INCIDENCES AND SPATIAL DISTRIBUTION OF STEM BORERS IN RICE CROP IN KAHAMA DISTRICT

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ABSTRACT

Studies were carried out to establish the role and significance of rice stem borers as pests in rice crop in Kahama District from November, 2013 to May, 2014. Twenty rice fields in four wards of Kahama District were surveyed to assess the presence of larvae and adult moths. Each field was divided into four strata within which four quadrats were established in each. In each quadrat, the damaged rice tillers (dead heart), damaged panicles (white head) and total number of tillers and panicles were counted. Stem borer incidences were computed from observations for each of the studied rice varieties and with reference to the sowing dates. Stem borer larvae were extracted from each of the damaged tiller and counted to establish stem borer dispersion. Moths were trapped by a black light trap cascaded with normal light attached to a white cloth and collected in vials for further identification in the laboratory. Dispersion was determined by three indices i.e. Morisista's index, Taylor power law and Iwao's mean crowding regression. Statistical packages (GenStat 15 edition VSN international) and (SPSS 16 version IBM Corporation) were used for data analysis of abundance and incidences respectively. Results indicated that the most abundant species was *Chilo partellus* (48.6%) followed by *Maliarpha separatalla* (35.4%) and lastly *Sesamia calamists* (16.1%). Dispersion indices suggested that borers were highly aggregated along the edges of rice fields compared to the middle of fields. Behenge and Supa varieties were more susceptible to stem borer damage than Kalamata and Mayobhe. The best sowing date with minimum stem borer damage was from 1 to 20, December. The current study has for the first time confirmed the presence and significance of rice stem borers in the lake zone of

Tanzania that calls for intensive intervention program to ensure farmers of continued food security and livelihood.

DECLARATION

I, Alfonce Leonard, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

This work is dedicated to my beloved father Leonard Mutiba, mother Salvansia Mbonye, and my wife Mernas J. Mpumbi.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percent
<	Less than
>	Greater than
^{0}C	Degree celcius
Iä	Morisit's index of aggregation
α	Alpha
β	Beta
a	Intercept of regression line
ANOVA	Analysis of Variance
b	Slope of regression line
B.	*Bactrocera sp.*
C.	*Chilo*
DH	Dead Heart
DDT	Dichlorodiphenyltrichloroethane
BC	Biological control
E.	*Eldana*
EAAPP	East Africa Agricultural Productivity Program
et al	and others
EIL	Economic Injury Level
FARA	Forum for Agricultural Research in Africa
Fig.	Figure
i.e.	That is
kg	Kilogram
IRRI	International Rice Research Institute
LSD	Least Significant Difference

LZARDI	Lake Zone Agricultural Research and Development Institute
MAFAP	Monitoring African Food Agricultural Policies
MAFC	Ministry of Agriculture Food Security and Cooperatives
m	Regressed mean
M.	*Maliarpha*
M’	Iwao’s mean crowding regression
NERICA	New Rice for Africa
pp	Pages
RLDC	Rural Livelihood Development Company
s.e	Standard error
S.	*Sesamia*
sp.	Species
S^2	Variance
WARDA	Africa Rice Center
WH	White head

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Rice (*Oryzae sativa* L.) is an important staple food crop throughout the world; it is a major source of food for nearly half of global population (Dhuyo and Soomro, 2007). Rice is cultivated and consumed in almost all African countries; however the countries experience higher rice consumption than amount produced (FARA, 2009).

Tanzania is the second rice producer in East, Central and Southern Africa after Madagascar (Banwo, 2002). Rice is the second highly cultivated cereal crop in Tanzania after maize. It is grown in three agro-ecosystems namely; rainfed lowland, rainfed upland and irrigated lowland (Mghase *et al.*, 2010). Several regions in Tanzania inclusive of Mbeya, Morogoro, Mwanza, Rukwa, Shinyanga, and Tabora are well known for rice production (MAFC, 2009). The crop is also grown in Arusha, Iringa, Kilimanjaro, Manyara, Mara, Tanga and Kigoma. Nowadays rice is said to be a first priority crop on research in the Lake Zone of Tanzania (Temu and Babu, 2008). Available data suggest a recent increase in rice consumption in urban and rural areas, at the capacity of 25-30 kg per person per year (Mghase *et al.*, 2010). This consumption has caused a gap between the demand and supply of rice which is fulfilled through importation.

Rice crop prefers warm and humid weather condition which are also suitable conditions for proliferation of insect pests; as a result, the crop is attacked by various pests which cause yield loss (Pathak and Khan, 1994). Stem borers comprising of various species of lepidopterous moth and dipterous stalk eyed, diopsid species are classified as serious insect species of rice (Amaugo and Emosairue, 2003). Lepidopteran pests are commonly known as cereal stem and cob borers which damage various crops including rice, maize, sorghum, millet and sugarcane. These pests have been reported as a major limitation to attainable potential rice yield in sub-Saharan Africa (Pathak and Khan, 1994). Rice stem borers are said to cause different yield loss as in various rice growing countries. In Africa and Asia they cause yield loss of 5-10% or 60% in terms of outbreak, in Bangladesh, India and Thailand they cause yield loss of more than 20% (Pathak and Khan, 1994).

1.2 Justification

Rice stem borers are among pests affecting rice wherever is grown contributing to high yield loss (Dhuyo and Soomro, 2007). Reported incidences of stem borers are approximately 30-50% of plant tillers in many rice producer countries in Africa (Ogah, 2013). Despite the incidence and enormous damages caused, very little work has been done on these problematic pests of rice in Tanzania (Banwo, 2002). Stem borer species responsible for such damages have not been delineated. Generally three species of rice stem borers have been reported to exist in Tanzania, namely, the White stem borer (*Maliarpha seperatella* Ragonot), African Pink Borer (*Sesamia calamistis* Hampson) and Spotted stem borer (*Chilo partellus* Swinhoe) (Banwo, 2002). The three stem borer species are suspected to be well distributed in rice growing areas of Mbeya, Morogoro, Mwanza, Shinyanga and Zanzibar (Banwo, 2002; Abdulla, 2007). However, the species dynamics, incidences and the spatial distribution of these stem borers in rice fields have not been examined and established. Varied infestation rates of rice stem borer have been reported elsewhere. In Nigeria, for instance, NERICA varieties were reported to have low incidences of stem borers (1-10%) compared to other varieties (Ogah, 2013). The current study aims at investigating the existing species of the rice stem borers, their incidences, the magnitude of damages caused and spatial distribution in rice fields in Kahama District and suggest possible control measures or mitigation measures.

1.3 Objectives

1.3.1 Overall Objective

To investigate the incidences, crop damage and spatial distribution of stem borers in rice fields in Kahama District.

1.3.2 Specific Objectives

The above overall objective will be achieved by the following specific objectives.

i. To determine the incidences of stem borers in rice grown in Kahama District.
ii. To examine the spatial distribution of stem borer species within rice fields in Kahama District.
iii. To determine the abundance of rice stem borer species existing in Kahama District.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Stem Borer

Stem borers which are found in East Africa belongs to orders of Lepidoptera and Diptera. Lepidopteran species includes; White stem borer (*Maliarpha seperatella*), African pink borer (*Sesamia calamistis*) and Spotted stem borer (*Chilo partellus*). The order Diptera is represented by the Stalk-eyed borer (*Diopsis thoracica*) (Srivastava *et al.*, 2003). All these species exhibit complete metamorphosis type of life cycle whereby eggs exists for 15 days, larval stage takes 40 days, pupa exists for 11 days and adults live for two to six days. The average life cycle of most rice stem borers range from 42 to 83 days (Srivastava *et al.*, 2003). Larva is the only destructive stage where by it finds suitable food to be used up to the end of pupa stage during which the pest protects itself from the enemies as well as adverse environmental condition. In rice stem borer, pupation stage always occurs in stem, straw or stubble. Some of the rice stem borers like *Sesamia inferens* pupate between leaf sheath and stem. Each larva destroys an average of three stems during its developmental process (Nwilene *et al.,* 2008).

