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Research Article
Lepidopteran Stem Borer Species Abundance and Associated Damages on Irrigated Kilombero Low Land Rice Ecosystem in Tanzania

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Abstract
Background: Rice stem borers are among the most biotic stresses of economic importance in agriculture. Little was known about stem borer problem in Tanzania prior to this study. Understanding stem borer abundance and damages would help to design appropriate stem borer integrated pest management strategy in rice. This study was aimed at investigating rice stem borer's species abundance and their associated damages in irrigated lowland rice ecosystem in Kilombero Tanzania. **Materials and Methods:** Field survey study on rice stem borer abundance and incidences were conducted in farmer's fields on selected rice varieties at varied growth stages in Kilombero district under irrigated rice schemes. Adult moths were trapped by light traps and incidences assessed based on dead hearts and white head in 1 m^2 quadrat in field stratum sampled at random. **Results:** Results indicated the presence of *Chilo* sp. and *Sesamia calamistis* in all study areas with *Chilo* sp., as most abundant species (79.24-92.05%) followed by *S. calamist* (7.97-20.77%). The abundance of these two stem borer species and their associated damage incidences varied significantly between rice varieties and rice growth stages ($p<0.05$). The insecticides sprayed on different rice varieties had neither effect on species abundance nor on incidences of stem borers under the study area suggesting that the sprayed insecticides did not control the pest. **Conclusion:** This study therefore concluded that control measures particularly IPM is highly recommended short of which the control of stem borer will in future be unachievable.

Key words: *Chilo* sp., *Sesamia calamistis*, insect abundance, damage incidences, Kilombero rice schemes, Tanzania

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Abiotic (soil fertility, salinity and drought) and biotic (pests and diseases) stresses are known to affect rice production in Tanzania. Insect pests are among major biotic stresses of agricultural concern[1]. More than 100 species of insects are known to attack rice crop where 20 of them are of economic importance[2]. Stem borers have been reported the most devastating pests of economic importance in rice[3,4]. About four rice stem borers species are known to infest rice in Africa. The species includes *Chilo* sp., *Diopsis longcornis* Macquart, *Maliarpha separatalla* Ragonot and *Sesamia calamistis* Hampson[5,6]. These stem borers have been reported to occur in 17 tropical African countries[7]. In Tanzania three rice stem borer species have been reported from Morogoro, Kahama, Mwanza, Mbeya, Shinyanga and Zanzibar. These includes white stem borer (*M. seperatella*), the pink stem borer (*S. calamistis*) and spotted stem borer (*Chilo partellus*, Swinhoe)[4,8].

Rice grain yield loss of up to 80% has been reported to be incurred where there are heavy stem borer's infestations under field conditions[9]. The abundance, distribution and damage of these stem borer species vary between different ecological zones[6], within host plants[10] and within crop growth stages[11]. The dead heart symptoms and white head symptoms are two damage symptoms manifested by stem borer caterpillar damages, the former being caused by borers attack during vegetative stage and the later caused by borers attack during flowering stage[12]. Dead heart damage symptom are recognized by presence of whitish or discoloured area at feeding site of leaf blade where the stem turns brown, wilts and dry at late stage while the white head symptoms can be recognized by presence of white or brown panicles with empty spikelets[11].

In Tanzania rice stem borers abundance ranges from 16-70%, dead heart and white head incidences of 7.8 and 2.9%, respectively have been reported in rain fed lowland rice ecosystem of the Lake Zone[13]. Being rain fed, the crop is grown only once per year. Little was known about stem borer incidences in irrigated low land rice ecosystem where rice crop is continuously cultivated like the Kilombero valley. In this area the stem borer problem could be bigger that perceived but facts to support this had to be established. The aim of this study was to investigate rice stem borer's species abundance and their associated damages in irrigated lowland rice ecosystem in Kilombero Tanzania.

