INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 7, No. 5, p. 51-58, 2015

RESEARCH PAPER OPEN ACCESS

Diversity and spatial distribution of stem borers and their natural enemies on off season sorghum, *Sorghum bicolour* (L.) Moench (Poaceae), in the Sudano-sahelian zone of Cameroon

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Article published on November 21, 2015

Key words: Cameroon, Lepidopteran stem borers, Pest control, Parasotoid, *Tetrastichus sp.*

Abstract

Lepidopteran stem borers are among the most damaging insect pests of cultivated Poaceae in Africa. The objective of this study was to assess the diversity and the relative abundance of Lepidopteran stem borers and evaluate the larva-pupalparasitization in farmer's fields. Surveys were conducted during two transplanted sorghum' cropping seasons (2012/2013 and 2013/2014) in 3 agro-ecological sub-units in the Sudano-sahelian zone of Cameroon: Mandaras' piedmonts (MP), Diamare plain (DP), Logon valley (LV). Destructive method was used to collect caterpillars and pupae from plants according to developmental stages of the sorghum this was followed by their identification. Pupae were reared under laboratory conditions and emerging insects were recorded. They were the expected moths or their parasitoids. During the two years, 180 fields were sampled. Three stem borers' species (Lepidoptera: Noctuidae) were identified and the most abundant being *Sesamiacretica*Lederer (68.27%), followed by *S. poephaga* (27.54%) and then *S. calamistis* (0.19%). It was also appeared that *S. cretica* and *S. poephaga* were present in sampled areas whereas, *S. calamistis*occurred only at LV. Parasitoids species obtained belong to 3 Orders: Hymenoptera,Diptera and Coleoptera. The most important pupalparasitoid of the zone was *Tetrastichus*sp (Hymenoptera: Eulophidae). Highest parasitization (17.15±14.59%) was recorded at MD followed by LV (14.15±7.42%) and the DP (11.19±0.69%). *Tetrastichus*sp is a potential biological control agent of stem borers and could be used in integrated pest management process to prevent economic damage ofthe sorghum by the borers.

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Introduction

Because of its seeds, its sugar content and its feed quality, Sorghum is a major cereal produced worldwide (Liu *et al.*, 2009). Transplanted sorghum is an off-season crop specific in the Lake Chad Basin (Carsky *et al.,* 2002; Seignobos, 2008) including northern Cameroon, northern Nigeria and West of Chad. It is a staple crop for smallholders whose production depends mainly on the intensity of the rainy season. Transplanted sorghum contributes to alleviate negative impact of food shortage in northern Cameroon. However, diverse insect pests attack and destroy transplanted sorghum in field mainly Lepidopterous stem borers. They are most important insect pests of maize, *Zea mays* L. and sorghum (Polaszek, 1998). It is recently reported (Djodda *et al*., 2013) that Lepidopterous stem borers, particularly *Sesamia*spconstituted the major pest on transplanted sorghum at Diamare (north Cameroon).

The very first step to put in place in the integrated pest management approach is to access the diversity, the spatial distribution, the relative abundance of the pest and thereafter, elicit the pest status of the targeted insect. It is established that survival of Lepidopterous stem borers is under environmental conditions (Bosque-Pe´rez and Schulthess, 1998; Ong'amo *et al.,* 2006, Tonou *et al.,* 2013). Some particularities explain specificity of the occurrence of some species in précised ecosystems. For instance, *Busueolafusca*is the dominant stem borer species in highlands while *Chilopartellus* (Swinhoe) (Lepidoptera: Crambidae) dominates in lowlands (Emana *et al*., 2008; Asmare *et al.*, 2014). Overholt *et al*., (2001) reported that *Sesamiacalamistis*and *Eldanasaccharina*are the major pests in West Africa whereas *B. fusca*and *C. partellus*are the dominant species in East Africa. In Sudano-sahelian zone of Cameroon, previous studies reported lepidopteran attacks caused heavy damage (Ayaji *et al*., 1996; Mathieu *et al*., 2006; Aboubakar *et al*., 2008). Nevertheless, spatial distribution of these species through the different agro-ecological sub-units of the zone is not yet known. Thus, understanding species distribution and abundance of stem borer communities will constitute basic information necessary for the implementation of efficient integrated pest management strategies. One of the most important steps in achieving this is by describing the diversity and the distribution of stem borers in area of cultivation of off season sorghum in the northern Cameroon.In the other hand, some previous studies done where stem borers are effective crop pest reported that their populations are regulated by diverse groups of both indigenous and exotic parasitoids (Bonhof *et al*., 1997; Zhou *et al*., 2003; Mailafiya *et al*., 2009). They are for some solitary and for other gregarious, they feed on their host internally (endoparasitoids) or externally (ectoparasitoids) (Metcalfe and Luckmann, 1975). The work to carry out in the present research on off season sorghum is the diversity of parasitoids of stem borers and their efficiency to reduce stem borer damages on crops is reduced.

