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Distribution of rice stem borers and their parasitoid in irrigated low land rice ecosystem in Kilombero valley, Morogoro, Tanzania

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Abstract
Distribution of rice stem borers and their parasitoid, in irrigated low land rice ecosystem in Kilombero district, Morogoro, Tanzania was studied from March – July 2017 in randomly sampled thirty rice fields. Rice stem borer larvae was sampled at two growth stages of rice, the vegetative stage and reproductive stage using 1m^2 quadrat. The study revealed the presence of one species of parasitoid from family braconidae (*Cotesia flavipes*) which was found parasitizing the stem borer larvae. The density of borers (larvae), parasitoids and parasitism rates were respectively 103.82, 16.2 and 47.91% recorded during reproductive stage. Relatively lower values were recorded during the vegetative stage with mean density of 71.13 stem borers, 10.18 parasitoids and 36.39% parasitism rates. Chilo sp was highly parasitized on compared to *Sesamia calamistis* due to their greater abundance. The Morister's index suggested an aggregated dispersion of both stem borers and parasitoids. The aggregation of borers and parasitoid (*C. flavipes*) were recorded more at edges of the field than at the middle of the field suggesting their sources to be from other hosts rather than rice crop.

Keywords: Stem borers, *Cotesia flavipes*, density, parasitism, field parts, rice growth stages Tanzania

1. Introduction

Stem borers particularly *Chilo* spp and *Sesamia calamistis* (Hampson) have been reported as major biotic constraints in cereals production in sub-Saharan Africa where a potential yield loss of up to 73% can be incurred [1]. The stem borers have four stages of growth which includes egg, larvae, pupa and adult where larvae have been reported as the only destructive stage [2]. The borers lay eggs at the basal of the leaf closer to the tips of leaf blades at the lower part of the leave blades where it takes about 3 – 4 days prior hatching [3]. The larvae craws upward along plants upon hatching where they can move to the neighbouring plants in between leaf sheath by the aid of wind or water through swimming and stay in the stem where they obtain food throughout the larvae stage [4]. The larvae undergo several instars depending on the species (Harris 1990) and temperature [4]. Depending on stem borer species, the larvae stage may last for about 25 – 58 days and pupation for about 5 – 14 days [5]. The first instar larvae of most stem borer species feed primarily on young and unfolded leaf tissues where older larvae feed internally by tunnelling the stem [6]. Pupation occurs within stem, straw or stubble of the rice crop [7]. In general, the life cycle of many rice stem borers from egg to adult ranges from 42 to 83 days [8].

Several groups of indigenous and exotic parasitoids such as Braconid, Cameron and the Eulophid have been reported as most important parasitoids attacking stem borers in maize and sorghum fields [9]. In Asia, Rami *et al*. [10] have reported augmentation test for mass release of stem borer parasitoids such as *Trichograma japonicum*, *Telenomus rowani* and *Tetrastichus schoenobii* with some success in controlling rice stem borers damages in China. In Africa, Moolman *et al*. [11] reported Bracon sp (Hymenoptera: Braconidae) and *Cotesia sesamie* (Hymenoptera: Ichneumonidae) respectively as parasitoids found parasitizing many stem borers species in Poaceae, Cyperaceae, Juncaceae and Typhaceae families in South Africa and Mozambique.

These parasitoids belong to the Hymenopteran insects with highly specialized ovipositors for stinging and depositing eggs in the host. The host is affected through stinging effect that causes permanent paralysis in the host body [12].

The study by Cugala [13] revealed *Trichogramma* spp as important parasitoids of eggs of stem borer species and *Cotesia* spp as important parasitoid of stem borer larvae in Zambia. In Tanzania several stem borer parasitoids including *Cotesia* spp, *Dolichogenidea aethiopica* Wilkinson have been reported in Maize and Sorgum [14]. Similar or different parasitoids can be found in rice which can in future be used as important biological control. This important information is lacking under Tanzania contest.

