswana. In cultivated habitats, the common larval parasitoids recorded were *Cotesia flavipes*, and *C. sesamiae*, and pupal parasitoids *Pediobius fuscus* and *Gambroides nimbipennis* while in natural habitats, larval parasitoids *Chelonus curvimaculatus* and *Goniozus indicus* and a pupal parasitoid, *Dentichasmias busseolae* were recorded. Furthermore, predatory ants (*Linepithema humile*, *Crematogaster peringueyi* and *Aenictus* species) were recorded in both cultivated and natural habitats. Cultivated and natural Poaceae; maize, sorghum, sweet sorghum, *Echinochloa pyramidalis*; natural Typhaceae, *Typha latifolia* and natural Cyperaceae-*Schoenoplectus corymbosus* and *Cyperus dives* formed the major plants hosting stemborers and related natural enemies. *Chilo partellus* and *Sesamia* spp. were the major parasitoid hosts with *C. partellus* predominating in cultivated habitats and *Sesamia jansei* in natural habitats. Larval parasitism ranged from 2.1-34.7% and 3.3-14.3% while pupal parasitism ranged from 6.1-10.6% and 6.7-9.1% in cultivated and natural habitats respectively. Parasitoids relative abundance ranged from 1.1-41.6% and 4.8-38.1% in cultivated and natural habitats respectively, with *C. flavipes* dominating in cultivated and *C. curvimaculatus* in natural. Overall, our results show that cultivated and natural environments in Botswana harbour parasitoid faunal diversity that may be worth

conserving for future efficacy of biological control programmes, and an equally diverse flora hosting these stem-borers.

Keywords—biodiversity; biological control; Lepidoptera; parasitoids; plant-insect-interactions

I. INTRODUCTION

Lepidopteran stem borers are the main destructive insect pests of cereal crops (maize, sorghum and millet) in sub-Saharan Africa accounting for ~5-75% of potential crop yield losses [1; 2; 3; 4]. The abundance and distribution of cereal stem borers may be influenced by abiotic factors such as temperature and precipitation, and biotic factors such as natural enemies and alternative host plants [5; 6]. Understanding the diversity, spatial distribution, relative abundance and ecological contribution of stem borer natural enemies in natural and agroecosystem environments is significant in ensuring ecosystem stability and putting in place the integrated pest management approach [7]. Stem borer natural enemy species diversity and abundance can vary across different landscapes, and diversity and distribution may be under threat due to global climate change [8; 9]. Through extensive field surveys, we assessed the diversity and abundance of stem borer natural enemies and their associated hosts in both cultivated and natural landscapes in Botswana. Such information is crucial in explaining the potential roles of

natural enemies in regulating insect pest populations, and may help in developing biological pest management systems.

2. MATERIALS AND METHODS

Field surveys on cereal crops and natural host plants were conducted in all the ten districts of Botswana during 2014/15 and 2015/16 austral summers. Natural lepidopteran stem borer host plants were sampled (i) around cereal crops, (ii) in open patches along forest roads, (iii) on banks of streams or rivers (iv) in swamps and (v) in national parks. For cultivated cereal crops, sweet sorghum, maize, millet and sorghum fields were selected every 10–15 km along minor and major roads in each respective district. Potential host plants exhibiting damage symptoms (dead hearts, scarified leaves, larval entry and exit holes and the presence of frass) were dissected in the field and borer life stages found were placed individually in 30 ml plastic vials containing artificial diet [10; 11]. Predatory insects, parasitoid cocoons or mummified larvae were placed individually in labelled plastic vials without diet, while pupae found were placed in the same plastic vials with a water-soaked cotton wool to avoid desiccation related mortality. All the vials were taken to the laboratory for subsequent incubation. In the laboratory, larvae, pupae and parasitoid cocoons were incubated at $25 \pm 1^\circ\text{C}$, $65 \pm 10\%$ and L12:D12 photoperiod [10; 5] in climate chambers (HPP 260, Memmert GmbH + Co.KG, Germany) until moth or parasitoid adult emergence.