Material and methods

Presentation of sampling sites

Surveys were conducted in 3 agro-ecological sub-units of the Sudano-sahelian zone of Cameroon. The Waza Logone Flood plain or Logon valley (LV) is characterised by annual average rainfall inferior to 600 mm. It is the low-altitude unit with 290m above sea level in mean. The peneplain of Diamare or Diamare's plain (DP) is characterised by annual average rainfall included to 600-800mm. The Mount Mandara piedmont (MP) is situated in altitude, about 550 above the sea level. The rainfall is best, around 100mm per year. The study areas experience unimodal rainfall, the rainy season is short, main rain July to August. Annual total precipitation is between 400mm at LV to 1000mm at MP. Annual mean temperature in the zone is 28°C. The Northern Sudano-Sahelian region (LV) is experiencing increased incidences of drought and desert advancement.

Sampling procedures

Surveys were conducted during two cropping seasons: to October 2012 at February 2013 and to October 2013 at February 2014. According to the relative importance of the transplanted sorghum area at each

sub-agro-ecological unit, randomly, selected 12, 4 and 2 localities were considered from respectively DP, LV and MP (Table 1). To each selected locality, five well managed farmers' fields (untreated) with a minimum size of 0.25 ha were selected. The fields were selected on the basis of accessibility and area coverage of sorghum; all fields were covered with the *safraari* sorghum cultivar.

Table 1. Location of selected sampling sites.

Agro ecologicalsub-units	Localities	Longitude	Latitude	Altitude (m)
Diamare's plain (DP)	Papata	14°35213	10°76507	390
	Lara	14°48983	10°14636	404
	Godola	14°28101	10°68018	459
	Wawili	14°02332	11°18625	387
	Mangavé	14°21889	10°93425	419
	Moutourwa	14°20230	10°23313	472
	Padam	14°36162	10°11730	419
	Mindif	14°45605	10°34126	407
	Pivou	14°41973	11°32420	309
	Ibba	14°43867	10°69740	367
	Dargala	14°61086	10°52831	354
Logone valley (LV)	Kousseri	14°97240	12°08608	290
	Magam	14°41189	12°36914	285
	Oudah	14°74490	12°19511	291
	Dabanga	14°63887	11°90600	290
Mandara piedmont (MP)	Zamay	13°91079	10°61991	617
	Mowo	14°01391	10°59325	593

A total of 90 fields from 18 localities was assessed. In each field, five plots with 10×10 m sizes were sampled. The assessments were conducted in vegetative, flowering, seedling and harvesting stages of sorghum. The same fields were used for different time of sampling. In each plot, all plants were counted, two attacked plants per plot (10 plants per field) were cut down at every sampling visit, dissected and data on the number of larvae, pre-pupa and pupae were collected.

Larvae collected are preserved in alcohol at 70° then subsequently identified according to the key of identification provided with Moyal and Tran (1989), Tran (1981) and that of Polaszek and Delvare (2000).Pupae were taken alive at the laboratory and kept separately in a glass tube closed with cotton until emergence of parasitoid or of stem borer. Parasitoids emerging from pupa were collected, counted, preserved at alcohol at 70° and insect sample was identified according to the key of identification of Polaszek and Delvare (2000). Death pupae that did not produce parasitoids were dissected and those containing some stages of parasitoid were considered as parasitized.