MATERIALS AND METHODS

Description of the study site: The study was conducted from December, 2016 to June, 2017 in Kilombero Irrigated rice schemes, Morogoro, Tanzania. The three wards that were covered in the present study were located at about 20 km from each other. The study locations included Signali (8°0'1.4234"S, 36°50'13.5179"E with 264 m a.s.l), Mkula (7°46'4.2672"S, 36°56' 43.4076"E with 261.27 m a.s.l) and Sanje (7°45'33.1981"S, 36°55'15.0247"E with 307.788 m a.s.l.) (Fig. 1). In these wards rice is intensively cultivated under irrigation system and water availability is assured throughout the year. Thirty fields, 10 fields in each ward were randomly selected and kept under surveillance for adult moth's species and associated larval damages. A split plot design was assumed during the survey where wards were considered as main plot and farmer's fields as subplots while each ward represented a replication. The plot size in each field was 1 acre (70×70 m) and the distance from one field to the other was at least 0.5 km.

Data were collected from four commonly grown rice varieties, namely, SARO5, SUPA, MbawaMbili and Lawama in each ward. These were the commonly grown varieties that were available in each ward. Fields sprayed or not sprayed with insecticides were also considered separately as management practices during data collection. In every ward five fields which were not sprayed with any insecticides and five fields sprayed with insecticides were selected for data collection. The insecticides recorded to be commonly used by farmers in the study area were Karate and Kung'fu which both have a common active ingredient the Lambda cyhalothrin.

Stem borer species abundance and distribution in the study area: Sampling for stem borer incidences was done at 6 weeks after planting (vegetative stage) and repeated at 12 weeks after planting, just before ripening stage (reproductive stage). Trapping of borers to assess their abundance was done following the method of Leonard and Rwegasira[13] with some modification. The modification was the use of light traps embedded in plastic containers instead of white cloth. The light traps with white and black light sources were embedded in a 6 L plastic container which was cut half way at the middle leaving the mouth funnel and mounted in upside down on another container of the same size without cuttings for collection of insects. The containers were painted in black colour outside but in white colour inside for light reflection.