Host plant-parasitoid and stem borer-parasitoid interaction networks were analysed in R using 'BIPARTITE' package [12]. Parasitoid species diversity in natural and cultivated habitats was computed using Simpson's diversity index [13]. Parasitism rate for larvae, pupae and relative abundance of each parasitoid were calculated as outlined by [14; 15; 16].

3. RESULTS

Parasitoid species diversity was significantly higher in cultivated ($D = 0.23$) than natural habitats ($D = 0.14$) (see Table 1). Nineteen (16 larval, 3 pupal) parasitoid species were recovered from three stem borer species in cultivated hosts while 11 parasitoid species (9 larval, 2 pupal) were recovered from 7 stem borer species in natural hosts (Table 1). Furthermore, 3 predator species were recovered from both cultivated and natural habitats (Table 1). The stem borer – parasitoid interaction network showed a moderate Shannon interaction diversity ($H' = 2.56$) and a low generality ($G_{qw} = 1.23$). Similarly, the host plant–parasitoid interaction showed moderate Shannon interaction diversity ($H' = 2.93$) and generality (G_{qw}) of 1.81. A total of 19 different parasitoid species were recovered from *C. partellus* in both cultivated and natural habitats (Fig 1A). In addition, a total of 11 maize and 10 sweet sorghum parasitoid species were recovered from stem borer species in cultivated habitats (Fig 1B). Furthermore, 4 parasitoid species were recorded parasitising stem borers attacking *Schoenoplectus corymbosus* in natural habitats (Fig 1B).

The highest level of parasitism was recorded in cultivated habitats compared to natural habitats. Larval parasitism ranged from 2.1- 34.7% and 3.3- 14.3% in cultivated (Table 2A) and natural (Table 2B) habitats respectively. In addition, pupal parasitism ranged between 6.1- 10.6% and 6.7- 9.1% in cultivated and natural habitats respectively (Tables 2A and B). Larval and pupal parasitoids relative abundance ranged from 1.1- 41.6% in cultivated and 4.8-38.1% in natural habitats (Fig. 2A and B). Hymenopteran parasitoids were more abundant than Dipteran parasitoids in both habitats accounting for 21 and 6 respectively.

4. DISCUSSION

Prior to this study, only nine parasitoids and no predatory species had been reported attacking lepidopteran stem borers in Botswana [17; 18]. Therefore, in addition to previous records, the present study reports 24 different parasitoids and 3 predatory species both in cultivated and natural host plants in the country. Our results showed a higher parasitoid diversity in cultivated than natural habitats in keeping with studies by [14] that reported a high parasitoid diversity in cultivated habitats in the coastal region of Kenya. The moderate Shannon interaction diversity and low generality recorded in this study for both stem borer–parasitoid and host plant–parasitoid interactions indicate on average that each stem borer species was attacked by one to two parasitoid species [see 19]. This also implies that every host plant hosted stem borers that were attacked by one to two parasitoid species. *Chilo partellus* was the most commonly targeted stem borer species by parasitoids and predators in cultivated habitats whilst in natural habitats *Sesamia* species were the most commonly targeted may be due to abundance of *C. partellus* and *Sesamia* species in cultivated vs natural habitats respectively. The larval parasitoids *C. flavipes* and *C. sesamiae* and pupal *P. furvus* were the most prevalent species, in keeping with previous results from eastern Africa [14; 5]. In natural habitats, the Cyperaceous host plant, *S. corymbosus* had the highest stem borer parasitoid diversity, in keeping with results by [4]. The graminaceous crops *Z. mays* and *S. bicolor*, had the highest stem borer parasitoid diversity, may be because cultivated plants constituted an important resource with higher levels of nutrients and low allelochemical toxicity relative to natural host plants [20; 5]. In cultivated habitats larval and pupal parasitism ranged 2.1-34.7% and 6.1- 10.6% respectively, in keeping with previous reports in east Africa for both larval [21; 5] and pupal [14] parasitism. Larval and pupal parasitism levels were also higher in cultivated than natural habitats, in agreement with results by [22]. Low parasitisation levels in natural habitats may be caused by lower densities of stem borers relative to cultivated habitats [5; 23] and this may have negative consequences on parasitoid host searching efficiency as in e.g. [24]. *Cotesia flavipes* recorded the highest larval parasitism levels in cultivated habitats (Table 2A), in corroboration with [25], who reported higher larval parasitism by *C. flavipes* in cultivated relative to natural habitats.