Analysis of the diversity of stem borers sampled

Evaluation of the diversity and the spatial distribution of stem borers' species sampled were assessed using 3 diversity indexes: Shannon index (H), Simpson's diversity index (*D*) and Hill's diversity numbers.

Shannon index (H)

Shannon index (*H*) value allows knowing not only the number of species but also the distribution of these species among the community. If the species are evenly distributed then the *H* value would be high. *H* is calculated according to formula:

$$H = -\sum_{i=1}^{S} \text{Pi lnpi}$$

In the Shannon index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

Simpson's diversity index (D)

Simpson's index (D) is a mathematical measure that characterizes species diversity in a given community. The proportion of species i relative to the total number of species (p_i) is calculated, squared, summed, and then the reciprocal is taken according to follow formula:

$$D = \frac{1}{\sum_{i=1}^{s} pi^2}$$

Hill's diversity numbers

A generalized notation provided by HILL that includes, as a special case, two often used heterogeneity indices, D and H. It's calculated according to formula:

$$Hill = \frac{1/D}{e^H}$$

D, is Simpson's index and H, is Shannon index.

Results and discussion

Species composition (Diversity and relative abundance)

During the two years of the study, a total of 720 visits were made in the 18 localities chosen to represent the three sub-agro-ecological units studied. 7,200 plants were dissected and a total of 38,974 stem borers' larvae were collected. Larvae belong to 3 different species including only family of Noctuidae, specially, *Sesamia* Genera. Stem borers larvae recovered were identified as *S. calamistis, S. cretica*, *S. poephaga*. The relative abundance of each species in relationship with the three sub agro-ecological units studied is giving in Table 2. These species varied in distribution among the three sub-agro-ecological units. The most abundant specie was *S. cretica* (68.27%), followed by *S. poephaga* (27.54%) and then *S. calamistis* (0.19%) (Fig. 1). Ajayi *et al.* (1996) indicated the presence of *Sesamiasp* as main stem borer on transplanted sorghum at this zone. Recently, Djodda *et al.* (2013) were identified two species of *Sesamia* (*S. cretica and S. poephaga*) at the transplanted sorghum in the Diamaré, one of the three sub-agro-ecological units studied here. Findings of the present research confirm the previous results, though, it highlight the distribution of these species through the study zone. The understanding of species distribution of stem borer communities in the Sudano-sahelian zone of Cameroon such as indicated by ours results constitute basic information necessary for future development of management strategies against these pests.

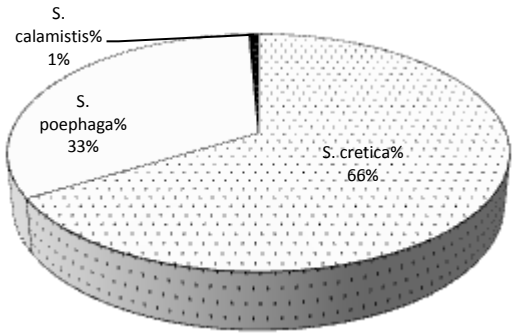

Fig. 1. Mean yield of the three stem borers species in the zone of study.

Stem borers' spatial distribution in the three sub-agro-ecological units (biogeography)

S. cretica and *S. poephaga* were species found in all the surveyed areas but, *S. calamistis* was recorded only at LV sub-unit (Fig. 2, Table 2). As demonstrated by Ong'amo *et al.,* (2012), the spatial distribution of stem borer's species was influenced by environmental conditions and host preference. Batalden *et al.*, (2007) concluded also that the current climate variability can be a source of the abundance or the distribution of stem-borer pests. *S. calamistis* which was recorded only at LV was described as main pests of millet and maize than the two others species which attack preferentially sorghum and maize than millet. Djimmandoungar (2002) recorded *S. calamistis* at both transplanted and rainy season sorghum at Djamena, bordering LV. The presence of *S. calamistis* only at LV might be due to proximity of this unit to Sahel zone where millet constitutes the main cereal crop. This suggests that pest species have higher affinity with their host, in others words, the

distribution of host influence the distribution of pest.This first part of the study permitted to establish the map of stem borers' species on transplanted in the Sudano-sahelian zone of Cameroon.