2.2 Biology

The biology of rice stem borers depends on the developmental stage of the pest. Stem borers lay eggs near the tips of leaf blades, at the basal half of the leaf, on the lower surface of the leaf blade or on the leaf sheath. The average hatching temperature for eggs of stem borers range from 21-33^{0}C and relative humidity of 90-100%.

Temperature has some effect on incubation period of eggs which tend to decrease with decrease in environmental temperature (Pathak and Khan, 1994). After hatching, the larvae craw upward along plants where they stay for a short time. Then they are dispersed by wind or through swimming in water to the neighboring plants where they attack the plants at the point between the leaf sheath and the stem. They stay in the stem where they obtain food throughout larva stage. Larvae undergo different instars depending on environmental temperature through which they are reared, usually five instars when reared at 23-29^{0}C or four instars when reared at 29-35^{0}C (Adiroubane, 2007). Numbers of moults also decrease depending on the growth stage through which larva feed on, when feeding on mature plants the number of molts decrease more than when feeding on tillering plants. Molts also tend to increase with decrease in number of host plants. In Lepidoptera, stem borers pupate in rice stem, straw or stubble and the optimum temperature for pupa development is 15-35^{0}C. Number of generation of rice stem borer depends on environmental condition of particular geographical area. In warm environment where there is a single rice growing season there are three to four generations (Indike, 2002).

2.3 Occurrence and Damage Signs

Rice stem borers attack the crop throughout the growing stages i.e. from seedling to ear setting stages (Indike, 2002). Damage caused by stem borers differs depending on the growth stages of these pests. Caterpillar tends to destroy the stem through boring the leaf sheath at the node point and then enter in the stem. They feed on the leaf sheath for about a week before entering into the stem. The larvae tend to attack the terminal shoot hence tend to cause 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 dies. 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”. It is estimated that for every 1% of white heads, the expected yield loss is about 1-3%. The stem borer damage therefore is assessed by symptoms of dead heart and white head (Banwo, 2002). It is difficult to estimate loss caused by larva because rice has a mechanism of producing tillers to replace the destroyed stems. About 80% tillers can be destroyed without affecting the yield (Nwilene *et al.,* 2008). In many rice growing countries, yield loss caused by rice stem borer range from 1-20% and in case of outbreak the loss can reach up to 100%.

2.4 Stem Borer Distribution in Africa

Lepidopteran stem borer of cultivated grasses in Africa, include 7 noctuids, 2 pyralids, and 12 crambids. Among these 21 species, only seven are most important pests in the Sahelian region (Omwega *et al.,* 1995). *Busseola fusca* and six *Sesamia* spp. are considered economically important. *Maliarpha separatella*, and *Eldana saccharina* are serious pests of rice in the family pyridae. Crambids is the largest group of injurious stem borer which consist of 12 species. Among these species, 7 belong to the genera *Chilo* Zinken. These stem borers are pests of various crops such as rice, maize, sorghum, sugarcane and some wild grasses.

In South Africa, *B. fusca* and *C. partellus* are important pests of maize and sorghum while *E. saccharina* is the pest of sugarcane. In West Africa, the major stem borer pests are *B. fusca*, *E. saccharina* and *S. calamistis.* These pests attack mostly maize and sorghum. In East Africa, the most important stem borer pests are *B. fusca, C. orichalcociliellus, C. partellus, E. saccharina, M. separatella* and *S. calamistis*. Most low land stem borer pests of rice in East Africa are *C. partellus* and *M. separatella* while *S. calamistis* is abundant in upland rice (Pathak and Khan, 1994). A survey conducted in Tanzania in the 1980s and 1990s reported that *C. partellus* is found in the lake zone and eastern zone (Omwega *et al.,* 1995).

Table 1: Important stem borer species in Africa and the Indian Ocean Islands, their distributions and major cultivated host plants

Family	Species	Distribution	Host plants
Crambidae	*Chilo partellus*	eastern and southern	maize, sorghum
	Chilo orichalcociliellus	coastal eastern, Malawi, Madagascar; South Africa, Zimbabwe	maize,sorghum
	Chilo aleniellus	West and Central	rice, maize
	Chilo sacchariphagus	Indian Ocean Islands; Mozambique	Sugarcane sugarcane
	Chilo zacconius	West	rice
	Chilo diffusilineus	tropical Africa	rice
	Coniesta ignefusalis	Sahelian Africa	millet
	Scirpophaga spp.	West	rice
Pyralidae	*Eldana saccharina*	sub-Saharan	sugarcane, maize, rice
	Maliarpha separatella	sub-Saharan, Indian Ocean Islands	rice
Noctuidae	*Busseola fusca*	sub-Saharan	maize, sorghum
	Sesamia calamistis	sub-Saharan	maize, sorghum, rice
	Sesamia nonagrioides botanephaga	West, Sudan	maize, rice, sorghum, sugarcane
	Sesamia cretica	Northeast	sorghum, maize

Source: Rami *et al.,* (2002).

2.5 Management of Stem Borers

2.5.1 Biological methods

2.5.1.1 Natural enemies

This method refers to environmental friendly and effective method of minimizing pests and pest effects all the way through the use of natural enemies (Charudattan *et al*., 2006). Also biological control is defined as a population – leveling process whereby one species population lowers the numbers of another species through predation, parasitism, pathogenicity or competition (Noorhosseini *et al*., 2010). The method is known as "natural control" because naturally the populations of species are regulated by number of factors including other organisms (Rami *et al*., 2002). Natural enemies regulate pest population below the economic injury level (EIL). The effectiveness of natural enemies is noticed when they are eliminated through frequent use of pesticides that kill the targeted species as well as natural enemies (Abdulla, 2007).

There are various predators of rice stem borers which feed on larvae as well as adults. These include dragonflies, earwigs and spiders. Braconid, Cameron and the Eulophid are most important parasitoids of *Sesamia spp*. *Trichogramma spp.* are natural enemies that parasitize the eggs of *Chilo suppressalis* (Noorhosseini *et al*., 2010). Biological control research has been conducted in some countries of Africa (Nwilene *et al*., 2008).

A good example is *Cotesia flavipes* that was imported from Asia and introduced in Cote d'Ivoire and Senegal to control *Chilo zacconius.* The effectiveness of natural enemies in keeping stem borer below the economic injury level (EIL) has been doubted by number of researchers (Rami *et al*., 2002). Biological control which involves augmentation is the release of mass of reared natural enemies. Few attempts of augmentation have been tested in China through mass release of stem borer egg parasitoids like *Trichogramma japonicum*, *Telenomus rowani*, and *Tetrastichus schoenobii*. The method is not economical for rice and has limited prospects for rice pest management (Rami *et al*., 2002).

2.5.1.2 Utilization of synthetic sex pheromones

Synthetic sex pheromones are an alternative to chemical method of controlling rice stem borer and it is environmental friendly (Su *et al*., 2003). Trap catches of male moths can provide useful information for the timing of insecticide applications. Sex pheromone baited traps are used for monitoring moth population of lepidopterans (Abdulla, 2007). Female *Chilo suppressalis* produce three sex pheromones which are baited in traps to control stem borers in rice fields. These hormones namely; Z-11-hexadecenal, Z-13-octadecenal and Z-9-hexadecenal, are commonly used in China. Campion and Nesbitt (1983) reviewed the identification and the utilization of sex pheromones and concluded that mass trapping is unlikely to provide satisfactory control but that mating disruption is more likely to be effective. However, the efficiency of mass trapping by sex pheromone in large field is uncertain.