Larval parasitoids *C. flavipes* and *C. sesamiae* and pupal parasitoid *P. furvus* had a higher relative abundance compared to other parasitoid species in cultivated habitats. This may imply that *C. flavipes* and *C. sesamiae* may potentially share the same habitat regardless of whether they are attacking the same host or not [26]. *Chelonus curvimaculatus* was recovered in both habitats, and had a higher abundance in natural than cultivated habitats. This implies that this parasitoid can switch habitats, hence can be used in classical biological control, in addition to *C. flavipes* and *C. sesamiae*.

In conclusion, the current study documents novel diversity of stem borer natural enemy species in Botswana, and their interactions with host stem borers and host plants in both natural and agroecosystems. Therefore, Botswana landscapes host parasitoid faunal diversity that may be worth conserving for future efficacy of biological control programmes, and an equally diverse fauna and flora hosting parasitoid-host stem borer interactions.

Figures and Tables

Table 1: Details of natural enemy species recovered from stem borers on cultivated and natural host plants in Botswana, and information on associated locality, parasitoid family, stem borer host and the developmental stage from which the parasitoid was isolated.

Location	Parasitoid species	Family	Habitat	Stem borer	Host stage
Chanoga	<i>Pediobius furvus</i> Gahan	Eulophidae	C	Cp	P
Mogobane					
Modipane					
Tsootsha					
Oodi	<i>Euvipio rufa</i> Szepilgeti	Braconidae	C	Cp	L
Mabele			C	Con	L
Maun	<i>Gambroides nimbiennis</i> Seyrig	Ichneumonidae	N	Tot	P
Mabele			C	Cp	P
	<i>Goniozus indicus</i> Ashmead	Bethylidae	C	Cp	L
Maun			N	Sj	L
Kazungula			N	Sn	L
Oodi	<i>Cotesia flavipes</i> Cameron	Braconidae	C	Cp	L
Seleka					
Bobonong					
Ramatlabama					
Mabele					
Glen valley					
Ramotswa	<i>Cotesia sesamiae</i> Cameron	Braconidae	C	Cp	L
Tlokweng					
Hatsalatadi					
Dithojane	<i>Chelonus curvimaculatus</i>	Braconidae	C	Cp	L

	Cameron				
Moshupa			N	Cp	L
Maun			N	Sj	L
Gaborone Dam			N	Sj, Cp	L
Glen valley	<i>Dolichogenide a polaszeki</i> Walker	Braconidae	C	Cp	L
Qabo	<i>Stenobracon rufus</i> Szepilgeti	Braconidae	C	Cp	P
Lobatse	<i>Temelucha picta</i> Holmgren	Ichneumonidae	C	Cp	L
Chanoga	<i>Chalcidoidea</i> sp	Encyrtidae	C	Cp	L
Bookane	<i>Ceraphronidae</i> sp	Ceraphronidae	C	Cp	L
Ditladi	<i>Eichneumonid</i> sp	Braconidae	C	Sc, Cp	L
Mabutsane	<i>Rhaconotus</i> sp	Braconidae	C	Cp	L
	<i>Norbanus</i> sp	Pteromalidae	C	Sc, Cp	L
Kumakwane	<i>Linepithema humile</i> Mayr	Formicidae	C	Cp	L
Ndumba					
Parakarungu			N	Es	P
Maun			N	Es	L
Nxamaseri			N	Es	L
Kasane	<i>Aenictus</i> sp	Formicidae	C	Sc	L
Mochudi			C	Cp	P
Matlapana					
Martins Drift			N	Es	L
Hatsalatadi	<i>Crematogaster peringueyi</i> Emery	Formicidae	C	Sc	L
Ramotswa					
Maun			N	Sj	L
Kasane	<i>Bracon testaceorufatus</i> Granger	Braconidae	N	Sc	L
Kanye	<i>Denticasmas busseolae</i> Heinrich	Ichneumonidae	N	Tot	P
Kasane	<i>Cremastinae</i> sp	Ichneumonidae	N	Sc	L
Maun	<i>Cercerinae</i> sp	Philantidae	N	Sj	L
Nxamaseri	<i>Formicidae</i> sp	Formicidae	N	Es	L
Samedupi	<i>Syzeuctus</i> sp	Ichneumonidae	N	Tot, Sj	L
Hatsalatadi	<i>Descampsina sesamiae</i> Mesnil	Tachinidae	C	Cp	L
Qabo					
Mabutsane	<i>Sturmiopsis parasitica</i> Curran	Tachinidae	C	Cp	L
Oodi	<i>Sepsidae</i> sp	Sepsidae	C	Cp	L
Hatsalatadi	<i>Chloropidae</i> sp	Chloropidae	C	Cp	L
Gatsatsa					
Satau	<i>Siphona murina</i> Mesnil	Tachinidae	N	Sn, Sp	L
Shakawe	<i>Phoridae</i> sp	Phoridae	N	Es	L