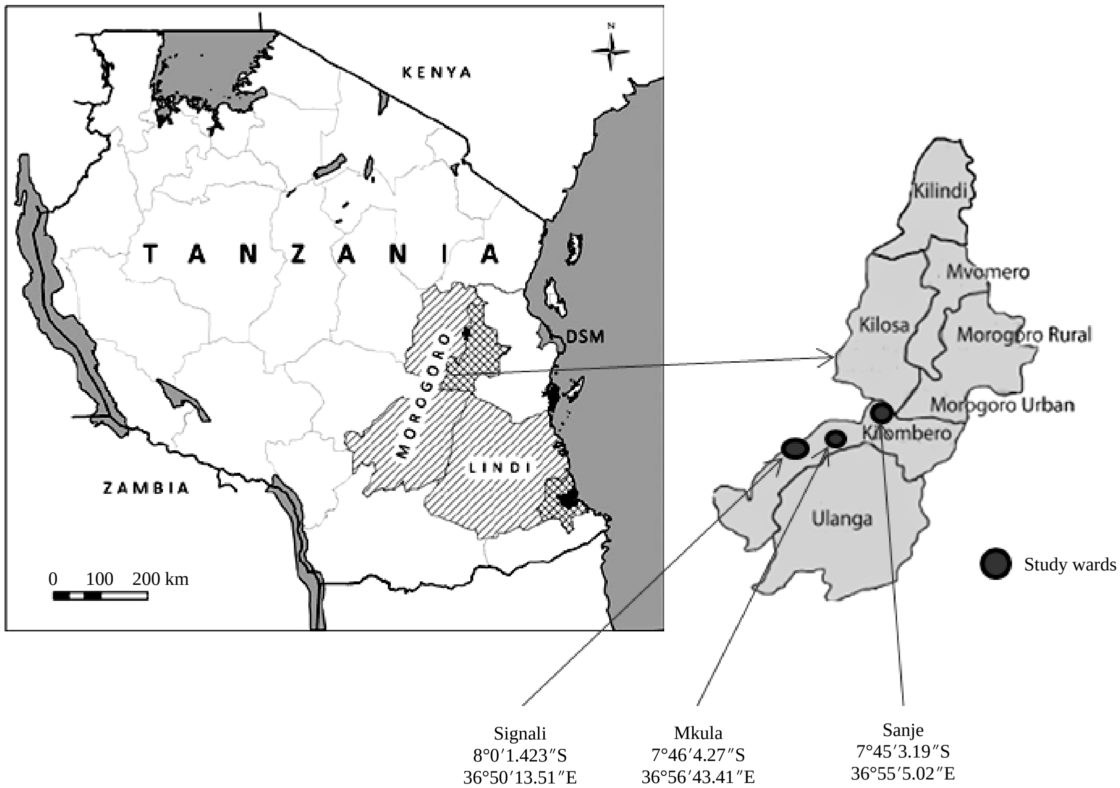

Fig. 1: Map of Tanzania showing the three studied wards in Kilombero district

The traps were hanged on a wooden stand and the lights switched on for attraction of adult moths. Trapping was done every earmarked day for two hours from 19:00-21:00 h East African time.

Moth species were collected in down container through funnel like mouth of the upper container. Moths that were found gathering in the upper containers were picked by hand. All the moth species fallen in the container through the funnel and hand collected from the trap were transferred to another well labelled container containing 75% alcohol and sorted letter for species identification. The identification of species was done using the identification guide[12]. Species abundance was calculated according to Rahaman *et al.*[1] method as follows:

Assessment of rice stems borers' incidence in farmers' fields: The sampled farmers' field were divided into four equal sized strata where in each stratum, four 1 m^2 quadrats were set for assessment of incidences which gave a total of 16 quadrats[13]. The assessment was done twice, at 6 weeks after planting (vegetative stage) for dead heart damage and near physiological maturity (12 weeks after planting) for white head damage[14]. The incidences were calculated following the method described by Baskaran *et al.*[15] as follows:

Data collection: The collected data were on existing species of stem borers, their abundance through trap for quantification across the study areas, number of tillers m^{-2} (damaged tillers and undamaged tillers) and number of panicles m^{-2} (damaged and undamaged) for estimation of incidences. The incidence data were tested for normality using R software[16] and found to conform to normal distribution and therefore there was no need for transformation. When tested for stem borer species abundance, the data on pink stem borers were found not normally distributed and therefore, normalized by log transformation prior to analysis.

Statistical analysis: The data for stem borers abundance and damage incidences were subjected to analysis of variance (one way ANOVA) using R statistical software means separated using the Fisher' least significant difference at $p \leq 0.05$ level. The analysis model was according to Gomez and Gomez[17] for split plot design, i.e.:

$$Y_{jkm} = \mu + R_i + A_j + \alpha_{ij} + B_k + AB_{jk} + \beta_{ijk}$$

Where:

- Y_{ijkm} = Response on stem borer abundance or incidence in different wards and in different fields
- μ = General mean
- R_i = Replication effect
- A_j = Effect of jth ward on stem borer abundance or incidence
- α_{ij} = Error for jth ward
- B_k = Effect of kth field on stem borer abundance or incidence
- AB_{jk} = Interaction effect on jth ward and kth field
- β_{ijk} = Error for kth field

RESULTS

Rice stem borer's species abundance in different wards: Two species of stem borers, *Chilo* sp. and *S. calamistis* were recorded from all the surveyed sites (Table 1). *Chilo* sp. was found highly abundant than *S. calamistis* in all three wards surveyed. Among the wards surveyed, the highest abundance of *Chilo* sp., was recorded in Siginali with mean abundance of 92.05% followed by Mkula (90.71%) and Sanje (79.24%). Abundance records for *S. calamistis*, were highest in Signali with mean abundance of 20.77% while Mkula had 9.29% and Sanje recorded 7.95%. There were significant differences in mean abundance among the wards for *C. partellus* (p = 0.017) and for *S. calamistis* (p = 0.017).