2.5.2 Cultural methods

Cultural control is regarded as important defense against pests and is among of the oldest traditional practices and always cannot be used as a tactic means of control (Dent, 1991). Cultural control is regarded as the most relevant and economical method of stem borer control for resource poor farmers in Africa (Rami *et al.*, 2002). Other control tactics are not relevant due to the reason that pesticides are too expensive that poor farmers cannot afford or sometimes are not available, resistant varieties are available in a wide range and biological control is not fully successful (Seshu-Redd, 1998; Polaszek, 1998). Cultural control is considered as important defense against pest and includes various techniques such as manipulation of planting date, tillage methods, intercropping, crop rotation and destruction of crop residues (Polaszek, 1998).

For the efficient management of stem borer by cultural practices, it is important to understand the stem borer's biology and ecology and the relationship with their respective crop. Although cultural control practices for stem borer management appear promising, they have not been adopted by many farmers in Africa (Rami *et al.,* 2002).

2.5.2.1 Management of crop residues

Crop residues are important for carrying stem borer larvae population from one growing season to the next season. Management of crop residues is mainly directed toward the control of rice stem borer (Litsinger, 1994). Rami *et al.* (2002) reported that in Kenya various stem borer species were observed in stalks after harvest, in Ethiopia larvae survived in stubble. Under these conditions, borers from the previous season stalks constantly infested the newly planted crops. For effective control practice, it is important to reduce the first generation of adult stem borer by destroying the larvae in previous season stalks.

2.5.2.2 Manipulating of sowing date

Growing crops at the period of least abundance of the pest ensures that the most susceptible stage of crop growth will not interfere with the period of peak stem borer activity (Rami *et al.,* 2002). Manipulation of sowing date is a disadvantage to the pest, which is susceptible to air or water temperature extremes, heavy rainfall, non-preferred crop growth stage, and an abundance of natural enemies. Early planting may minimize the incidences of various pests including stem borers (IRRI, 2001). In Pakistan sowing time showed the impact on the incidence of stem borer by which early sown rice crop was the most resistant having the lowest borer infestation among other plantings (Muhammad, 2012). In subsistence farming system of Africa manipulation of sowing date is not practical since farmers depend on rainfall for rice production.

2.5.2.3 Fertilizer and farm manure application

Plant nitrogen content has an effect on stem borer damage. Infestation and survival of stem borers in rice increase with an increase in nitrogen content (Rami *et al*., 2002). Application of nitrogen fertilizer has been investigated to encourage stem borer damage to various crops. For example in Nigeria rice damage by *Maliarpha separatella* increased with the application of fertilizer, in South Africa sorghum planted without nitrogen fertilizer had less stem damage than that having nitrogen fertilizer (Rami *et al*., 2002). Time of nitrogen fertilizer application has an influence on stem borer development; nitrogen fertilizer application is recommended at the time when incidence of stem borer is low.

2.5.2.4 Intercropping and habitat management

Habitat management is considered as a part of conservation biological control method which changes habitat to improve availability of natural resources for natural enemies for optimal performance (Litsinger, 1994). This management can occur within crop, within farm, or landscape level. Inter cropping has been widely practiced in Africa by small scale farmers for the aim of reducing risk of crop failure, increasing yield and improving soil fertility. In East Africa, studies have been carried out to find crop combinations for reducing stem borer population on cereal crops. Most findings concluded that inter cropping cowpea with maize and sorghum reduced the incidences of stem borers (Rami *et al*., 2002). Inter cropping was found to be an effective way of reducing damage caused by *Chilo partellus* larvae migrating from one plant to another when rice is intercropped with maize.

2.5.2.5 Use of resistant varieties

Rice breeding programs has been concentrated on selecting for insect resistant varieties so as to obtain more resistant cultivars. Host plant resistant varieties have no effect on the environment and the method is compatible with other insect control methods (Rami *et al*., 2002). Farmers in Africa depend on traditional varieties whereby most of them are low yielding and less resistant to stem borers (WARDA, 2008). Many research trials concluded that certain rice varieties had less stem borer damage than susceptible varieties (Khan *et al.,* 2005). Some examples of rice varieties which are resistant to stem borer damage include IR36, lR32, IR66 and IR77. Some of African rice varieties such as NERICA4 are said to be tolerant to rice stem borers (Nwilene *et al.,* 2008).

2.5.3 Chemical methods

Chemical control is encouraged when all other control methods are deemed to be ineffective. Pesticides to be applied should have low-toxicity so that exposure to other non targeted species as well as humans is reduced (Abdulla, 2007). Most chemicals are used as insecticide granules which are applied to the standing water. It is recommended to apply pesticides when damage exceeds 10% and 5% dead heart and white head respectively (Nwilene *et al.*, 2008). Some of pesticides used to control stem borers include Fipronil, Carbofuran, Carbosulfan, Diazinon, Chlorpyrifos, Phenthoate and Quinalphos. The usage of DDT for controlling pests has been burned out due to its effect to the environment.

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CHAPTER THREE

3.0 ABUNDANCE AND SPATIAL DISPERSION OF RICE STEM BORER SPECIES IN KAHAMA DISTRICT, TANZANIA

3.1 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. Twenty farmer's fields were kept under surveillance for larvae and adult moths throughout the growing season from November 2013 to May, 2014. Stem borer larvae were extracted randomly from the damaged tillers in 16 quadrats established in each field. Adult moths were trapped by light traps and collected in vials with ethyl acetate for identification. Results indicated the presence of *Chilo partellus, Maliarpha separatalla* and *Sesamia calamistis* in all study areas. The most abundant species was *Chilo partellus* (48.6%) followed by *Maliarpha separatalla* (35.4%) and *Sesamia calamists* 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 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.

3.2 Introduction

Stem borers are major biotic constraints to cereal production in sub-Saharan Africa (Mailafiya *et al.*, 2010). These stem borers have been reported to be responsible for potential yield losses ranging between 5-10% or 60% in terms of outbreak in Africa and Asia (Pathak and Khan, 1994). Stem borers exhibit complete metamorphosis type of life cycle whereby larva is the only destructive stage (Srivastava *et al.*, 2003). With exception of *Sesamia calamistis* that borers directly into stems (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.,* 2010).

About twenty stem borer species have been reported to be the most serious insect pests of rice throughout the world. In Africa four species are said to be of economic importance, these include *Chilo spp, Diopsis longcornis* Macquart*, Maliarpha separatalla* Ragonot and *Sesamia calamistis* Hampson (Ogah, 2013). These stem borers occur in most of tropical Africa, of which they have been recorded in 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 between different ecological zones (Ogah, 2013).

In Tanzania three lepidopteran stem borers have been reported, these include, the White stem borer (*Maliarpha seperatella*), African Pink Borer (*Sesamia calamistis*) and Spotted stem borer (*Chilo partellus*) (Banwo, 2002). These stem borers are distributed in major 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, 2001).

Relative abundance and composition of stem borer species are important aspects to consider in determining kind of stem borers present in certain location. Various studies of lepidopterous stem bores in Africa investigated 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, there is a need to study the abundance and species composition in rice varieties and the influence of varied sowing dates in rice production. This will help to know which varieties are preferred by certain stem borer species and whether sowing time coincides with moth population peak.

Rice stem borers have been reported by farmers as problematic pests that contribute to high rice yield loss in Kahama District. The spatial and temporal distribution and abundance of stem borers vary among and within host plants probably due to their suitability for oviposition and larval development (Addo-Bediako and Thanguane, 2012). However, the species dynamics, abundance and the spatial dispersion of these stem borers in rice fields has not been examined and established in Tanzania. The current study aimed at investigating the existing species of the rice stem borers, the abundance and spatial dispersion in rice fields in Kahama District.

3.3 Materials and Methods

The study was carried out in Kahama District which is located between latitudes 3015" and 4030" south of Equator and latitude 31030" and 33000" east of Greenwich (Esabella, 2012). Among 5 divisions in the District, rice is highly produced in Msalala division. The study was carried out in five wards of Msalala division namely Bulige, Chela, Kashishi and Ngaya.

