

Research

Abundance and Spatial Dispersion of Rice Stem Borer Species in Kahama, Tanzania

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ABSTRACT. Species diversity, abundance, and dispersion of rice stem borers in farmer's fields were studied in four major rice growing areas of Kahama District. Stem borer larvae were extracted from the damaged tillers in 16 quadrants established in each field. Adult Moths were trapped by light traps and collected in vials for identification. Results indicated the presence of *Chilo partellus*, *Maliarpha separata*, and *Sesamia calamistis* in all study areas. The most abundant species was *C. partellus* (48.6%) followed by *M. separata* (35.4%) and *S. calamistis* was least abundant (16.1%). Stem borers dispersion was aggregated along the edges of rice fields in three locations (wards) namely: Bulige, Chela, and Ngaya. The dispersion in the fourth ward, Kashishi was uniform as established from two of the three dispersion indices tested. Further studies would be required to establish the available alternative hosts, the extent of economic losses and the distribution of rice stem borers in the rest of the Lake zone of Tanzania.

Key Words: abundance, dispersion, stem borer, rice varieties, Tanzania

Stem borers are major biotic constraints to cereal production in sub-Saharan Africa (Mailafiya et al. 2011). These stem borers have been reported to be responsible for yield losses in rice ranging between 5 and 10% or 60% in case of outbreak in Africa and Asia (Pathak and Khan 1994). Stem borers exhibit complete metamorphosis whereby larva is the only destructive stage (Srivastava et al. 2003). With exception of *Sesamia calamistis* (Hampson) that borer direct into stem (Bosque-Pérez and Schulthess 1998), the larvae of first instars in most stem borer species initially feed on young leaf tissues while older larvae feed into stem tissues (Mailafiya et al. 2011).

Approximately 20 stem borer species have been reported as most serious pests of rice throughout the world. In Africa, four species are said to be of economic importance namely: *Chilo* spp., *Diopsis longicornis*, *Maliarpha separata* (Ragonot), and *S. calamistis* (Ismaila 2010, Ogah 2013). These stem borers occur in most tropical African countries namely: Angola, Cameroon, Cote d'Ivoire, Ethiopia, Ghana, Gambia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Nigeria, Reunion, South Africa, Tanzania, Zanzibar, and Zimbabwe (Ismaila 2010). The distribution and abundance of these stem borer species vary among different ecological zones (Ogah 2013).

In Tanzania, three lepidopteran stem borers have been reported to include the white stem borer (*M. separata*), African pink stem borer (*S. calamistis*), and Spotted stem borer (*Chilo partellus*, Swinhoe) (Banwo 2002). These stem borers are highly distributed in rice growing regions like Mbeya, Morogoro, Mwanza, Shinyanga, and Zanzibar. The rice stem borers are among insect pests that lower rice potential yield. Very little work has been done in Tanzania to study the insect pests of rice (Banwo et al. 2001).

In the Lake Victoria zone of Tanzania particularly Kahama district rice growers complained bitterly about damages caused by stem-boring caterpillars. Preliminary visit and interview with growers in 2012 suggested that stem borers could be a problem but substantial facts had to be established (G. M. Rwegasira, personal communication). The species diversity, abundance, and the spatial dispersion of the existing stem borers in rice fields remained unknown. According to Addo-Bediako and Thanguane (2012), the spatial and temporal distribution and abundance of stem borers vary among and within host plants possibly due to their suitability for oviposition and larval development.

Rice stem borers attack the crop from seedling to ear setting stages. Damage caused by stem borers differs depending on the growth stages of the plant (Indike 2002). Caterpillars tend to destroy the stems through boring the leaf sheaths at the node point, feeding on the leaf sheath for about a week after which they enter the stem. Larvae destructive effect on the terminal shoots are manifested through the damage symptom known as "dead heart" (Pathak and Khan 1994). Dead heart symptom is characterized by whitish or discolored area at feeding site of leaf blade and finally the stem turns brown, wilts, and dry. If the stem borers attack at the flowering stage of the plant the panicle becomes white and empty, this symptom is known as "white head" (Pathak and Khan 1994, Indike 2002).