Among the parasitoids of stem borers, *Cotesia* spp have been reported as only parasitoid observed attacking multiple stem borers' species such as *Chilo.* spp, *Sesamia calamistis* and *Busseola fusca* [15]. This parasitoid of Asian origin was introduced in Kenya in 1991 for classical biological control programme where it was proved to reduce the population of *C. partellus*, *C. orichalcociliellus* and *S. calamistis* by 30% in maize crop [16] and later was introduced in Sothern and Eastern African countries including Mozambique in 1996, Uganda and Somalia in 1997 [17] and in Ethiopia in 1999 [18]. In Tanzania *C. flavipes* was reported parasitizing *C. partellus* and *S. calamistis* in maize and sorghum crop [14]. The source of *C. flavipes* population in Tanzania is unknown but is most likely the source released by ICIPE in Somalia, Kenya and Uganda [15, 19]. Parasitism of Lepidopterous stem borers by *C. flavipes* have been focused on only two cereal crops which includes *Zea mays* and *Sorghum bicolor* and four wild host plants which includes *Cyperus* spp, *Panicum* spp, *Pennisetum* spp and *Sorghum* spp [20, 21] but limited facts are available on stem borers parasitism in rice crop. Stem borers density and parasitism rates may depend on growth stages of crop. Dejen *et al*. [15] have reported the highest *C. partellus* larvae density and parasitism rates by *C. flavipes* during booting stage than harvesting stage in *Z. mays* and *S. bicolor* crops in Ethiopia providing the knowledge gap for studying population density and parasitism rates of stem borers in low land rice ecosystem in Tanzania. Population density of borer pest complex in different growth stages of the rice plant would be useful to decide appropriate time for management practices such as insecticide application. This study, therefore, aimed at assessing the stem borers density and extent of *C. flavipes* parasitism at different growth stages of rice crop.

2. Materials and Methods

2.1. Description of the study sites

The present study was conducted in the famous Rice growing Kilombero Valley in Morogoro Tanzania from March – July 2017 in three wards which are under irrigated low land rice ecosystem viz; Signali (8° 0' 1.4234" S, 36° 50' 13.5179" E, 264m a.s.l), Mkula (7° 46' 4.2672" S, 36° 56' 43.4076" E, 261.27 m a.s.l) and Sanje (7° 45' 33.1981" S; 36° 55' 15.0247" E, 307.788 m a.s.l). From each ward ten farmers' fields of at least one acre and which are located at a distance of at least 0.5 km were selected for the study from each ward. Rice fields were divided into three equal parts (two edge parts and middle) where an equal number of plants with stem borer symptoms were randomly uprooted from each part (50 plants from each) along X/Y coordinates using the method of Niyibigira *et al*. [14] for destructive sampling and dissected to remove medium to large (3^{rd} – 6^{th} instar) larvae from the stem. The sampling assumes a split plot design where wards were termed as main plot and farmers' field's as subplots. Sampling was conducted at 6 weeks after planting (vegetative) and 12 weeks after planting (reproductive) stage of rice growth.

The larvae were reared individually on small pieces of rice stems placed in glass vials (8.5 x 2.7cm) at room temperature (26.9 ± 1^0C) and inspected every two days for mortality or parasitoid emergence [22]. Stems were replaced at each inspection to avoid fungal attack. The pupal stages were removed from the vial and placed in separate bottle plugged with cotton wool. All emerging adult moths were identified and then destroyed. The specimens of each emerged parasitoids species were labelled and preserved in 100% alcohol and sent to Sokoine University of Agriculture laboratory for identification. The emerged parasitoids were identified using identification guide as described by Pathack and khan [3] and parasitism rates calculated using the method of Degen *et al*. [15] as follows;

$$\%\ \text{Parasitism} = \frac{\text{No of parasitized larvae}}{\text{Total number of larve}} x100$$

2.2. Distribution of rice stem borers and their parasitoids

The spatial distribution pattern for stem borer and their parasitoids was determined by Morista index of dispersion as described by Morisita[23] and as modified by Amaral *et al*. [24] as follows.

$$\text{Morista's index } (I\delta) = \left(\frac{B-A}{A^2-A}\right)q;$$

Whereby $I\delta$ = Index or Coefficient of dispersion, q =Total number of plots sampled, A = Sum of species in each plot, B = Sum of squares of number of species in each plot. If $I\delta < 1$, $I\delta = 1$ and $I\delta > 1$ indicate uniform, random, and aggregated spatial distribution patterns, respectively.