Rice stem borer species abundance in insecticide treated fields: The abundance for *Chilo* sp., was higher than that of *S. calamistis* in all four rice varieties and in both insecticide sprayed and unsprayed rice fields (Table 2). Numbers for both *Chilo* sp. and *S. calamistis* were highest in SARO 5 rice variety in both sprayed and unsprayed fields than in the other varieties. Greatest numbers recorded in unsprayed fields were for *Chilo* sp. in SARO 5 (94.32%) and lowest were that of *S. calamistis* in Mbawambili (15.18%). In sprayed fields, the highest was *Chilo* sp. recorded in SARO5 (89.95%) while the lowest was that of *S. calamistis* recorded in Lawama variety (11.67%). There was no significance differences in stem borers species abundances in both sprayed and unsprayed fields in varieties (p>0.05).

Rice stem borers species abundance in different rice growth stages: The two stem borers species were more abundant at reproductive stage than the vegetative stage (Fig. 2). Greatest abundance was that of *Chilo* sp., which was recorded in SARO 5 variety both during reproductive (100%) and vegetative (95.24%) stages of rice. The greatest abundance data recorded for *S. calamistis* was on SUPA variety being 24.54% during reproductive and 23.69% during vegetative stages. Unlike *Chilo* sp., the *S. calamistis* was least abundant on SARO5 with records of 4.76% during reproductive stage and 0% during vegetative stage).

Table 1: Rice stem borers species abundance in Kilombero rice schemes, Tanzania

	Mean stem borer abundance (%)±SE	
Wards	*Chilo* sp.	*S. calamistis*
Signali	92.05±4.46[b]	7.95±4.46[a]
Mkula	90.71±4.46[b]	9.29±4.46[ab]
Sanje	79.24±4.46[a]	20.77±4.46[b]
$F_{2,9}$	5.17	5.17
p-value	0.017	0.017
LSD	9.2	9.2

Means for *S. calamistis* were log transformed prior analysis and values are reconverted in original scale. Values followed by the same letters in a column are not statistically different ($p \leq 0.05$). SE: Standard error, LSD: Least significant difference

Table 2: Rice stem borers species abundance in insecticide sprayed and unsprayed rice fields in Kilombero in Tanzania

	Stem borers abundance %±SE			
	Chilo sp.		*Sesamia calamistis*	
Rice varieties	Un sprayed fields	Sprayed fields	Unsprayed fields	Sprayed fields
SARO5	94.32±8.12[a]	89.95±6.27[a]	5.68±0.3[b]	10.05±0.37[a]
SUPA	86.31±8.12[a]	88.35±6.27[a]	13.69±0.13[ab]	11.65±0.37[a]
Mbawambili	84.81±8.12[a]	89.27±6.27[a]	15.19±0.13[a]	10.73±0.37[a]
Lawama	90.62±8.12[a]	88.33±6.27[a]	9.38±0.13[a]	11.67±0.37[a]
$F_{2,3}$	1.04	0.20	3.07	0.44
p-value	0.44	0.997	0.113	0.731
LSD	14.53	21.30	14.53	18.01

Means for *S. calamistis* were log transformed prior analysis values reconverted to original scale. Values followed by the same letters in a column are not statistically different ($p \leq 0.05$). SE: Standard error, LSD: Least significant difference

