BIO-ECOLOGY AND MANAGEMENT OF AFRICAN WHITE RICE STEM BORER, MALIARPHA SEPARATELLA RAGONOT (LEPIDOPTERA: PYRALIDAE) AT MWEA IRRIGATION SCHEME, KENYA.

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DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other university or any other award.

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DEDICATION

This degree is dedicated to my late parents (R.I.P) Honorable Isaac Kega Muthua and Alice Wangui Kega who brought me up and saw me through my education life and to rice farmers at Mwea and other irrigation schemes in Kenya who invest all their lives growing rice.

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ACRONYMS AND ABBREVIATIONS

A.S.L……………………………………Above sea level

CABI…………………………………...Commonwealth Agricultural Bureau International

CV……………………………………….Coefficient of variation

EPNS..Entomopathogenic nematodes

ERA…………………………………...Economic review in agriculture

F.A.O…………………………………..Food and Agricultural Organization of United Nations

G.I.S…………………………………... Geographic Information System

G.O.K…………………………………Government of Kenya

G.P.S…………………………………. Geographic Positioning System

IRRI…………………………………... International Rice Research Institute

K.A.R.I………………………………. Kenya Agricultural Research Institute

MIAD…………………………………Mwea Integrated Agricultural Development Centre

M.O.A…………………………………Ministry of Agriculture

M.R.G.M.S…………………………Mwea Rice Growers Multi Purpose Cooperative Society

MT……………………………………..Metric tons

N.I.B…………………………………..National Irrigation Board

p………………………………………Probability level of significance

RKMP…………………………………Rice Management Portal

SD……………………………………..Standard deviation from the mean

S.E……………………………………..Standard error of difference of means

W.A.R.D.A……………………………West Africa Rice Development Association

ABSTRACT

In Kenya rice is the third most important cereal grain in consumption after maize and wheat and about 400,000 rice farmers, the majority of them women earn their livelihood out of the crop's production. However, its production is constrained by both abiotic and biotic factors. One of the most important biotic constraints is the African white rice stem borer, *Maliarpha separatella* Ragonot. Despite the importance of this pest, information on the factors that influence its distribution, extent of crop losses and management practices in Kenya is scanty. In addition the level of knowledge that farmers have on this pest is undocumented, hence it is difficult to gauge its importance from the farmers' perspective. Therefore this study was carried out; 1) to provide information on socio-cultural and economic factors that influence distribution and the management of the pest 2) to determine the pest's spatial and temporal fluctuations 3) to determine the level of losses caused by the pest and develop economic injury levels 4) to evaluate entomopathogenic nematodes against the pest 5) to screen rice cultivars resistant to the pest 6) to evaluate the effectiveness of a combination of entomopathogenic nematodes and resistant rice cultivars in the management of the pest. To meet these objectives a farmer survey was carried out at Mwea irrigation scheme to investigate factors that limit rice production and the extent of farmers' local knowledge and management of *M. separatella.* A scheme wide observation trial on the pest was set up at Mwea irrigation scheme to investigate how the pest fluctuates in the scheme and the factors that influence this fluctuation. To understand yield losses attributable to the pest, a screen house experiment was set up at Kenya Agricultural Research Institute, Mwea where rice plants were artificially infested with *M. separatella* egg batches at early infestation and late infestation which was 3 and 6 weeks after transplant date (WAT) respectively.

A laboratory experiment was set up to evaluate effective entomopathogenic nematodes against the pest and field trials on resistant rice cultivars and a combination of these two in the management of the pest were conducted at the Kenya Agricultural Research Institute - Mwea field testing station. These studies were carried out from February 2010 to July 2011. The results from the survey indicated that rice cultivation in the scheme was for commercial purposes. The average age for the majority of farmers (62%) was 42 years. Most the farmers had about eight years rice farming experience and their main sources of information was from other farmers. Age, rice farming experience and rice farming as the only occupation, had a highly positive significant influence on the *M. separatella* knowledge and being a female significantly increased the probability of not having knowledge of *M. separatella.* The percentage number of farmers who used pesticides to control *M. separatella* was 77%. About 60% of the respondents indicated that not controlling the pest will be too costly for the farmer in terms of yield losses. Empirical results showed that irrigation water provision schedule and cropping system significantly influenced spatial and temporal fluctuation of *M. separatella* in the scheme. High pest infestations occurred in areas of sporadic irrigation and where double cropping of rice was carried out. There were no significant differences in pest infestations in the main season crop and the ratoon crop ($p>0.05$). The percent number of whiteheads and tunneled tillers in farms under System for Rice Intensification were not significantly different from the flood irrigated fields ($p>0.05$). *Maliarpha separatella* infestations in the various planting regimes was independent of water provision ($p>0.05$). The results from the screen house experiment showed that maximum yield reduction (91%) occurred to the plants infested with 8 egg batches in the early infestation. There were no significant differences in the plants infested with 6 egg batches in the early infestation period, from those infested with 8 egg batches in the late infestation ($p>0.05$).