2.3. Data collection and analysis

Data collected under this study were the number of stem borer larvae per strata and number of parasitoids per strata. Stem borer density and parasitoids density were analysed using R software and bar charts drawn using excels. Spatial distribution of both stem borer and parasitoids were established using Morisista index of dispersion as described by Morisita [23] and as modified by Amaral *et al*. [24]. The Parasitism rates were calculated from each ward, field part and growth stages of rice crop and subjected to R statistical software for analysis. Means were separated using Fishers Least Significant difference (LSD) at $P \leq 0.05$. Regression analysis was performed using Excel to determine relationship between stem borer density and parasitism rates.

3. Results

3.1. Distribution of rice stem borers and their parasitoid in Kilombero

Morita's dispersion index for stem borer larvae indicated that there was more number of stem borer larvae at rice vegetative stage in three wards of Signali, Mkula and Sanje with an aggregate distribution of both stem borer larvae and parasitoids (Table 1).

Table 1: Effect of locations and rice growth stage on dispersion index of rice stem borers and their parasitoids

Ward	Morisita's Index for stem borers larvae		Morisita's Index for parasitoids	
	Vegetative	Reproductive	Vegetative	Reproductive
Signali	9.673	8.542	13.562	11.472
Mkula	9.323	8.289	14.547	13.008
Sanje	9.088	8.589	17.374	13.265

3.2. Stem borer larvae and *C. flavipes* density in field parts

There were significant differences between fields in mean stem borer density and *C. flavipes* density per stratum (Fig 1 and 2). The highest stem borer and *C. flavipes* density was recorded from edges of the rice field than from the middle of the fields regardless of the rice phenological stages.

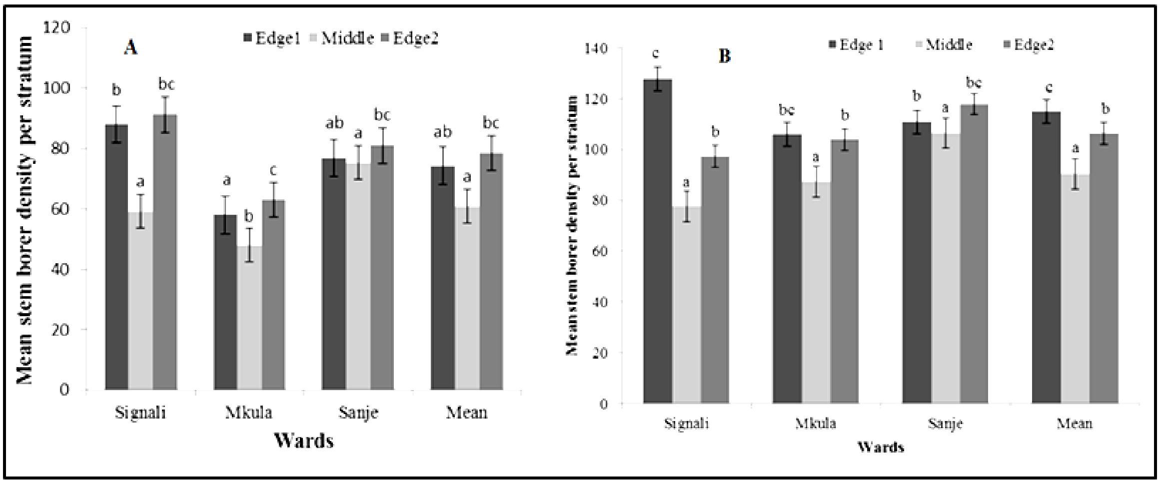

Fig 1: Stem borers aggregation at vegetative (A) and at reproduction stage (B) within rice field. Bars with the same letter are not significant (P < 0.05) using Fisher's Least significant difference test.