Table2. Percentage of different stem borers' species in the three sub-agro-ecological studied units.

	S. cretica%	*S. poephaga%*	*S. calamistis%*
LV	62.27±2.81	36.67±2.63	1.02±0.45
DP	74.49±2.98	25.50±2.98	0
MP	62.27±2.81	36.67±2.63	0

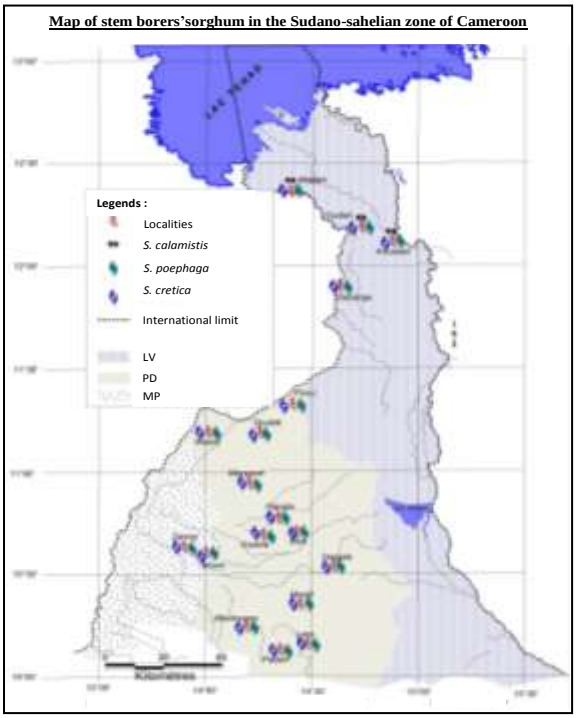

Fig. 2. Spatial distribution of stem borers' species of transplanted sorghum.

Structuring of stem borers' communities in the three sub-agro-ecological units

Tables 3 and 4 present respectively the calculated diversity indices of the three studied areas and the index of repartition of borers through the study zone. Values of calculated *H* varied to 0.53 at the PPM at 0.69 at the LV. According to Frontier (1983), increasing of number of species at a given ecosystem can be expressed by the increasing of the *H* value. Results indicated that the three sub-agro-ecological units studied have approximately equivalent richness in term of species. Values of Hill index confirm the presence of few species at the studied zone. It might be concluded that transplanted sorghum was attacked by a limited number of stem borers' species at sudano-sahelian zone of Cameroon. As regards spatial distribution of stem borers' species identified on transplanted sorghum, the calculated values of repartition index (I) are superior to 1 (Table 4). This testifies the hypothesis of an aggregate distribution of pests in the fields. Generally, gregarious distribution of species indicates a concentration of food resource. Animal have tendency to gather around the source of food. Indeed, *Sesamia*sp, main stem borer present at the study zone lay a mass of eggs on sorghum. After hatching, youngest larvae feed on these plants, then moving to others proximate plants, this can explains the gregarious distribution of borers throughout the studied zone.

Table 3. Calculated diversity Indices in the three agro-ecological sub-units.

Indices	Years	LV	DP	MP
H	2012/2013	0.69	0.62	0.53
	2013/2014	0.64	0.58	0.66
J'	2012/2013	0.58	0.54	0.76
	2013/2014	0.62	0.52	0.52
D	2012/2013	0.54	0.56	0.58
	2013/2014	0.55	0.57	0.54
Hill	2012/2013	0.93	0.96	0.99
	2013/2014	0.95	0.98	0.96

Table 4. Index of repartition of stem borers' species.

species	LV	DP	MP
S. cretica	13.61	15.76	19.92
S. poephaga	6.43	12.18	16.15
S. calamistis	9.69	/	/

Diversity and occurrence of parasites

Occurrence of parasites

During the study period, a total of 3195, 1030 and 467 pupae were recovered respectively at PD, LV and MP. Calculated mean parasitization level was 11.19±0.69% at PD, 14.15±7.42% at LV and 17.15±14.59% at MP. This suggested that parasitoids were good mortality factors reducing the population of stem borers.