The district is characterized by tropical climate. The average daily temperature in Kahama District is 22°C (Duguma *et al.,* 2013). It experiences unimodal rainfall, falling from October to May. Sometimes dry spell is experienced in the months of January and February. The average annual rainfall is 1000mm and is well distributed in the whole district. However, over the recent years, below average rainfall amounts have been experienced. Soils in Kahama District range from sandy to Sandy-loamy and clay-loamy. In low lying areas known as mbuga (seasonally flooded), silty clay soils are common (Duguma *et al.,* 2013).

Farmer's rice fields were randomly chosen at an approximate interval of 1km between farms. A plot size of about 1 acre (70m x 70m) was earmarked by using fibre tape. A guard row of approximately 15-20 meters 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 1m x 1m size were established for sampling, thereby making a total of 16 quadrats in each field. A Split plot experimental design was applied. Wards were regarded as main plot factor while farmer's fields were regarded as sub plot factor. Farmer's fields were chosen randomly in each of the selected ward. Name of the rice variety and sowing date in each of the selected fields were noted.

Numbers of larvae of stem borers present in different tillers were counted in each quadrat. The spatial distribution pattern for stem borer was determined by three indices of dispersion, including Morisista index, Iwao's mean crowding regression and Taylor's power law as described by Morisista (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, 2011). These indices are described by the formula below.

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

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 through solving the following equation:

$$m' = \alpha + \beta m \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

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 and m was replaced with the mean and variance from the count data.

$$m' = m + \left(\frac{S^2}{m}\right) - 1 \qquad \text{………………………………………………………(3)}$$

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.

$$\log(S^2) = \log(a) + (b)\log(m) \qquad \text{……………………………..………........(4)}$$

Two light traps were used for moths trapping during night time in each field. Where by White cloth was reinforced with ropes and tied between two stands/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 and sorted later to identify the respective species.

Plate 1: Trapping stem borers using light trap

Identification of stem borer species was done by using the identification guide by Pathak and Khan (1994). Species abundance was calculated according to Thomas (2005) as follows;

$$\text{Abundance of species} = \frac{\text{Number of individuals of the same species}}{\text{Total number of moth}} \times 100\% \qquad \text{....(5)}$$

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 borers' abundance were subjected to the analysis of variance (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. Significant differences among means were separated using Least Significant Difference test (LSD) at probability level of 5%. The analysis model was according to Gomez and Gomez (1984) for split plot design, i.e. $X_{ijkm} = \pi + R_i + A_j + \alpha_{ij} + B_k + AB_{jk} + \beta_{ijk}$; Where: X_{ijkm} =Response, π = General effect, R_i = Replication effect, A_j = Main plot effect, α = Main plot error, B_k = Subplot effect, AB_{jk} = Main plot and subplot interaction effect and β_{ijk} = Subplot error.

3.4 Results

3.4.1 Species density and abundance in different wards

Three species of stem borers, *C. partellus*, *M. seperatella* and *S. calamistis* were recorded from all surveyed sites (Fig. 1). All three stem borer species were captured in all twenty farms assessed. Of the four wards surveyed, *C. partellus* was highly abundant in Chela (70.7%) and Ngaya (56.8%) while *M. separatella* was highly abundant in Kashishi (58.9%) and Bulige (45.0%). *Sesamia calamisitis* was observed to be less important in Bulige, Kashishi and Ngaya. In Chela *Sesamia calamisitis* (16.7%) was the second abundant species after *Chilo partellus*. In overall mean abundance, *C. partellus* was highly abundant (48.6%) followed by *M. separatella* (35.4%) and lastly *S. calamisitis* (16.1%). Significant differences of stem borer species numbers were observed in four wards surveyed ($P < 0.05$) (Table 2). Abundance of *M. seperatella* also varied significantly among the wards ($P<0.05$).

Table 2: Abundance (%) of stem borer species at different locations (wards)

	Wards				
Stem borer species	**Kashishi (Mean±SE)**	**Bulige (Mean±SE)**	**Chela (Mean±SE)**	**Ngaya (Mean±SE)**	**Mean abundance (%) (Mean±SE)**
Chilo partellus	33.0±6.95ab	33.8±6.95ab	70.7±6.95a	56.8±6.95a	48.6±6.95a
Maliarpha seperatella	58.9±8.32a	45.0±8.32a	12.6±8.32b	25.1±8.32b	35.4±8.32ab
Sesamia calamistis	8.1±4.61b	21.5±4.61b	16.7±4.61b	18.1±4.61b	16.1±4.61b
CV(%)	64.8	64.8	64.8	64.8	64.8
F- value	0.004	0.004	0.004	0.004	0.004
LSD at 0.05	32.5	21.02	36.42	18.21	32.4

Values within a column with a letter in common are not significantly different at $P < 0.05$

Figure 1: Lepidopterous stem borers: (a) ***Chilo partellus (*****b)** ***Maliarpha seperatella*** **(C)** ***Sesamia calamistis***

3.4.2 Species abundance in rice varieties

In all three rice varieties assessed, *C. partellus* was highly abundant followed by *M. seperatella* and the less abundant species was *S. calamistis* (Table3). There were significance difference among stem borer species at P <0.05 level of significance (Table 3). Although no significant differences were observed on the interaction between borer species and rice varieties *C. partellus* was numerically higher in abundance in Kalamata and Supa than Mayobhe. The species *M. separatella* and *S. calamistis* were numerically higher in Mayobhe variety than in Kalamata and Supa. Therefore the results indicate that stem borer species abundance is not affected by rice varieties.

Table 3: Abundance (%) of stem borer species in different rice varieties

	Varieties			
Stem borer species	**Kalamata (Mean±SE)**	**Mayobhe (Mean±SE)**	**Supa (Mean±SE)**	**Mean abundance (%) (Mean±SE)**
Chilo partellus	69.9±6.57a	53.5±6.57a	55.0±6.57a	59.5±6.57a
Maliarpha seperatella	19.6±6.95b	24.4±6.95b	29.4±6.95b	24.5±6.95a
Sesamia calamistis	10.4±4.49b	22.0±4.49b	15.6±4.49b	16.0±4.49b
CV%	71.6	71.6	71.6	71.6
F- value	<0.001	<0.001	<0.001	<0.001
LSD at 0.05	34.81	20.10	20.10	34.0

Values within a column with a letter in common are not significantly different at P < 0.05

3.4.3 Species abundance at different rice sowing date

There was no significance difference of stem borer species at different sowing date at P <0.05 level of significance (Table 4). Significance difference is present among different stem borer species. *Chilo partellus* abundance was higher in rice sown from 15th to 30th November (51.6%) than the rice sown from 1st to 20th December and from 28th December to 05th January (47.1% and 47.0% respectively) (Table 4). *Maliarpha separatella* abundance was higher in rice sown from 1st to 20th December (44.5%) than that sown from 15th to 30th November (25.5%) and 28th December to 05th January (36.1%). *Sesamia calamists* was the least in abundance compared to all stem borer species among different rice sowing date, its abundance was high in rice sown in 15th to 30th December (22.9%).