Relative abundance and composition of stem borer species are important aspects to consider in determining the stem borer species present in certain location (Banwo et al. 2001). Various studies of lepidopteran stem borers in Africa have been determining rice stem borer's species abundance basing on upland and irrigated rice (Alam 2011). In Tanzania, abundance and composition of stem borer species have been determined in maize fields and wild host plants in Eastern Zone of Tanzania (Abdulla 2007). However, the abundance, species composition and dispersion as influenced by the different sowing dates in commonly grown rice varieties has never been established under small-scale growers' system. This study aimed at bridging such knowledge gap and established an understanding on varieties most preferred by certain stem borer species and the sowing dates that coincide with peak moth population so that the two can be avoided to minimize damages and yield losses associated with the pests. This study aimed at investigating the existing species of the rice stem borers, the abundance, and spatial dispersion in rice fields in Kahama district, the major rice growing area in the Lake zone of Tanzania.

Materials and Methods

Sampling Procedure in Survey Sites. Twenty farmer's fields were kept under surveillance of larvae and adult moths throughout the growing season from November 2013 to May 2014 in four major rice growing wards of Kahama district (Bulige, Chela, Kashishi, and Ngaya). Rice fields were randomly chosen at approximately interval of 1 km from one farm to the other. A plot size of about 1 acre (70 by 70 m) was

earmarked by using fiber tape. A guard row of ~15–20 m was maintained. Stratified sampling method was used in all selected farms where by the farm was divided into four strata. In every stratum, four quadrats of 1 by 1 m size were established for sampling, thereby making a total of 16 quadrats in each field. In each field selected, sowing date and rice variety were noted. The varieties selected were Kalamata, Mayobhe, and Supa.

A split plot experimental design was considered. Wards were regarded as main plot factor while farmer's fields were regarded as sub plot factor. Name of the rice variety and sowing date in each of the selected fields were recorded.

Stem Borer Species Density and Abundance. Two light traps were used in moths trapping during night time in each field. Where by a white cloth was reinforced with ropes and tied between two stands and wooden splints. Two electrical bulbs (black and white light sources) were attached to the cloth to attract the moths. Moths gathering on the white cloth were collected into collection vials applied with ethyl acetate (99.9%-Harris Reagent: Batch, 922393) and sorted later to identify the respective species. Moths were trapped two times at vegetative stage and two times at reproductive stage in all 20 farms surveyed. Trapping was done for 3 h from 20:00 to 23:00. East Africa time in each farm. Eighty samples were obtained throughout the district.

An identification guide by Pathak and Khan (1994) aided the species identification. Species abundance was calculated according to Thomas (2005) as follows:

$$\text{Abundance of species} = \frac{\text{Number of species}}{\text{Total number of moth}} \times 100\%$$

Stem Borer Distribution. Numbers of larvae of stem borer were counted in each quadrat by observing the number of larvae present in the damaged tillers. Larvae were extracted twice at both vegetative stage and reproductive stage; therefore, 80 samples of larvae were obtained through the surveyed area. The spatial distribution pattern for stem borer was determined by three indices of dispersion, including Morisita index, Iwao's mean crowding regression, and Taylor's power law as described by Morisita (1959), Iwao (1968), and Taylor (1965), respectively. These three indices were chosen so as to obtain consensus of dispersion, because the use of only one index can be misleading (Casey and Trumble 2012). These indices are described by the formula below.

$$\text{Morisita's index (I}\delta) = \frac{\sum_{i=1}^N n_i(n_i - 1)}{n(n - 1)} N$$

Whereby $I\delta$ = Index or Coefficient of dispersion, N = number of samples, n_i = number of individuals in the sample, n = total number of individuals in the sample. If $I\delta < 1$, $I\delta = 1$ and $I\delta > 1$ indicate uniform, random, and aggregated spatial distribution patterns, respectively.