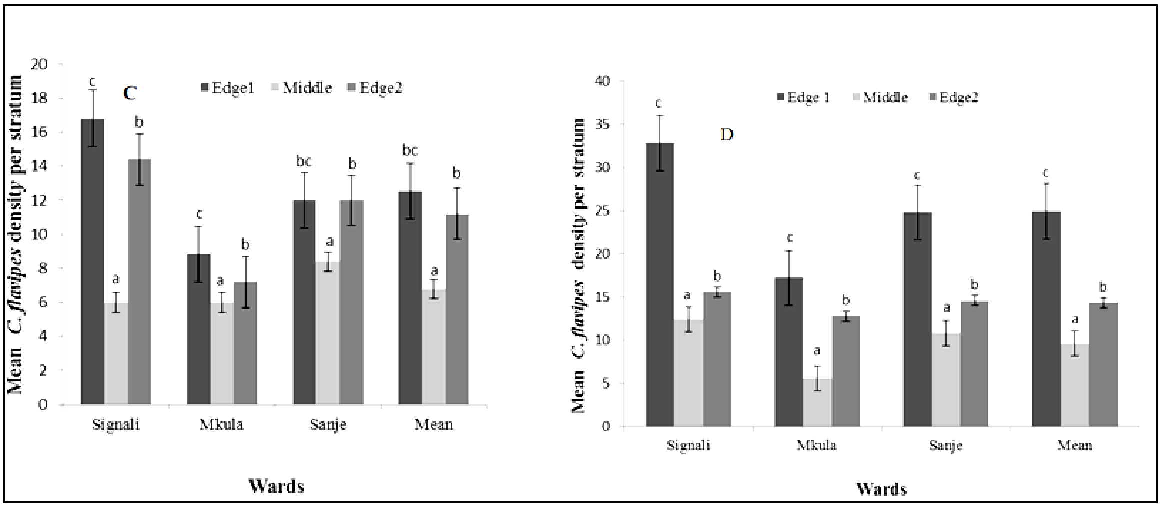

Fig 2: *C. flavipes* aggregations at vegetative (c) and at reproduction stage (D) within rice field. Bars with the same letter are not significant (*P*< 0.05) using Fisher's Least significant difference test.

3.3. Stem borers larvae parasitism rates at different rice growth stages

The rate of stem borer parasitism by *C. flavipes* was similar across locations, but differed between rice growth stages (Table 2). There was high rate of parasitism of stem borers at rice reproductive stage (42.8% to 51.6%) than at vegetative stage (34.5% to 39.1%).

Table 2: Stem borers parasitism in three wards surveyed at different rice growth stages

Wards	*Chillo* sp parasitism %		*S. calamistis* parsitism %		Total parasitism %	
	Vegetative stage	Reproductive stage	Vegetative stage	Reproductive stage	Vegetative stage	Reproductive stage
Mkula	33.17a	37.57a	1.46a	5.26a	34.63a	42.83a
Sanje	32.6075a	43.61a	2.81a	5.65a	35.42a	49.26a
Signali	35.572a	48.25a	3.57a	3.39a	39.14a	51.64a
$F_{2,2}$	0.04	2.12	0.35	0.1	0.21	0.35
P- value	0.957	0.087	0.731	0.91	0.816	0.725
S.E	6.344	5.915	0.7704	1.315	15.27	22.22
LSD	16.48	15.37	2.002	3.416	20.42	30

Means within columns followed by the same letters do not differ significantly (*P*<0.05) (Fishers least significant difference)

3.4. Rate of stem borer parasitism by *C. flavipes* in field parts at different rice growth stages

There were significant differences between field parts samples in rate of stem borers parasitism (Table 3). The rate of parasitism was high at the edge of the rice fields sampled than at the middle of the field both at vegetative and reproductive stages. There was high rate of parasitism at rice reproductive growth stage (18.7% to 45.5%) than at rice vegetative stage (23.7% to 67.5%).