Table 4: Abundance (%) of stem borer species at different sowing date

	Sowing date			
	15-30.11.2013	**1-20.12.2013**	**28.12.2013 - 05/01/2014**	**Mean Abundance(%)**
Stem borer species	**(Mean±SE)**	**(Mean±SE)**	**(Mean±SE)**	**(Mean±SE)**
Chilo partellus	51.6±6.95a	47.1±6.95a	47.0±6.95a	48.6±6.95a
Maliarpha seperatella	25.5±8.32b	44.5±8.32a	36.1±8.32a	35.4±8.32a
Sesamia calamistis	22.9±4.61b	8.7±4.61b	16.8±4.61b	16.1±4.61b
CV%	80.2	80.2	80.2	80.2
F- value	0.023	0.023	0.023	0.023
LSD at 0.05	24.5	28.8	22.8	22.54

Values within a column with a letter in common are not significantly different at $P < 0.05$

3.4.4 Stem borer distribution

Mean stem borer larvae per quadrat in four wards studied ranged from 1.00 – 2.63 in Kashishi, 0.60 – 2.31 in Bulige, 0.00 – 6.00 in Chela and 1.00 – 6.13 in Ngaya (Table 5). In kashishi two indices were in agreement that stem borer population were uniformly distributed in fields while one index 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 suggested the aggregate distribution of stem borer larvae while one index showed uniform distribution.

Morisista's index was greater than 1 in Bulige, Chela and Ngaya indicating aggregated population distribution while in Kashishi was less than one indicating uniform distribution (Table 5). The slopes of the regression lines for Iwao's mean crowding regression were numerically greater than 1 in Bulige, Chela and Ngaya, indicating aggregated distribution while in Kashishi the slope was significantly less than one indicating uniform distribution. Slopes of the regression lines for Taylor's power law were greater than 1 in Kashishi, Bulige and Ngaya indicating aggregate distribution of larvae, in Chela slope was less than 1 indicating uniform distribution.

In all of four wards surveyed, stem borer larvae were more aggregated along the edges of rice fields than in the middle parts (Fig. 2). The aggregation of larvae along the edges of field do not differ much than the concentration in the middle of the field. Among these wards, Chela had the highest number of larvae followed by Ngaya, Kashish and Bulige has the least (Fig. 2).

Table 5: Dispersion indices for stem borer larvae as influenced by study locations

			Iwao's mean crowding regression			Taylor power law		
Ward	**Range of means**	**Morisista's index**	**a**	**b**	**R^2**	**a**	**b**	**R^2**
Kashishi	1.00 – 2.63	0.85	0.741	0.53	0.59	-0.28	1.49	0.91
Bulige	0.60 – 2.31	1.10	-0.14	1.13	0.84	-0.01	1.02	0.63
Chela	0.00 – 6.00	2.95	0.57	1.02	0.82	0.18	0.88	0.38
Ngaya	1.00 – 6.13	3.87	1.40	1.10	0.94	0.41	1.01	0.87

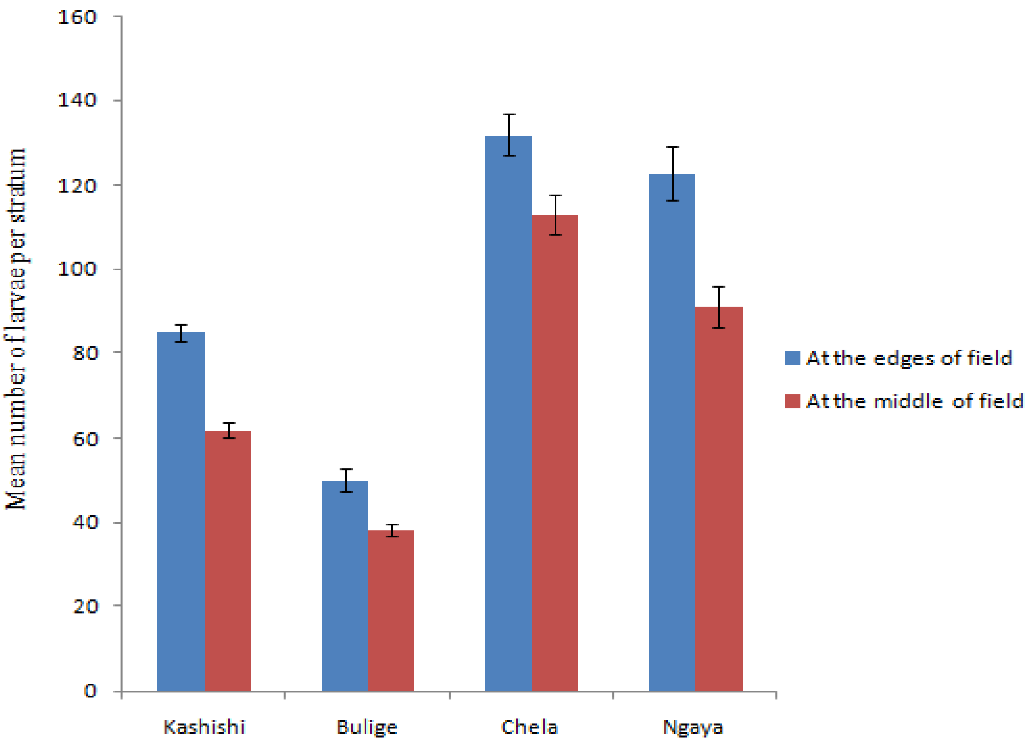

Figure 2: Stem borers' aggregation within rice fields

3.5 Discussion

During stem borer trapping, three stem borer species were found in all four wards surveyed. These species are *Chilo partellus, Maliarpha separatella* and *Sesamia calamisitis*. The study confirms previous finding by Banwo (2002) who reported three stem borer species in Tanzania inclusive Shinyanga, the species are *Chilo partellus, Maliarpha separatella* and *Sesamia calamisitis*.

In general *Chilo partellus* was more dominant throughout Kahama District than *Maliapha separatella* and *Sesamia calamisitis*. This is due to the reason that *C. partellus* complete its life cycle faster than other species found in Kahama District. Nsami *et al*. (2001) reported that *C. partellus* was highly abundant in Eastern Zone of Tanzania where it constituted 80% while *S. calamistis* constituted only 4%. Abdulla (2007) reported that *C. partellus* completes life cycle faster than other stem borer species hence high population growth than other species. *C. partellus* colonizes suitable feeding niches much earlier than the indigenous stem borers, therefore it reduces the number of other stem borer species that colonize the habitat (Ofomata *et al.*, 2000).

Abundance of stem borers was observed to be affected by site (wards). *Chilo partellus* was more abundant in Chela and Ngaya while *Maliapha separatella* was more abundant in Bulige and Kashishi than other wards (Table 2). The significant differences in stem borer abundance observed between wards might be due to difference in available host plants around rice fields. Govender *et al*. (2011) reported that in South Africa stem borer species abundance differ depending on available host plants. Also Moolman *et al*. (2013) reported the difference in species density among different host plant surveyed.

Abundance of stem borer species was determined among rice varieties grown at Kahama District where by the results showed that rice varieties do not affect abundance of stem borer species. *Chilo partellus* was most abundant in all varieties followed by *Maliapha separatella* and *Sesamia calamisitis* was less abundant than others. The results confirm previous findings by Mailafiya *et al.* (2011) who reported the dominance of stem borer species in different host plants rather than plant varieties in Kenya. Factors affecting the abundance of stem borers might be the same in all sites where rice varieties were planted hence contributed the same results in all varieties surveyed. This is evident from research conducted by Johnnie (2012) stem borers of maize, reported rain fall and humidity as important environmental factors that affecting stem borer abundance.

Stem borer host plants is another factor that affect the abundance of stem borer species. Abundance of stem borer species in rice varieties grown in different wards was the same due to the same host plants available around the surveyed rice fields. Govender *et al.* (2011) reported that stem borer abundance differ between plant species; his research confirmed that *Cyperus sexangularis* is almost bored by *Chilo sp.* The dominance of stem borer species in the same host plant was not the same in different locality. Rice varieties have effect on stem borer damage incidence rather than abundance (Muhammad, 2011).