Iwao's mean crowding regression was determined by solving the following equation:

$$m' = \alpha + \beta m$$

Where α (estimated by a) = intercept of the ordinate, β (estimated by b) = slope of the regression line, when m is regressed by mean. Mean crowding m' , was derived from the equation

$$m' = m + (S^2/m) - 1$$

and m was replaced with the mean and variance from the count data. For the part of Taylor power law, the relationship between mean and variance, $S^2 = am^b$, was used to solve the coefficient a and b with linear regression when the log transformation was used.

$$\log(S^2) = \log(a) + (b)\log(m)$$

Test $b = 1$: $t = (b - 1)/SE_b$, and test $\beta = 1$: $(\beta - 1)/SE_\beta$ where SE_b and SE_β are the standard errors of the slope for the mean crowding regression. Calculated values are compared with tabulated t values with $n - 2$ degrees of freedom. If the calculated $t(t_c) < t$ table (t_t) the null hypothesis ($b = 1$) would be accepted and spatial distribution would be random. If $t_c > t_t$, the null hypothesis would be rejected (Arbab 2014).

Data Analysis. The collected data were tested for normally using SPSS statistical package upon which conformity to the normal distribution suggested no need for transformation. Data for borer's abundance were subjected to the one way (ANOVA) and mean separation tested at $P < 0.05$ by using Genstat 15 edition statistical package (VSN international). Coefficient of dispersion data were analyzed by Iwao's crowding regression and Taylor power law indices, regression and parameters were generated by using SPSS statistical package. The least significant difference among means was established at 5%.

Results

Species Abundance and Density in Study Areas. Three species of stem borers, *C. partellus*, *M. separataella*, and *S. calamistis* were recorded from all surveyed sites in the 20 farms assessed (Fig. 1). Of the four wards surveyed, *C. partellus* was highly abundant in Chela (70.7%) and Ngaya (56.8%) while *M. separataella* was highly abundant in Kashishi (58.9%) and Bulige (45.0%). *S. calamistis* was observed to be less important in Bulige, Kashishi and Ngaya. In Chela, *S. calamistis* (16.7%) was the second abundant species after *C. partellus* (Table 1).

Species Abundance in Rice Varieties. In all three rice varieties assessed, *C. partellus* was highly abundant followed by *M. separataella* and the less abundant species was *S. calamistis* (Table 2). A statistically significant difference ($P < 0.05$) was noted among stem borer species (Table 2). *C. partellus* was numerically higher in abundance in Kalamata and Supa varieties than Mayobhe variety. The species *M. separataella* and *S. calamistis* were numerically higher in Mayobhe variety than in Kalamata and Supa. Generally, the results suggest that the abundance of stem borer species is not influenced by rice varieties.

Species Abundance in Different Rice Sowing Date. Significant differences were noted among the different stem borer species on each of the sowing dates. *C. partellus* abundance was highest across the different sowing dates, i.e. 51.6% (15–31 November) and 47% for the crop sown on 1–20 December and 28 December to 05 January (Table 3). *M. separataella* recorded abundance lower than that of *C. partellus* but higher than *S. calamistis* across all sowing dates. *S. calamistis* was the least in abundance. With exception *M. separataella*, the other two stem borer species were highly abundant at the start of the season and the number declined as season progressed.

Stem Borer Distribution. Mean stem borer larvae per quadrat in the four wards ranged from 1 to 2.63, 0.6 to 2.31, 0 to 6 and 1 to 6.13 in Kashishi, Bulige, Chela, and Ngaya, respectively (Table 4). In Kashishi, two indices (0.85 and 0.53) conceded that stem borer population were uniformly distributed in fields while one index (Taylor power law) showed aggregated distribution. In Bulige and Ngaya, all indices were in agreement that stem borer larvae were aggregated in rice fields. In Chela, two indices (Morisita's index and Iwao's mean crowding regression) suggested the aggregate distribution of stem borer larvae while one index (Taylor power law) showed uniform distribution.