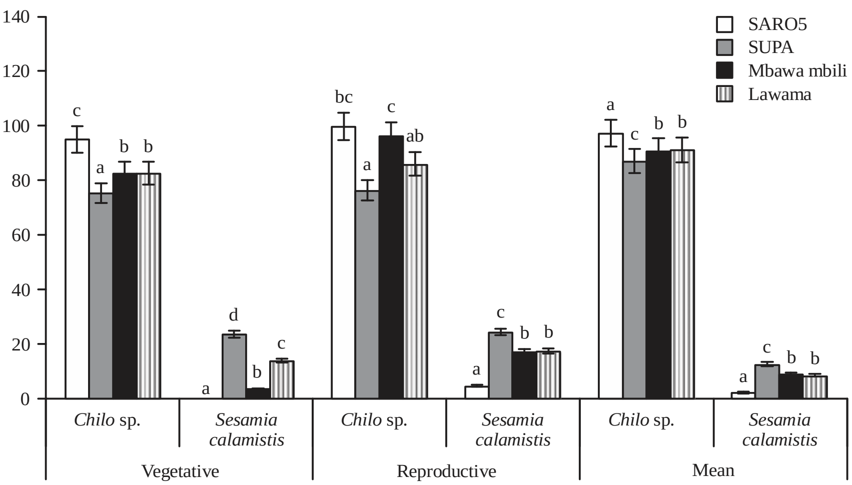

Fig. 2: Stem borer species abundance in four rice varieties assessed at vegetative and reproductive stages of crop growth
Bars with the same letter are not significantly different at p>0.05 as per Fisher's test of Least significant difference

Table 3: Rice stem borers incidences in Kilombero wards in Tanzania

Ward	Damage incidences (%) Dead heart at vegetative stage	White head at reproductive stage
Signali	8.98±1.45[ab]	5.24±0.89[a]
Mkula	9.77[b]	5.49±0.89[a]
Sanje	4.27±1.45	4.68±0.89[a]
$F_{2,3}$	4.20	0.90
p-value	0.032	0.42
LSD	1.856	1.29

Values followed by the same letters in a column are not statistically different ($p \leq 0.05$). SE: Standard error, LSD: Least significant difference

Table 4: Stem borers dead hearts and white head incidences in sprayed and un sprayed fields in Kilombero in Tanzania

	Damage incidences (%)			
	Dead heart at vegetative stage		White head at reproductive stage	
Rice varieties	Sprayed fields	None sprayed fields	Sprayed fields	None sprayed fields
SARO5	7.68±1.04[b]	12.42±1.66[b]	5.48±0.28[b]	6.680±0.83[a]
SUPA	4.59±1.04[a]	8.77±1.66[a]	4.63±0.2[ab]	5.819±0.83[ab]
Mbawambili	4.75±1.04[a]	9.74±1.66[a]	3.63±0.28[a]	6.880±0.83[b]
Lawama	3.54±1.04[a]	7.16±1.66[a]	3.65±0.28[a]	4.513±0.83[a]
$F_{2,3}$	6.230	8.460	3.210	2.940
p-value	0.028	0.014	0.104	0.121
LSD	2.459	2.623	1.715	2.171

Values followed by the same letters in a column are not statistically different ($p \leq 0.05$). SE: Standard error, LSD: Least significant difference

Stem borer dead heart and white heads in wards: The dead heart incidences were higher than white head in both wards (Table 3). Among the surveyed wards, Signali and Mkula had more damage incidences than Sanje for both dead heart and white head. There were significant differences in dead heart incidences during vegetative stage among wards (p = 0.032) but there was no significant differences in white head incidences during reproductive stage (p = 0.422). At vegetative stage, the highest incidence was recorded in Mkula (9.77%) and Signali (8.98%) with the least incidence of 4.27% in Sanje.

Stem borers dead hearts and white head incidences in insecticide treated fields: There were significant differences between sprayed and unsprayed fields in dead heart incidences (Table 4). Higher incidences for rice stem borers were recorded at the vegetative stage than the reproductive stage in both sprayed and unsprayed fields. More dead heart and white head incidences were recorded in unsprayed than sprayed fields. There were significant differences between rice varieties in sprayed and unsprayed fields in dead heart formation. Rice variety, SARO5, had the highest dead heart and white head for both sprayed and unsprayed fields.