Sowing date has no effect on the abundance of stem borer species as there is no significance difference observed on the abundance of stem borer species across different sowing date at $P < 0.05$ level of significance (Table 4). The peak of stem borer abundance was different among species due to the reason that stem borer species complete their life cycle at different time. That is why *Chilo partellus* abundance was higher in rice sown on 15 to 31, November than that of *Maliapha separatella* which abundance was high in rice sown on 1st, December to 20th, December. The same observation was reported by Abdulla (2007) that *Chilo sp*. complete their life cycle earlier than other species hence becomes higher abundant.
Stem borer abundance is affected by the growth stage of rice plant. At the time when stem borer trapped rice were in different growth stages that is why abundance was

not the same. At flowering stage rice tillers had large stem diameter and for that reason made better quality of food for stem borer population growth (Muhammad, 2013).

In all of four wards surveyed, at least one of the three indices showed that stem borer larvae were aggregated (b>1) (Table 5). In Bulige, Chela and Ngaya results indicated that stem borers were aggregated along the field edges while in Kashishi three indices of dispersion showed that stem borer larvae were uniformly distributed throughout the fields although they were much concentrated at the edges of field (Fig. 2). These larvae were aggregated along the edges of rice fields in all four wards surveyed (Fig. 2). This study confirms the previous findings by Gounou and Schulthess (2004) who reported the aggregate distribution of stem borer in various host plants assessed. Concentration of stem borer larvae along the field might have caused by migration of stem borers from other host plants around rice fields.

Aggregation of stem borer larvae along the edges of rice fields is an indication that stem borer larvae came from other host plants around the rice fields. In East Africa, 39 wild host plants of stem borers have been identified. Most common wild host plants in the region are belonging to the families Poaceae, Cyperaceae and Typhaceae (Le Ru *et al.*, 2006). Mailafiya *et al.* (2011) reported numerous wild host plants like *Cperus spp, Panicum spp, Pennisetum spp, Sorghum spp.* All of these host plants are found in Kahama Districtsince were the source of stem borer larvae that infected rice fields. Knowing spatial dispersion of these stem borer is useful for development of sampling plan since one should concentrate where the larvae are dispersed. For these stem borers, sampling plan should concentrate on the edges of rice fields. Casey and Trumble (2012) reported that for the development of sampling plan, spatial dispersion can help in choosing sampling unit; one should concentrate on examining the edge of the field since stem borers are aggregated. 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). Stem borer sampling error is caused by aggregate spatial distribution behavior of lepidopteran rice stem borers (Ndemah *et al.*, 2001; Gounou and Schulthess, 2004).

3.6 Conclusion

This study indicates that three stem borer species i.e. *Chilo partellus, Maliarpha separatella* and *Sesamia calamisitis* are distributed wherever rice is grown in Kahama District. Of the three species, *Chilo partellus*is the most abundant followed by *Maliarpha separatella* while *Sesamia calamisitis* was observed to be of less significance. *Chilo partellus* are dominant in Chela and Ngaya while *Maliarpha separatella* are dominant in Bulige and Kashishi wards. Abundance of stem borer species is neither affected by rice varieties grown nor manipulation of sowing date. The results indicate that rice stem borers exhibits aggregated dispersion in Bulige, Chela and Ngaya while in Kashishi are uniformly distributed.

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CHAPTER FOUR

4.0 STEM BORER-BASED DEAD HEARTS AND WHITEHEAD INCIDENCES IN RICE VARIETIES AND DIFFERENT SOWING DATES UNDER SUBSISTENT RICE PRODUCTION IN KAHAMA, TANZANIA

4.1 Abstract

The incidences of stem borer damage in rice varieties and different sowing date were investigated in four major rice growing wards. Five farmers were chosen randomly in each surveyed ward. Farms were divided into four strata whereby four quadrats were established in each stratum. At vegetative rice growth stage, dead heart damage and total tillers per quadrat were counted while at reproductive stage white head damage and total number of panicles per quadrat were counted and used to calculate stem borer damage incidences. Data were subjected to analysis of variance (ANOVA) by using SPSS 16 version statistical software package (IBM Corporation). The incidences of stem borer damage varied significantly between rice varieties and sowing dates at $P < 0.05$. Behenge and Supa varieties were more susceptible to stem borer damage than Kalamata and Mayobhe. Rice sown in medium date (1 to 20, December) had lower stem borer damage incidence than rice sown in early (1 to 30, November) and late time (28, December to 05, January). More research is needed to assess incidences of rice stem borer in improved and local rice varieties.

4.2 INTRODUCTION

Rice is the main staple food throughout the world; it is consumed by almost half of the global population (Dhuyo and Soomro, 2007). Rice fields cover about 11% of the earth's arable land and by far the most important crop worldwide (Ogah, 2013). Rice is a popular food in Africa especially South of Sahara (Banwo, 2002). The crop is produced in east and west parts of Africa.

Rice is the third most important food and cash crop in Tanzania after maize; it is the source of employment and income for many farming households (MAFC, 2009). About 17 percent of households in Tanzania produce rice (MAFAP, 2012). Rice production in Tanzania covers approximately 681 000 ha representing 18 percent of the cultivated land. About 48 percent of rice is produced in Morogoro, Shinyanga and Tabora where there are more favorable growing conditions (RLDC, 2009).

Tanzania depends on traditionally grown local varieties of rice which imported from Arabic countries before 1960. These varieties include Behenge, Kalamata, Kula na bwana, Supa and many others (RLDC, 2009). The varieties are favored due to their ability to adapt climatic condition and the taste preference of Tanzanians.

Low rice yield in Tanzania is contributed by many factors; these include diseases, weeds and insect pests. Rice stem borers are among the 13 insect species reported as major constraints of rice production in Tanzania (Banwo, 2002). These stem borers are; *Maliarpha seperatella*, *Sesamia calamistis* and *Chilo partellus* (Abdulla, 2007). All three species are distributed in major rice growing regions including Shinyanga.

The larvae are the destructive growth stage of stem borer pests. These larvae bore and feed on the leaf sheath whereby they cause whitish discoloration at a feeding site. Larvae from the sheath bore into the stem; they stay in the pith and feed on the inner surface of the walls. Always the feeding separates apical parts of the plant from the base (Pathak *et al.,* 1998). When this type of damage occurs at vegetative stage of the plant growth, the central leaf whorl does not unfold. It becomes brown, and die out, but the lower leaves remain green and healthy. This damage is known as “dead heart” and the affected tillers die out without producing panicle. At flowering stage of the plant, the damage results in the drying of panicle. The damaged panicles become white and empty; this damage symptom is called “white head” (Pathak and Khan, 1994).

Rice varieties react differently to stem borer attack. Some rice cultivars are susceptible while others are tolerant to stem borer damage. Susceptibility of rice varieties to stem borer damage is associated by physiological characters such as high water and silica content in the plant (Pathak *et al.,* 1998). Resistant varieties contain antibiosis factors that hinder larvae development; for example benzoic acids, salicylic acid and some fatty acids inhibit growth of stem borer larvae.

Manipulating of sowing time has been used in stem borer management program. In Pakistan early sowing date has low stem borer incidences than medium and late sowing dates (Muhammad, 2011). In West Africa, late planted maize experiences high stem borer damage than that planted in early time (Rami *et al.,* 2002).

Stem borer pests have for many years been complained about by farmers as the major factor contributing to high rice yield loss in Kahama District. Stem borer damage vary among rice varieties. Some cultivars have been reported to be tolerant to stem borer damage for example NERICA varieties (Khan *et al.,* 2005). Manipulation of sowing date is among the methods commonly used to control stem borer damage in Pakistan (Muhammad, 2012). The current study aimed at investigating the incidence of stem borer damage (dead heart and white head) among rice varieties grown by farmers and the impact of manipulation of sowing date on the incidence of stem borer damages in particular the dead hearts and whiteheads in Kahama District.