Morisita's index was greater than one in Bulige, Chela, and Ngaya indicating aggregated population distribution while in Kashishi was < 1 indicating uniform distribution (Table 4). The slopes of the regression lines for Iwao's mean crowding regression were numerically > 1 in Bulige, Chela, and Ngaya, indicating aggregated distribution while in Kashishi the slope was significantly < 1 indicating uniform distribution. Slopes of the regression lines for Taylor's power law were > 1 in Kashishi, Bulige, and Ngaya indicating aggregated distribution of larvae whereas in Chela slope was < 1 indicating uniform distribution.



Fig. 1. Lepidopterous stem borers trapped during survey: (a) *C. partellus*, (b) *M. separatella*, and (c) *S. calamistis*.

In all of four study locations, stem borer larvae were more aggregated along the edges of rice fields than in the middle parts (Fig. 2). Among these wards, Chela had the highest number of larvae followed by Ngaya and Kashishi while Bulige had the lowest (Fig. 2).

Discussion

During stem borer trapping, three stem borer species were found in all four wards surveyed. These species are *C. partellus*, *M. separatella*, and *S. calamistis*. Similar findings were reported by Banwo (2002). In general *C. partellus* was more prevalent throughout Kahama District than *M. separatella* and *S. calamistis*. The possible reason for such prevalence is the tendency for *C. partellus* to complete its life cycle faster than other species found in the District. Abdulla (2007) reported that *C. partellus* completes life cycle faster than other stem borer species hence high population growth than other species. Similar trend was observed by Nsami et al. (2001) who reported that *C. partellus* was highly abundant in Eastern Zone of Tanzania where it constituted 80% while *S. calamistis* constituted only 4%. *C. partellus* colonizes suitable feeding niches much earlier than the indigenous stem borers, outcompeting and reducing the number of other stem borer species that colonize the similar habitat (Ofomata et al. 2000).

Abundance of stem borers was observed to be affected by locations (wards). *C. partellus* was more abundant in Chela and Ngaya while

M. separatella was more abundant in Bulige and Kashishi than other wards. Given the fact that the rice variety influence on stem borer was insignificant difference in stem borer abundance observed between wards might be due to differences in alternative host plants available around rice fields. Mailafiya et al. (2011) reported the dominance of stem borer species in different host plants rather than plant varieties in Kenya. Likewise, Muhammad (2012) reported that rice varieties have effect on stem borer damage incidence rather than abundance.

Other workers (Govender et al. 2013) reported that in South Africa stem borer species abundance differ depending on the available host plants. Moolman et al. (2013) also reported on the difference in species density among different host plants surveyed. The supposition of alternative host plants being a major cause for varied abundance of stem borer is further supported by the observation by Johnnie (2012) that maize stem borers apart from being affected by host plant distribution, rainfall and relative humidity are the key environmental factors that affect their abundance.

The peak of stem borer abundance varied among species due to the reason that stem borer species complete their life cycle at different time. As such, *C. partellus* was more abundant in rice sown from 15 to 31 November than that of *M. separatella* whose abundance was highest in rice sown from 1 to 20 December. The similar observation was reported

Table 1. Mean (\pm SE) abundance (%) of stem borer species at the study locations (wards)

Ward	Insect species	Abundance (pi)
Kashishi	<i>C. partellus</i>	33.0 \pm 6.95ab
	<i>M. sepearatella</i>	58.9 \pm 8.32a
	<i>S. calamistis</i>	8.1 \pm 4.61b
	F-ratio	5.65
	df	2, 24
	P-value	0.004
Bulige	<i>C. partellus</i>	33.8 \pm 6.95ab
	<i>M. sepearatella</i>	45.0 \pm 8.32a
	<i>S. calamistis</i>	21.5 \pm 4.61b
	F-ratio	5.09
	df	2, 24
	P-value	< 0.001
Chela	<i>C. partellus</i>	70.7 \pm 6.95a
	<i>M. sepearatella</i>	12.6 \pm 8.32b
	<i>S. calamistis</i>	16.7 \pm 4.61b
	F-ratio	12.41
	df	2, 24
	P-value	<0.001
Ngaya	<i>C. partellus</i>	56.8 \pm 6.95a
	<i>M. sepearatella</i>	25.1 \pm 8.32b
	<i>S. calamistis</i>	18.1 \pm 4.61b
	F-ratio	15.3
	df	2, 24
	P-value	<0.001