Table 3: Stem borers parasitism in three field parts surveyed at different rice growth stages

Field part	Crop growth stage	
	Parasitism at Vegetative (%)	Parasitism at Reproduction (%)
Edge 1	45.5b	67.5b
Edge2	44.9b	52.46ab
Middle	18.77a	23.77a
$F_{2,2}$	8.62	8.31
P- value	0.035	0.038
S.E	2.41	4.56
LSD	20.42	30.26

Means within columns followed by the same letters do not differ significantly ($P<0.05$) (Fishers least significant difference)

3.5. Relationship between *C. flavipes* parasitism rates and stem borer larvae density

Rate of parasitism of stem borers by C. *flavipes* was directly correlated to stem borer density (Fig. 3) both at vegetative and reproductive growth stage of rice

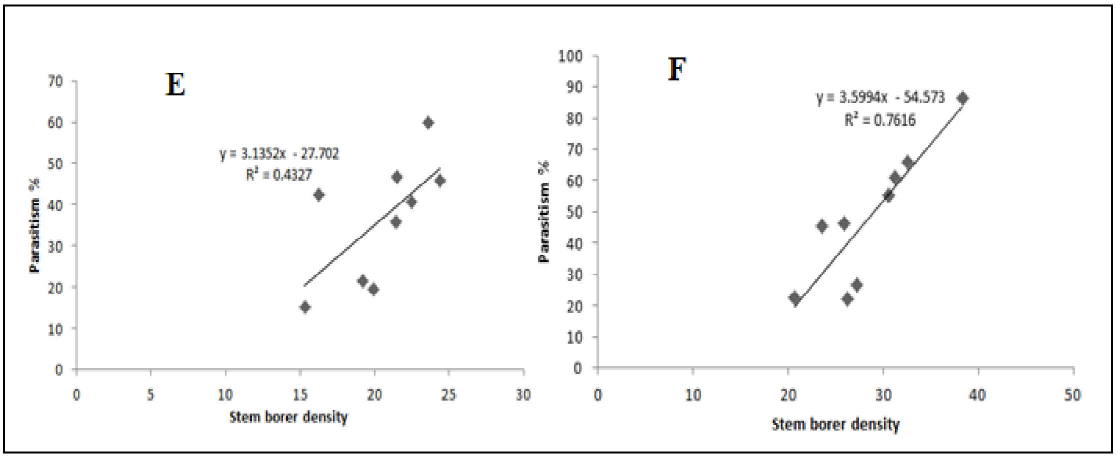

Fig 3: The relationship between mean percentage of stem borers parasitism and stem borer density per strata at Vegetative (E) and Reproduction (F) stages of rice in Signal, Mkula and Sanje wards of Kilombero District. The 9 points in the graph showed mean of three wards in three field parts.

4. Discussion

The results under this study reported the highest density of stem borers larvae stages and parasitoid in the edge parts than middle parts of the field in all three wards surveyed. These findings are in parallel with the study of Casey and Trumble [25] who reported that for the development of sampling plan, one should concentrate on the edge of the field because it is where the borers are accumulated. Concentration of borers and parasitoid in edge parts of the field implies that the borers come from alternative host plants which are around the field. Gounou and Schulthess [26] reported distribution and aggregation of stem borers in various plant hosts assessed which are in line with the findings of this study. This is further reinforced by the study of Harris [27] who reported cereal stem borers as polyphagous in nature for their behaviour of attacking several gramineous and other non-cultivated wild host plants. Le Ru *et al.* [28] reported several wild host plants of stem borers in East Africa including Poaceae, Cyperaceae and Typhaceae which are also found in Kilombero district. These alternative host plants were probably the sources of stem borer's reservoirs for rice crop under the study area. Showler *et al.* [29] reported the higher abundance and diversity of Mexican rice borer (*Eoreuma loftini*) in sugarcane field infested with grasses and broad leaf weeds or mixture of both weed types as compared to weed free sugarcane field.