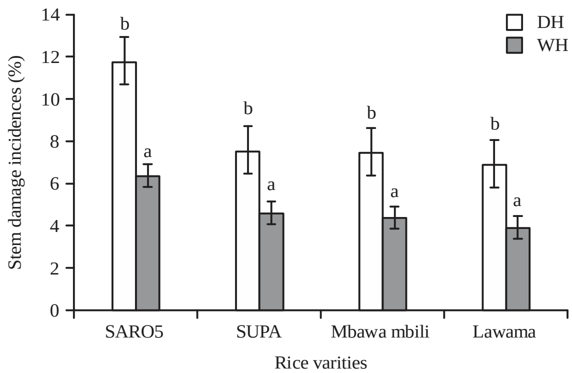

Fig. 3: Rice stem borer incidences in different rice varieties in the study areas. DH: Percentage dead heart and WH: Percentage white head

Bars with the same letter are not significant at p>0.05 based on Fisher's test of Least significant difference

Response of rice varieties to stem borer incidences: The SARO5 was the most susceptible variety to stem borers damage with 11.81% dead heart and 6.38% white head formation followed by SUPA (7.5% dead heart, 4.6% white head) and Mbawambili (7.5% dead heart, 4.4% white head) (Fig. 3). Lawama was somehow tolerant to stem borer damage due to its lowest record of (6.95% dead heart and 3.94 white head) damage incidences. In all varieties, the dead heart incidences were higher than white head incidences.

DISCUSSION

The present study revealed the presence of two stem borer species in Kilombero notably spotted stem borers (*Chilo* sp.) and the pink stem borer (*S. calamistis*) in which *Chilo* sp., was a dominant and most abundant species in all fields surveyed. The reason for abundance of *Chilo* sp., compared to *S. calamistis* may be due to its biological nature of completing life cycle earlier than other stem borer species hence high population build up in a short time. This is supported by the report of Ofomata *et al.*[18] that *C. partellus* is characterized by colonizing feeding niches considerably earlier than the native stem borers. It out competes and decrease the number of other stem borer species that live in similar environment. The findings were also consistent with the study by Nsami *et al.*[19], who reported that the abundance of *C. partellus* constituted about 80% while *S. calamistis* accounted for only 4% of stem borer species in the Eastern zone of Tanzania. Further report on stem borer by Leonard and Rwegasira[8] indicated highest abundance of *C. partellus* in rainfed low land rice ecosystem in Kahama district as compared to *M. separatella* and *S. calamistis*.

Abundance of stem borers was observed to be affected by growth stages of rice crop. The highest abundance was recorded during reproductive stage than vegetative stage of rice for the two stem borer species. The causes of such variation may be due to availability of enough food for borers to feed that favoured fast growth and population build up during reproductive stage and less during vegetative stage. This was consistent with the study of Sarwar[20], who reported that stem borer population build up occurs during flowering stage due to increased rice tillers and large stem diameter that ensures production of better quality food in stems.

Analysis on the influence of rice varieties on stem borer species abundance was statistically significant. The two rice varieties which are SARO5 and SUPA were recorded with highest abundance as compared to Mbawambili and Lawama varieties. The reasons could be due to differences in chemical characteristics of the varieties including aroma as basic attraction to stem borer's damage. The SARO5 and SUPA rice varieties are known to be aromatic[21] the preferred characteristic for stem borers[20]. Similar observations were made by Sarwar[22], who reported high stem borers damage in aromatic varieties than non-aromatic varieties by describing the aroma characteristic as one of the key attraction factor in adult moths for elevated feeding and oviposition. In contrast there were reduced stem borer longevity, reproduction and increased mortality in non-aromatic varieties due to production of antibiosis chemicals that lowered the population.

The abundance of stem borers and white head damage incidence was not affected by insecticide spray among rice varieties. The reasons could either be development of pest resistance due to continues use of one insecticide in controlling one kind of insect, wrong time of application and the use of incorrect dosage due to lack of knowledge on pesticide use. Control of stem borers using insecticides is sometimes difficult to achieve because the larvae (the destructive stage) and pupa of borers completes their cycles inside the stems. Moreover, they have overlapping population in the field which complicates the timing in insecticide application for a successful control[23].