C, cultivated; N, natural; Cp, *Chilo partellus*; Con, *Concofrontia* sp; Sj, *Sesamia jansei*; Sn, *Sesamia nonagrioides*; Tot, *Totricidae* sp; Sc, *Sesamia calamistis*; Es, *Eldana saccharina*; Sp, *Sesamia perplexa*; L, larva; P, pupa

Table 2A: Larval and pupal parasitism in cultivated host plants in Botswana.

Host Plant Species	Host species	Parasitoid species	% Parasitism
Maize	<i>Chilo partellus</i>	<i>Cotesia flavipes</i>	34.7 (33)
		<i>Cotesia sesamiae</i>	18.8 (13)
		<i>Euvipio rufa</i>	4.3 (2)
		<i>Sepsidae</i> sp	2.1 (1)
		<i>Pediobius furvus</i>	8.5 (5)
		<i>Descampsina sesamiae</i>	5.9 (1)
		<i>Chalcidoidea</i> sp	7.7 (1)
		<i>Telemucha picta</i>	2.9 (1)
		<i>Dolichogenidea polaszeki</i>	6.3 (1)
		<i>Stenobraccon rufus</i>	6.1 (2)
Sorghum	<i>Chilo partellus</i>	<i>Cotesia flavipes</i>	5.7 (2)
		<i>Cotesia sesamiae</i>	12.5 (2)
		<i>Chloropidae</i> sp	4.5 (2)
		<i>Descampsina sesamiae</i>	6.3 (1)
Sweet sorghum	<i>Concofrontia</i> sp	<i>Ceraphonidae</i> sp	7.1 (1)
		<i>Euvipio rufa</i>	5.9 (1)
		<i>Echneumonidea</i> sp	2.8 (1)
		<i>Chilo partellus</i>	17.6 (3)
	<i>Chilo partellus</i>	<i>Cotesia sesamiae</i>	29 (9)
		<i>Goniozus indicus</i>	5.9 (1)
		<i>Rhaconotus</i> sp	4.3 (1)
		<i>Norbanus</i> sp	4.3 (1)
		<i>Sturmiopsis parasitica</i>	4.3 (1)
		<i>Chelonus curvimaculatus</i>	9.1 (1)
		<i>Echneumonidea</i> sp	3.2 (1)
		<i>Gambroides nimbiopennis</i>	10.6 (3)

() number of parasitised hosts

Table 2B: Larval and pupal parasitism in natural host plants in Botswana.