Table 2. Mean (\pm SE) abundance (%) of stem borer species on different rice varieties

Variety	Insect species	Abundance (pi)
Kalamata	<i>C. partellus</i>	69.9 \pm 6.57a
	<i>M. sepearatella</i>	19.6 \pm 6.95b
	<i>S. calamistis</i>	10.4 \pm 4.49b
	F-ratio	11.9
	df	2, 24
	P-value	<0.001
Mayobhe	<i>C. partellus</i>	53.5 \pm 6.57a
	<i>M. sepearatella</i>	24.4 \pm 6.95b
	<i>S. calamistis</i>	22.0 \pm 4.49b
	F-ratio	6.20
	df	2, 24
	P	<0.001
Supa	<i>C. partellus</i>	55.0 \pm 6.57a
	<i>M. sepearatella</i>	29.4 \pm 6.95b
	<i>S. calamistis</i>	15.6 \pm 4.49b
	F-ratio	12.35
	df	2, 24
	P-value	<0.001

by [Abdulla \(2007\)](#) that *Chilo* spp. complete their life cycle earlier than other species hence becomes highly abundant.

The rice growth stages are also likely to have influenced the stem borer abundance. Trapping of the borers at different growth stage of the crop led to varied numbers suggesting the possible influence of such a crop based parameter. Increased abundance was noted with increase in tillers. According to [Muhammad, \(2012\)](#) large stem diameter usually develop toward flowering stage due to increased rice tillers that subsequently ensures better quality of food for stem borer population build up.

In all of four wards surveyed, at least one of the three indices showed that stem borer larvae were aggregated. In Bulige, Chela, and Ngaya results indicated that stem borer were aggregated along the field edges while in Kashishi two (Morisista's index and Iwao's mean crowding regression) indices of dispersion showed that stem borer larvae were uniformly distributed throughout the fields despite being much concentrated at the edges of field. These larvae dispersion indices generally suggested an aggregated distribution along the edges of rice

Table 3. Mean (\pm SE) abundance (%) of stem borer species as influenced by the sowing dates

Sowing date	Insect species	Abundance (pi)
15 Nov. 2013–30 Nov. 2013	<i>C. partellus</i>	51.6 \pm 6.95a
	<i>M. sepearatella</i>	25.5 \pm 8.32b
	<i>S. calamistis</i>	22.9 \pm 4.61b
	F-ratio	5.23
	df	2, 24
	P-value	0.002
01 Dec. 2013–20 Dec. 2013	<i>C. partellus</i>	47.1 \pm 6.95a
	<i>M. sepearatella</i>	44.5 \pm 8.32a
	<i>S. calamistis</i>	8.7 \pm 4.61b
	F-ratio	10.50
	df	2, 24
	P-value	<0.001
28 Dec. 2013–5 Jan. 2014	<i>C. partellus</i>	47.0 \pm 6.95a
	<i>M. sepearatella</i>	36.1 \pm 8.32ab
	<i>S. calamistis</i>	16.8 \pm 4.61b
	F-ratio	9.78
	df	2, 24
	P-value	<0.001

fields in all study sites. Similar findings were reported by [Gounou and Schulthess \(2004\)](#) on stem borer distribution in various host plants. Aggregation of stem borer larvae along the field margins might have been caused by migration of stem borers from alternative host plants around the rice fields. In East Africa, 39 wild host plants of stem borers have been identified, mostly belonging to the families Poaceae, Cyperaceae, and Typhaceae that are commonly found throughout the region ([Le Ru et al. 2006](#)). [Mailafiya et al. \(2011\)](#) reported numerous wild host plants like *Cyperus* spp., *Panicum* spp., *Pennisetum* spp., *Sorghum* spp.. All of these host plants are found in Kahama District suggesting their potential as alternative hosts to the rice stem borers infecting the crop whenever is established.