4.3 Materials and Methods

The study was carried out in Kahama District which is located between latitudes 3015" and 4030" south of Equator and latitude 31030" and 33000" east of Greenwich (Esabella, 2012). Among five divisions in Kahama District, rice is highly produced in Msalala division. The study was carried out in five wards namely Bulige, Chela, Kashishi and Ngaya which are the major rice producers throughout the Msalala division.

The district is characterized by tropical climate. The average daily temperature in Kahama District is 22°C. The district experiences unimodal rainfall, falling from October to May (Duguma *et al.,* 2013). Sometimes dry spell is experienced in the months of January and February. The average annual rainfall is 1000mm and is well distributed in the whole district. However, over the recent years, below average rainfall amounts have been experienced. Soils in Kahama District range from sandy to Sandy-loamy and clay-loamy. In low lying areas known as mbuga (seasonally flooded), silty clay soils are common (Duguma *et al.,* 2013).

Rice fields were randomly chosen at approximate interval of 1km from one field to the other. A plot size of about 1 acre (70m x 70m) was demarcated by using fibre tape. A guard row of approximately 15-20 meters 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 1m x 1m size were established for sampling, therefore 16 quadrats were established in each field.

The experimental design was a split plot. Wards were regarded as main plot/factor while farmer's fields were regarded as sub plot/ factor. Farmer's fields were chosen randomly in each of the selected ward. Name of the rice variety and sowing date in each of the selected fields were noted.

The assessments were done three (3) weeks from planting for dead heart damage and ten (10) weeks after planting for white heart damage. Number of damaged tillers as dead heart and white heads in each quadrat were counted. The total number of tillers and panicles within the quadrat were also counted to establish the value upon which the percentage incidence would be derived as described by Suresh *et al.* (2009).

$$\text{Incidences} = \frac{\text{Number of dead heart or white head damage}}{\text{Total number of tillers or panicles}} \times 100\% \qquad \ldots\ldots\ldots\ldots(6)$$

At each sampling unit (quadrat), data collected included; number of tiller damaged as dead heart, number of tiller damaged as white head, total number of tellers and panicles per quadrat.

Collected data for determination of stem borer incidence were subjected to analysis of variance (ANOVA) and mean separation test undertaken at P<0.05 using SPSS 16 version statistical software package (VSN International). Significant differences among means were separated using the Least Significant Difference test (LSD) at probability level of 5%. The analysis model was according to Gomez and Gomez (1984) for split plot design, i.e.. $X_{ijkm} = \pi + R_i + A_j + \alpha_{ij} + B_k + AB_{jk} + \beta_{ijk}$ .Where: X_{ijkm} = Response, π = General effect, R_i = Replication effect, A_j = Main plot effect, α = Main plot error, B_k = Subplot effect, AB_{jk} = Main plot and subplot interaction effect and β_{ijk} = Subplot error.

4.4 Results

4.4.1 Effect of site (ward) on incidence of stem borer

Incidences of stem borer at vegetative stage (dead hearts) were observed in 19 of 20 farms surveyed while at reproductive stage incidences (whitehead) were observed in all of 20 farms surveyed. Dead heart incidences ranged from0.56% to 7.57%while the white head incidence ranged from 0.34% to2.89%.Stem borers incidences were high at vegetative stage than at reproductive stage (Table 6). Among the surveyed wards, Kashishi and Ngaya had more damage incidences than Bulige and Chela (Table 6). There were significant differences in both dead heart and white head incidences (P<0.05). At both vegetative and reproductive stages Kashishi and Ngaya had higher stem borer damage incidence than Bulige and Chela.

Table 6: Rice stem borer incidences (%) in different wads

	Incidences	
Ward name	**Dead heart (%)**	**White head (%)**
Kashishi	3.69a	2.38b
Bulige	2.21b	1.79c
Chela	2.54b	1.69c
Ngaya	3.67a	2.59a
Mean	**3.03**	**2.11**
LSD	1.13	0.80
s.e	0.18	0.14

Values within a column with a letter in common are not significantly different at P < 0.05

Table 7: Stem borer incidences in different farmers at Kahama District

No.	Name of farmer	Variety	Average tillers per quadrat	Average dead heart damage	Dead heart incidence (DH) (%)	Average panicles per quadrat	Average white head damage	White head Incidences (DH)(%)
1.	Lufega	Supa	87.34	2.00	2.29cd	23.88	0.69	2.89bc
2.	Nicholaus	kalamata	128.43	2.62	2.04cd	66.37	0.75	1.13de
3.	Samweli	Supa	21.40	1.62	7.57a	47.81	1.31	2.74bcd
4.	Mashimba	Mayobhe	42.74	1.00	2.34cd	46.64	1.25	2.43bcd
5.	Emmanuel	Behenge	45.86	1.94	4.23b	53.73	1.44	2.68bcd
6.	Kanyama	Kalamata	67.57	1.50	2.22cd	43.60	0.75	1.72cde
7.	Inviolata	Kalamata	100.43	2.31	2.30cd	30.43	0.56	1.84cde
8.	John	Supa	49.62	1.31	2.64cd	40.61	1.06	2.61bcd
9.	Daudi	Behenge	47.12	1.31	2.78cd	32.29	0.62	1.92cde
10.	Masanja	Mayobhe	50.45	0.56	1.11d	72.09	0.62	0.86e
11.	Nkinda	Kalamata	88.25	0	0d	78.48	0.62	0.79e
12.	Augustino	Mayobhe	108.99	2.06	1.89cd	55.88	0.19	0.34e
13.	Selina	Kalama	130.37	4.25	3.26bc	47.17	0.50	1.06de
14.	Shikoro	Supa	108.70	3.00	2.76cd	31.96	1.25	3.91ab
15.	Serikali	Behenge	124.48	6.00	4.82b	50.64	1.19	2.35bcd
16.	Masumbuko	Behenge	91.61	6.12	6.68ab	58.39	1.81	3 .19bc
17.	Zuberi	Behenge	74.42	2.56	3.44bc	42.30	2.06	4.87a
18.	Maziku	Mayobhe	64.64	1.81	2.80cd	53.91	0.62	1.15cde
19.	Madaha	Supa	61.44	1.88	3.06bc	56.68	1.06	1.87cde
20.	Daudi	kalamata	42.02	1.00	2.38cd	42.34	0.80	1.89cde
Mean	-	-	76.79	2.24	3.03	48.76	0.96	2.11
LSD	-	-	-	-	1.93	-	-	1.65
s.e	-	-	-	-	0.98	-	-	0.85

Values within a column with a letter in common are not significantly different at P<0.05

4.4.2 Stem borer incidences in varieties

Rice varieties grown in Kahama District are the local varieties; these varieties include Behenge, Kalamata, Mayobhe and Supa. The most susceptible varieties to stem borers damage were Behenge followed by Supa having incidences of (4.30 % for dead heart and 3.07% for white head) and (3.53% for dead heart and 2.81% for white head) respectively. Mayobhe and Kalamata were somehow tolerant to stem borer damage (Table 8). In all varieties the incidence of stem borer was higher at vegetative stage than at reproductive stage. There was significance difference of stem borer incidences among rice varieties ($P<0.05$). Studies showed that rice genotypes differ in resistant ability to stem borer attack. Farmers grow local rice varieties due to the aroma characteristic despite being susceptible to stem borer’s damage although they differ in the degree of tolerance (RLDC, 2009).