The density of stem borers and parasitoid (C. *flavipes* under this study were observed high in reproduction stage than in vegetative stage of rice growth. Consistent with the results in this study, Litsinger *et al.* [30] also observed higher stem borer larvae density during reproduction than vegetative stage of maize crop suggesting the reason being the assurance of borers in getting more nutritious food in stem at reproduction/tasselling stage of maize. They also reported high larvae parasitism rates during reproduction stage than in vegetative stage which implies high density of the parasitoids in late stages than early stages of maize growth. The findings of this study are further supported by BRRI Annual Report [31] which described various ecological factors including plant ages as among factors affecting fluctuation of pest and natural enemies in rice ecosystem. In addition, Wale *et al.* [32] reported the population of ants which were commonly seen preying on *Busseola fusca* of sorghum in Ethiopia increased with crop phenology. Against the findings of this study, Rahman *et al.* [33] reported stem borer hunting spiders reach peak during 60 to 75 days after transplanting and their population further declines with the age of the crop.

The study showed aggregation distribution of stem borers (larvae) and that of parasitoid(*C. flavipes*) within the fields according to Morisita index where it was greater than one in all wards surveyed. This agrees with the study of Leonard and Rwegasira [34] who reported aggregated distribution of stem borer larvae in rain fed rice ecosystems in different wards of Kahama District in Tanzania. Highest parasitism rates were recorded in Signali in both rice phenology but not significantly different among wards. The similarities in parasitism rates can be due density of borers in similar trends in both wards and in both field parts. This agrees with the study of Elliott *et al.* [35] who reported the abundance of natural enemy populations to increases with increase in host population. According to this study, the density of borers and parasitoid were high at the edge parts than at the middle of all fields surveyed where highest parasitism was also recorded. The reasons would probably due to edge parts of the field being closer to natural habitats with alternative hosts which ensure availability of enough food for assurance of parasitoid survival. Maliafiya *et al*. [21] reported natural habitat as essential means of providing refuges for some parasitoid species for stem borers. Parasitism of borers by *C. flavipes* was recorded high at reproduction stage than vegetative stage. This was in line with the study of Degen [15] who reported high parasitism rates of *C. flavipes* on sorghum stem borer (*C. partellus*) larvae in Ethiopia during booting stage than harvesting stage of sorghum. In addition Sow *et al*. [36] described a significant correlation between *Cotesia plutellae* Kurdjumov (Braconidae), a larval parasitism rates of Diamond back moth (*Plutella xylostella* L. (Lepidoptera: Plutellidae) with the age of cabbage which is also in line with the findings of this study. This study reports for the first time on parasitism of stem borers by *C. flavipes* in rice crop in Tanzania with parasitism rates of 36.4% - 47.9%. Previous study recorded parasitism rates of 3.9% and 1.9% in Zanzibar [14], 76.4% in Kenya [21], 31% in Uganda [37], 73% in Ethiopia [38] and 30% in India [39] which were all from maize and sorghum crop.

The present study revealed a significant positive relationship between parasitisim rates of *C. flavipes* and stem borers density. This was parallel with the study of Maliafiya *et al*. [40] who reported that under normal circumstances the parasitoid richness are positively correlated with borers abundance. The results of this study are further supported by the study of Matama *et al*. [37] of Uganda who reported a positive association between percentage parasitism of *C. flavipes* and population density of *C. partellus* in Sorghum and Maize crops.

5. Conclusion

The findings from this study revealed the presence of two stem borer species (*Chilo* spp and *S. calamistis*) and one species of Braconoid wasp (*Cotesia flavipes*) in which their densities varied with crop phenology and edges of the field. The rate of parasitism of stem borers by C. *flavipes* was directly correlated to stem borer density. Further studies should be conducted to assess relationship between parasitoid density and borers' damages under rice ecosystems in Tanzania.

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