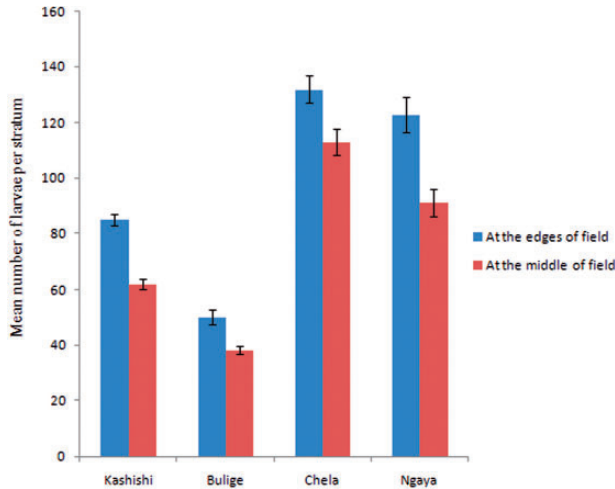
Understanding the spatial dispersion of these stem borer is useful for development of sampling plan since one should concentrate where the larvae are dispersed. Based on the study findings, the sampling plan for these stem borers should concentrate on the edges of rice fields. [Casey and Trumble \(2012\)](#) reported that spatial dispersion can be useful in choosing a sampling unit when developing the sampling plan. Therefore, one should concentrate on obtaining sample from where the insect is known to concentrate hence examining the edge of the field would be relevant in the case of rice stem borers in Kahama and possibly many other areas in the Lake zone of Tanzania. Although this is subject to sampling errors as observed by [Ndemah et al. \(2001\)](#) and [Gounou and Schulthess \(2004\)](#) on Lepidoptera that stem borer sampling error is caused by aggregate spatial distribution behavior of lepidopteran rice stem borers, the guided sampling plan is always a key to practical findings. Dispersion data agree to a better understanding of the relationship between an insect and its environment and give basic knowledge for interpreting spatial dynamics and come out with efficient sampling programs ([Casey and Trumble 2012](#)). In contrast to the findings by [Arbab \(2014\)](#) who reported random distribution of *Chilo suppressalis* in rice fields in Iran, the stem borers in Kahama district were aggregated along the rice fields. Probably the difference of these two findings was due to the difference in other host plants around the rice fields.

Conclusion

This study indicates that three stem borer species, i.e. *C. partellus*, *M. sepearatella*, and *S. calamistis* are distributed wherever rice is grown in Kahama District. Of the three species, *C. partellus* is the most abundant followed by *M. sepearatella* while *S. calamistis* was observed to be of less significance. *C. partellus* are dominant in Chela and Ngaya while *M. sepearatella* are dominant in Bulige and Kashishi wards. Abundance of stem borer species is neither affected by rice varieties

Table 4. Dispersion indices for stem borer larvae at the study locations covered

Ward	Morisista's index	Iwao's mean crowding regression					Taylor power law				
		α	β	SE_{β}	R^2_{adj}	P_{reg}	a	b	SE_b	R^2_{adj}	P_{reg}
Kashishi	0.85	0.741	0.53	0.52	0.59	0.129	-0.28	1.49	0.06	0.91	0.006
Bulige	1.10	-0.14	1.13	0.28	0.84	0.030	-0.01	1.02	0.09	0.63	0.106
Chela	2.95	0.57	1.02	0.27	0.82	0.035	0.18	0.88	0.33	0.38	0.265
Ngaya	3.87	1.40	1.10	0.16	0.94	0.007	0.41	1.01	0.09	0.87	0.020

**Fig. 2.** Stem borers aggregation within rice fields.

grown nor manipulation of sowing date. Generally, rice stem borers exhibits aggregated dispersion in Bulige, Chela, and Ngaya while in Kashishi are uniformly distributed.

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