Plate 2: Dead heart damage of stem borer

Plate 3: White head damage of stem borer

Table 8: Stem borer incidences (%) in varieties

	Incidences	
Variety	**Dead heart (DH) (%)**	**White head (WH) (%)**
Supa	3.53a	2.81a
Kalamata	2.56b	1.58b
Mayobhe	2.40b	1.58b
Behenge	4.30a	3.07a
Mean	**3.03**	**2.11**
LSD	0.97	1.23
s.e	0.18	0.14

Values within a column with a letter in common are not significantly different at $P<0.05$

4.4.3 Stem borer incidences in different rice sowing date

Sowing date has an effect on the incidences of stem borer damage. The results showed difference in incidences of stem borers within rice sown in different date (Table 9). Early sown rice (15/11/2013 – 30/11/2013) had high incidence of stem borer at vegetative stage (2.853% DH) than medium (1/12 - 20/12/2013) and late sown rice (28/12/2013 - 05/01/2014) having 2.3125% DH and 2.6% DH respectively. In contrast to reproductive stage, late sown rice had higher incidence (2.6% WH) than medium (1.4% WH) and early time (2.3% WH). There were significant differences within white head incidences while no significant differences were observed in dead heart incidences at $P<0.05$ level of significance (Table 9). According to these results, the best planting date with minimum stem borer damage is from 1, December to 20, December.

Table 9: Stem borer incidences (%) in different rice sowing date

	Incidences	
Sowing date	Dead heart (DH) (%)	White head (WH) (%)
15-30/11/2013	2.85a	2.30ab
1-20/12/2013	2.31a	1.40b
28/12-05/01/2014	2.60a	2.62a
Mean	2.59	2.11
LSD	1.03	1.22
s.e	0.16	0.19

Values within a column with a letter in common are not significantly different at $P < 0.05$

4.5 Discussion

The results showed significant differences between dead heart and white head stem borer damage in the twenty farms surveyed ($P<0.05$). These results implicate stem borers as serious pests throughout Kahama District. Touhidur *et al*. (2004) reported the relationship between white head damage and yield loss; whereby 1% white heads causes 1 to 3% yield loss. Since the highest white head incidence was 3.07 in Behenge variety; stem borers can cause a yield loss of 3% to 9% for farmers growing such variety in Kahama District.

At vegetative stage the plant can compensate the low percent incidence by developing new tillers while at reproductive stage even low incidence can cause yield loss. Muralidharan and Pasalu (2005) reported that plants can compensate low percentage at early dead heart damage, but the stems and panicles born by compensatory nodal tillers become light and lead to yield loss of 1% for every 2% dead heart incidence. Muhammad (2012) reported differences in incidences of stem borers between vegetative (dead heart incidence) and reproductive stage (white head incidence) to be caused by the crop sugar content and amount of phenols. At maximum tillering stage, sugar content becomes high in stem tissues hence high larvae incidence while at reproductive stage stem tissues contain high amount of phenols hence low larvae incidences.

There were significant differences in stem borer damage among the wards surveyed. The difference in stem borer damage might be due to rice varieties grown in particular areas since Behenge variety which is more susceptible is grown at Ngaya and Chela which have also high incidence of stem borer damage (Table 8). Touhidur *et al.* (2004) reported that population density, the timing injury and rice growing conditions are factors that favor stem borer attack. These factors might have caused the differences in incidences of stem borers among farmers and wards.

Damage incidences in rice varieties varied significantly at reproductive stage (White head) ($P<0.05$). Kalamata and Mayobhe varieties are naturally tolerant to stem borer due to their low damage incidence. Resistance characteristic possessed by these varieties may be caused by possession of repellent structures or lack of feeding stimulus in the plant and either due to the presence of materials or deficiency of nutrients which are important for the insect pest (Muhammad, 2012). Mechanism of resistance to stem borer may be contributed by two physical characteristics that caused by direct mortality and sub-lethal effect to young stem borer larvae. Tightness of leaf sheaths around the silk prevents larval movement. Also premature hardness of the internodes reduce penetration and feeding of the larvae (Zhu *et al.,* 2002).

The results from this study confirm the previous findings by Ogah (2013) that the differences in stem borer infestation observed among the rice genotypes suggest that the genotypes respond differently to stem borer attack. Similar observation was reported by Muhammad (2012) whereby the rice cultivars studied contained variable resistant gene to yellow stem borers. Farmers in Kahama District grow local varieties due to their aroma characteristic. These cultivars are susceptible to stem borer attack. This concurs with findings by Muhammad (2012) that aromatic germplasm are more sensitive to stem borer attack than non aromatic varieties. Pathak and Khan (1994) reported that rice varieties differ in the level of stem borer susceptibility. However, varieties resistant to one stem borer species are not necessarily resistant to another species. They further reported that rice varieties which are highly resistant to stem borer have not been investigated, but the scores vary from high susceptible to moderate resistant varieties.

There were significant differences in the effect of sowing time on pest incidence at reproductive stage (Table 9). In general, early and late planting had the highest stem borer incidence than medium planting time. Manipulation of sowing time ensures that crops are grown when the pest is least abundant so that the crop does not interfere with peak period of moth activity (Rami *et al.,* 2002).

This study confirm the previous finding by Muhammad (2012) who reported that stem borer incidences differ in different rice sowing date. He reported that in Pakistan early sown crop was most resistant to stem borer attack having the lowest incidence among other plants. The differences in the findings might be caused by the stem borer species responsible to the damage, since stem borer species reach at the peak in different time. Manipulation of sowing date insures that the most susceptible crop growth stage does not coincide with the period of peak moth activity (Rami *et al*., 2002). Hendarsih and Usyati (2005) reported that in Indonesia stem borer infestation increased with delay in planting time, early planted rice cultivars had low stem borer infestation compared to late planted varieties. Historically shifting in planting time has been reported in Java Indonesia since 1920s and 1930s and was observed to be effective way of controlling both yellow and white stem borers (Rami *et al.,* 2002).

Sowing date has been reported to reduce the stem borer infestation in different crops in Africa (Lucius and Oniemayin, 2011). Studies in Ethiopia, using different planting times under natural infestation in maize crop showed a positive correlation between crop loss and late planting time.

4.6 Conclusion

The study indicated that rice stem borers incidence is higher at vegetative stage than reproductive stage. The incidences at vegetative stage ranged from 0.56% to 7.57% while at reproductive stage ranged from 0.34% to 2.89%. Damage incidence of these pests was higher in Kashishi and Ngaya than in Bulige and Chela wards. Among four rice varieties grown by farmers; Behenge and Supa were more susceptible to stem borer damage than Mayobhe and Kalamata. Farmers who sow rice crop early at the start of the planting season and very late time experience high incidence of stem borer damage than in medium time.

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CHAPTER FIVE

5.0 OVERALL CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study reveals that three stem borer species i.e. *Chilo partellus, Maliarpha separatella* and *Sesamia calamisitis* are distributed wherever rice is grown in Kahama District. Of the three stem borer species, *Chilo partellus* is most abundant followed by *Maliarpha separatella* while *Sesamia calamisitis* is less abundant. *Chilo partellus* is dominant in Chela and Ngaya while *Maliarpha separatella* is dominant in Bulige and Kashishi.

Stem borers exhibit aggregate kind of dispersion in most rice fields surveyed while uniform distribution is rarely occurring in rice fields. The position of aggregation is along the edges of rice fields. Rice stem borer damage incidence was higher at vegetative stage than reproductive stage and damage incidences differ from one ward to another.

Susceptibility of rice varieties to stem borer attack was highly variable. Behenge and Supa were more susceptible to stem borer damage than Mayobhe and Kalamata. Therefore Mayobhe and Kalamata were found to be tolerant to stem borer attack suggesting minimal crop loss caused by the insect pest.

5.2 Recommendations

1. Future studies should target to establish the extensiveness of rice stem borer problem in the Lake Zone, since stem borer abundance and damage may vary with respect to ecological conditions.

2. The need to undertake assessment of stem borer incidence in other crops and wild host plants cannot be overemphasized due to the recorded aggregation along the edges of rice field.

3. Screening of farmer preferred varieties to tolerance against rice stem borer is of paramount importance and should be coupled with yield loss estimates to guide rational management options.

4. The manipulation of sowing date as stem borer management option in Kahama should target planting from 1st -20th December of the respective year. However, due to variation in planting time due to rain onset, further studies may be required to re-affirm the dates.