Historically farmers under the study area used to spray the same insecticide (Lambda cyhalothrin) every season when stem borer damages signs are observed in the fields suggesting the possible development of resistance. This corresponds with the report by Li *et al.*[24] that a significant and unexpected resistance level was detected in *Sesamia inferens* from Miaoli, Changhua, Chiayi and Tainan counties due to continuous application of Imidacloprid and Clothianidin insecticides. Further, the findings by Sarwar *et al.*[25] have reported that many farmers rely on the use of insecticides in control of stem borers but most of them are not successful. Likewise, Muralidharan and Pasali[9] reported insignificant difference between diazinon and carbofuran insecticides in reduction of incidences of yellow stem borers at white ear head stage in India.

The insecticides used by farmers in the study area none systemic and unfortunately the timing of application is also wrong because actions are taken after the damages have been caused when dead heart or white head are observed. Nwilene *et al.*[26] reported that a good timing for spraying insecticides in managing the borers is 20 days after planting to combat Dipteran stem borers and 50- 70 days after planting in order to combat Lepidopteran stem borers. Similar findings were by ISU[27], who suggested that for insecticides to be effective, spraying had to be done before most larvae tunnelled into stalk.

The current study revealed differences in stem borer incidences among wards, rice variety and growth stage of rice. The difference in stem borer damage might be due to rice varieties grown ward and time of damage. The SARO5, the variety most grown in Siginali and Mkula wards was very susceptible given the greatest stem borer damages. Moreover the (the most abundant stem borer, *Chilo* sp., was plentiful in the two wards. Such scenario could be explained by the observation of Rahman *et al.*[28], who reported that the population density, the timing of injury and rice growing conditions were the key factors that favour stem borer damage.

Rice varieties genetic characteristics such as aroma have also implication in stem borers preferences for damages. Sarwar[20] reported high stem borer dead heart incidences of 5.44% and white head incidences of 4.75% in Aromatic Basmati-370 and dead heart incidence of 3.21% and white head incidence of 2.47% in none aromatic IR8 rice varieties. The low incidence in none aromatic varieties could be due to production of antixenosis which reduces plant attractiveness and tolerance to stem borer damages[29]. Ogah[6] suggested that varieties respond differently to stem borer attack hence the differences in stem borer incidences observed among the rice varieties.

Higher incidence was recorded in vegetative than reproduction stage of rice growth. The reason could be the ability of the rice crop to compensate the low per cent incidence during vegetative stage by producing new tillers which sometimes become damaged and increase the incidences with constant incidence during reproduction stage. Muralidharan and Pasalu[9] reported that low percentage of dead heart tillers can be compensated by producing more tillers at early dead heart damage, where the nodal tillers become light and lead to yield loss of 1% in every 2% dead heart incidence. This was also consistent with the study by Sarwar[20], who reported the highest stem borers incidences during vegetative stage than in reproduction stage, the reason being the sugar content and phenol content in stem tissues of the crop where the former one is high at maximum tillering stage which favour high larvae incidence and later become high during reproduction stage which favour low larvae incidence.

CONCLUSION AND FUTURE RECOMMENDATIONS

The two stem borer species, *Chilo* sp. and *Sesamia calamistis* were found to exist in Kilombero Rice production Schemes of which the former was more abundant than the later. The abundance of stem borer species and damage incidences were varied based on growth stages of rice crop. Damages associated with rice stem borers were similar in insecticide sprayed and non-sprayed fields suggesting the ineffectiveness of the commonly used Lambda cyhalothrin insecticide. Further studies should target to establish facts on whether the rice stem borers have developed resistance the insecticides being used. Research into alternative control measures particularly IPM is highly recommended short of which the control of stem borer will in future be unachievable.

SIGNIFICANCE STATEMENT

This study reports on stem borer species abundance and their associated damages in irrigated lowland rice that would help researchers to design appropriate stem borer integrated pest management strategy in rice.

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