Host Plant Species	Host species	Parasitoid species	% Parasitism
<i>Sorghum bicolor</i> subsp <i>arundinaceum</i>	<i>Sesamia calamistis</i>	<i>Bracon testaceorufatus</i>	4 (1)
	<i>Sesamia nonagrioides</i>	<i>Siphona murina</i>	3.3 (1)
<i>Schoenoplectus corymbosus</i>	<i>Sesamia jansei</i>	<i>Goniozus indicus</i>	4.8 (1)
		<i>Cercerinae</i> sp	9.5 (2)
	<i>Tortricidae</i> sp	<i>Chelonus curvimaculatus</i>	14.3 (3)
		<i>Denticasmas busseolae</i>	9.1 (2)
		<i>Chelonus curvimaculatus</i>	7.8 (5)
<i>Cyperus dives</i>	<i>Chilo partellus</i>	<i>Goniozus indicus</i>	3.5 (1)
<i>Oryza longistaminata</i>	<i>Sesamia nonagrioides</i>	<i>Gambroides nimbiopennis</i>	6.7 (1)
<i>Typha latifolia</i>	<i>Sesamia jansei</i>	<i>Syzeuctus</i> sp	4.2 (1)
<i>Chrysopogon nigritanus</i>	<i>Sesamia calamistis</i>	<i>Cremastinae</i> sp	4 (1)
<i>Cyperus papyrus</i>	<i>Eldana saccharina</i>	<i>Formicidae</i> sp	3.8 (1)
<i>Vossia cuspidata</i>	<i>Sesamia perplexa</i>	<i>Siphona murina</i>	4.5 (1)
<i>Echinochloa</i>	<i>Sesamia jansei</i>	<i>Syzeuctus</i> sp	5.2 (1)

<i>pyramidalis</i>			
<i>Cyperus papyrus</i>	<i>Eldana saccharina</i>	<i>Phoridae</i> sp	3.7 (1)

() number of parasitised hosts

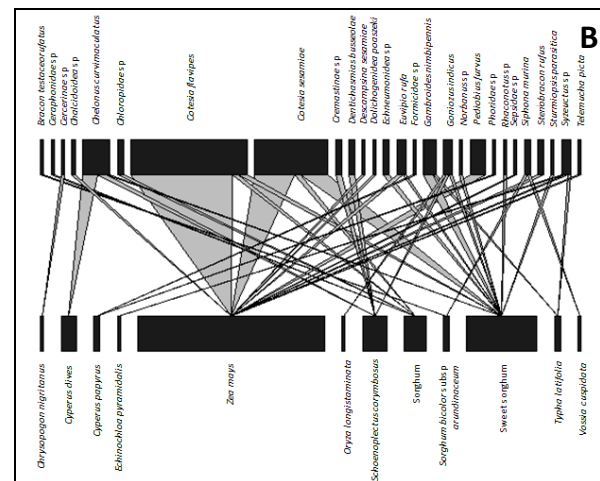
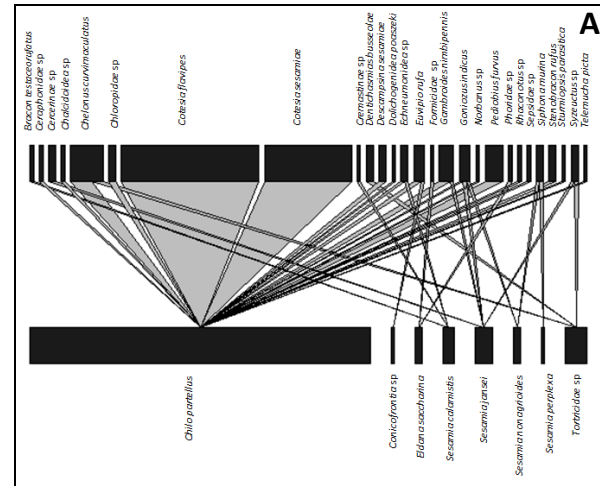


Fig. 1: Quantitative bipartite interaction networks for (A) stem borer - parasitoid and (B) host plant - parasitoid in cultivated and natural habitats in Botswana