Mailafiya *et al.,* 2011, have obtained a 15.0% level larval parasitization. At the DP, the parasitization level was remained constant, around 11% throughout the different stages of the sorghum (Fig. 3). Nevertheless, the parasitisation level at the LV and MP was high (25.22% and 36.67% respectively) at vegetative stage and was notorious decreased at flowering, seedling and harvesting stages (Fig. 3). These results show that parasitoids attack stem borers early since vegetative stage. This means that their utilization at this stage of the sorghum could prevent or reduce number of early emerging moths responsible of massive attacks of sorghum at succeeding stages.

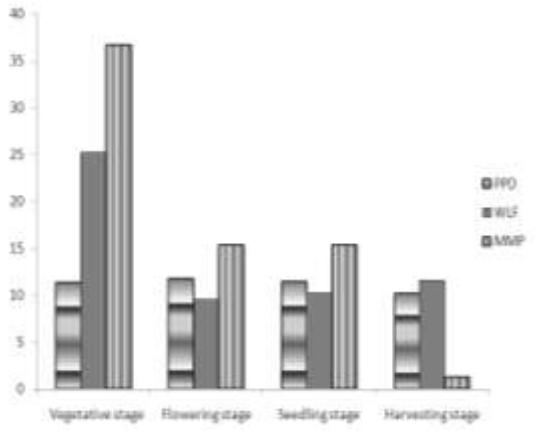

Fig. 3. Parasitization level during different developmental stages of sorghum.

Diversity of parasites

Parasitoids reared from the stem borers belonged to three orders, namely Diptera, Coleoptera and Hymenoptera. The two families of Hymenopteran order were Eulophidae and Pteromalidae. The major specie collected was *Tetrastichus sp*. This specie was recorded as parasitizing pupae of some Lepidoptera (Duong *et al*., 2011; Vergas *et al*., 2011).According to table 5, the number of *Tetrastichussp* collected was important throughout the study zone compared to the other species. This suggested that *Tetrastichu ssp* is well adapted at the study zone and could be an important potential biological control agent of stem borer pest in Sudano-sahalian zone of Cameroon. All the Hymenopteran parasitoids recorded were internal (endoparsitoid). Dipteran, *Megaseliasp* is a solitary parasitoid while Hymenopteran are gregarious ones as soon as the Coleopteran parasitoid. Parasitoids are insects which lay their egg in or on others insects and finally kill them. Generally, the most known parasitoid belong to Diptera or Hymenoptera (Vergas *et al*., 2011; Wisdom *et al*., 2012, Fabricio *et al*., 2015), however, during this study Coleopteran were emerged from a stem borer pupa. Deeper study must be conducted to define exactly the status of these Coleopterans and their utilization as potential biological control agent of stem borers.

Table 5. Diversity and relative abundance parasitoids.

			Number per sub-unit		
Orders	**Families**	**Species**	**MP**	**LV**	**DP**
Hymenoptera	Eulophidae	*Tetrastichussp*	2046	2971	7199
Hymenoptera	Pteromalidae	nd	0	65	1320
Diptera	Phoridae	*Megaseliasp*	0	0	1
Coleoptera	*nd*	*nd*	0	0	32

nd : not identified

Conclusion

The results of the present study provided the map of stem borer species through the Sudano-sahelian zone of Cameroon and indicate the existence of natural enemies of the borers, mainly *Tretrastichussp*. Parasitizing *Sesamia* sp. pupa. Potential utilization of this larva-pupalparasitoid should, however, be investigated for improvement in the mass rearing, the dispersion in the field and the association with others potential eggs and larvae parasitoids.

Acknowledgement

Authors are grateful to farmers for according their farms during the two years of this work. They

acknowledge the technical assistance offered by some agricultural technicians during field collection materials

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