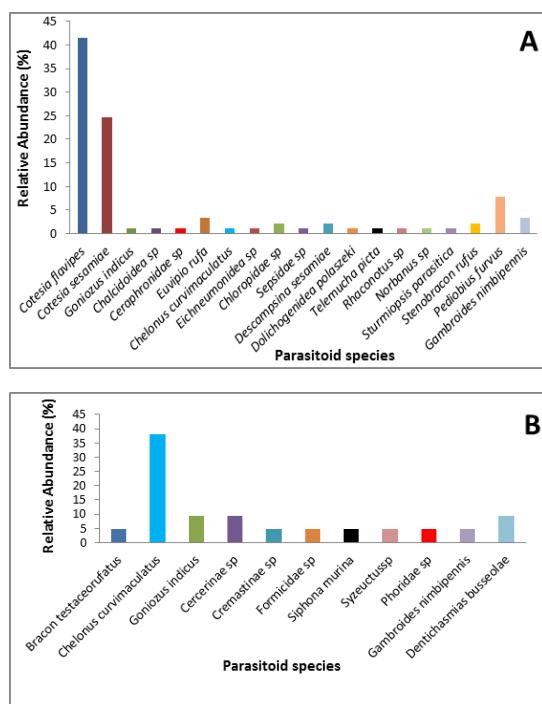


Fig. 2: Relative abundance of cereal stem borer parasitoids in (A) cultivated and (B) natural habitats in Botswana

ACKNOWLEDGMENTS

The authors would like to recognize valuable support from Botswana International University of Science and Technology (BIUST), International Centre for Insect Physiology and Ecology (ICIPE), Kenya, South African Sugar Research Institute (SASRI), South Africa, Ministry of Agriculture and department of National Museum and Monuments, Herbarium unit, Botswana. We are also grateful to Reuben Kandjii and the Ministry of Agriculture staff for the active support in the survey.

REFERENCES

- [1] De Groote H (2002) Maize yield loss from stemborers in Kenya. *Journal of Insect Science* 22: 89–96.
- [2] Kfir R, Overholt WA, Khan ZR, Polaszek A (2002) Biology and management of economically important lepidopteran cereal stemborers in Africa. *Annual Review of Entomology* 47: 701–713. PMID: 11729089.
- [3] Kipkoech AK, Schulthess F, Yabann WK, Maritim HK, Mithöfer D (2006) Biological control of cereal stem borers in Kenya: A cost benefit approach. *Annales de la Société entomologique de France (N.S.): International Journal of Entomology* 42: 519–528
- [4] Moolman HJ, Van den Berg, J, Conlong D, Cugala D, Siebert SJ, Le Ru BP (2013) Diversity of stemborer parasitoids and their associated wild host plants in South Africa and Mozambique. *Phytoparasitica* 41: 89–104
- [5] Mailafiya DM, Le Ru BP, Kairu EW, Calatayud PA Dupas S (2009) Species diversity of lepidopteran stem borer parasitoids in cultivated and natural habitats in Kenya. *Journal of Applied Entomology* 133: 416–429
- [6] Addo-Bediako A, Thanguane N (2012) Stemborer distribution in different sorghum cultivars as influenced by soil fertility. *Agricultural Science Research Journal* 2: 189–194.
- [7] Conlong DE, Rutherford SR (2009) Conventional and New Biological and Habitat Interventions for Integrated Pest Management Systems: Review and Case Studies using *Eldana saccharina* Walker (Lepidoptera: Pyralidae). Chapter 10, pp 241–261. In Peshin, R and Dhawan, A.K. (Eds). *Integrated Pest Management: Innovation-Development Process*, Vol.1. Ch. 10. Springer, Dordrecht, The Netherlands. ISBN 978-1-4020-8991-6 (Print); 978-1-4020-8992-3 (online). DOI 10.1007/978-1-4020-8992-3_10.
- [8] Batalden RV, Oberhauser K, Peterson AA (2007) Ecological niches in sequential generations of eastern North American Monarch butterflies (Lepidoptera: Danaidae): the ecology of migration and likely climate change implications. *Environmental Entomology* 36: 1365–1373.
- [9] Kodjo TA, Komi A, Mawufe AK, Komlan W (2013) Maize stemborers distribution, their natural enemies and farmers' perception on climate change and stemborers in southern Togo. *Journal of Applied Biosciences* 64: 4773–4786
- [10] Onyango FO, Ochieng'-Odero JPR (1994) Continuous rearing of the maize stem borer *Busseola fusca* on an artificial diet. *Entomologia Experimentalis et Applicata* 73: 139–144
- [11] Tefera T, Mugo S, Tende R, Likhayo P (2010) Mass Rearing of Stem borers, Maize weevil and Larger grain borer Insect Pests of Maize. CIMMYT. Nairobi.
- [12] Dormann CF, Fruend J, Bluethgen N, Gruber B. (2009) Indices, graphs and null models: analyzing bipartite ecological networks. *The Open Ecology Journal* 2: 7–24.
- [13] Simpson EH (1949) Measurement of diversity. *Nature* 163: 688.
- [14] Zhou G, Overholt WA, Kimani-Njogu SW (2003) Species richness and parasitism in assemblage of parasitoids attacking maize stem borer in coastal Kenya. *Ecological Entomology* 28: 109–118.
- [15] Dejen A, Getu E, Azerefege F, Ayalew A (2013) Distribution and Extent of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) Parasitism in Northeastern Ethiopia. *International Journal of Insect Science* 5: 9–19
- [16] Rahaman MM, Islam KS, Jahan M, Mamun MAA (2014) Relative abundance of stem borer species and natural enemies in rice ecosystem at Madhupur, Tangail,

- Bangladesh. Journal of the Bangladesh Agricultural University 12: 267–272, ISSN 1810-3030
- [17] Conlong DE, Graham DY (1988) Notes on the natural host surveys and laboratory rearing of *Goniozus natalensis* Gordh (Hymenoptera: Bethyridae), a parasitoid of *Eldana saccharina* Walker (Lepidoptera: Pyralidae) larvae from *Cyperus papyrus* L. in Southern Africa. Journal of the Entomological Society of Southern Africa 51: 115-127
- [18] Obopile M, Mosinkie KT (2003) Natural enemies of lepidopterous stemborers on maize and sorghum in Botswana. UNISWA Journal of Agriculture 11: 64-69
- [19] Helena, M., Peixoto, P., Pufal, G., Staab, M., Martins, C.F., Kleins., A.M. (2016). Diversity and specificity of host-natural enemy interactions in an urban-rural interface. Ecological Entomology 41: 241-252.
- [20] Ofomata VC, Overholt WA, Lux SA, Van Huis A Egwuatu RI (2000) Comparative studies on the fecundity, egg survival, larval feeding and development of *Chilo partellus* (Swinhoe) and *Chilo orichalcociliellus* strand (Lepidoptera: Crambidae) on five grasses. Annals of the Entomological Society of America 93: 492-499.
- [21] Matama-Kauma T, Schulthess F, Ogwang JA, Mueke JM, Omwega CE (2007) Distribution and relative importance of lepidopteran cereal stemborers and their parasitoids in Uganda. Phytoparasitica 35: 27-36
- [22] Mailafiya, D.M., Le Ru, B.P., Kairu, E.W., Dupas, S. and Calatayud, P.A. (2011) Parasitism of lepidopterous stemborers in cultivated and natural habitats. Journal of Insect Science 11: 1-19
- [23] Moolman J, Van den Berg J, Conlong D, Cugala D, Siebert S, Le Ru BP (2014) Species diversity and distribution of lepidopteran stem borers in South Africa and Mozambique. Journal of Applied Entomology 138: 52-66
- [24] Udayagiri S, Welter SC (2000) Escape of *Lygus hesperus* (Heteroptera: Miridae) eggs from parasitism by *Anaphesiole* (Hymenoptera: Mymaridae) in strawberries: plant structure effects. Biological Control 17: 234-242.
- [25] Sétamou M, Jiang N, Schulthess F (2005) Effect of the host plant on the survivorship of parasitized *Chilo partellus* Swinhoe (Lepidoptera: Crambidae) larvae and performance of its larval parasitoid *Cotesia flavipes* Cameron (Hymenoptera: Braconidae). Biological Control 32: 183-190.
- [26] Overholt WA, Songa JM, Ofomata V, Jeske R (2000) The spread and ecological consequences of the invasion of *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) in Africa. In E. E. Lyons and S. E. Miller Invasive species in eastern Africa: Proceedings of a Workshop held at ICIPE, July 5-6, 1999. ICIPE Science Press, Nairobi