On the basis of cost benefit ratio, the economic injury level was 6 and 8 egg batches per square meter of rice plants for early and late infestation respectively. The corresponding economic threshold level was 4 egg batches/ m^2 in the early infestation and 6 egg masses/ m^2 in the late infestation.

The entomopathogenic nematode, *Heterorhabtidis indica* Poinar, Karunaka & David was found to have significant efficacy on the pest under laboratory conditions ($p<0.05$).

The rice cultivar M27608 was tolerant to *M. separatella* damage and M27615 was resistant. Combination of these two cultivars with *H. indica* significantly reduced *M. separatella* damage ($p<0.05$). From this study, it can be concluded that knowledge of managing *M. separatella* infestation at Mwea irrigation scheme is scanty and the farmer's local knowledge of *M. separatella* influences its management practices. Sporadic water provision and continuous rice cropping increase *M. separatella* infestations, but ratooning of the rice crop does not increase the pest infestation. *Maliarpha separatella* infestation causes reduction in rice yields and results in substantial economic losses. The management of the pest is possible by use of a combination of effective entomopathogenic nematodes and resistant rice cultivars.

CHAPTER 1

INTRODUCTION

1.1.Background information

Globally, rice is one of the most important food crops in the fight against hunger. It is the grain with the highest consumption (GOK, 2009). The total global annual production of milled rice in 2008/2009 was 459.6 million metric tons (MT) (GOK, 2010). It is estimated that there will be five billion rice consumers worldwide by 2030 and to feed these people rice production will need to be increased by 40% (Khush, 2005). Rice production in Africa increased from 8.6 MT of paddy in 1980 to 18.6 MT in 2005 (FAO, 2006). Despite such dramatic growth, demand continues to exceed supply and Africa continues to rely on imported rice.

In Kenya, rice is the third most important cereal grain after maize and wheat in consumption (GOK, 2009). It is second after maize in consumption. Of the three grain staples, it has the highest annual per capita consumption growth rate at 12%, followed by wheat at 4% and maize which is the main cereal staple by only 1% (GOK, 2009). Kenya is food insecure and depends on rice imports and aid from development partners to meet her food requirements (Gitu, 2004). In 2008, the country was a net importer of rice as only 80,000 MT of rice was produced against a consumption of 320,000 MT. The country imported 240,000 MT to cover the deficit, or 75% of its total rice requirements at a cost of seven billion Kenya shillings (GOK, 2009).

It has been reported that resource-poor farmers in developing countries, who rely on rice, lose an estimated 10% of yield each year because of insect pests (WARDA, 2008). In addition diseases have been cited as a major constraint to rice production.

The major diseases of rice in Kenya are the Rice Yellow Mottle Virus (*Sobemovirus*) vectored by rice flea beetles *Chaetocnema spp*, Sheath blight caused by *Rhizoctonia solani*, Brown spot (*Helminosporium spp*) and Rice blast (*Pyricularia grisea*) (National Rice Technical Committee, 2011). Rice is attacked by many species of insects which include grass hoppers (Orthoptera: Acrididae), crickets (Orthoptera: Gryllotalpidae), rice-sucking bugs (*Aspavia* spp), *Stenocoris* spp., *Mirperus* spp (Hemiptera: Alydidae), green stink bug *Nezara virudula* (Hemiptera: Pentatomidae), leaf hoppers *Cicadulina spectra* (Hemiptera: Cicadellidae), plant hoppers(Homoptera: Delphacidae), leaf mining beetles *Trichspa sericae* (Coleoptera: Hispidae), whorl maggot *Hydrellia philippina* (Diptera: Ephydridaea) and rice caseworm, *Nymphula depunctalis* (Lepidoptera: Pyralidae) (National Rice Technical Committee, 2011), but it is the stem borers that are the most important in terms of yield losses. Four stem borer species have been reported on rice in Kenya namely stalk eyed fly, *Diopsis thoracica* (Dipera: Diopsidae), spotted stalk borer, *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae), pink stalk borer *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae). The most common is African white rice stem borer, *Maliarpha separatella* Ragonot (Lepidoptera: Pyralidae) which attacks rice crop at all the growth stages and causes high yield losses on late planted rice and the ratooned crop (National Rice Technical Committee, 2011). Reports indicate that the most susceptible variety at Mwea to *M. separatella* is Basmati 370 which also happens to be the most popular variety due to its long grains and aroma (Kimani *et al.*, 2010). Stem borers can be controlled by use of cultural methods, application of biological control agents and use of insecticides (Riba, 2007). Harvesting at ground level, ploughing in the stover after harvesting and flooding the rice fields have been reported to destroy majority of larvae in the stubble and any diapausing larvae (Navarajan, 2007, Riba, 2007).

Riba (2007) also reported that since adult moths oviposit eggs near the tip of the leaf blade, clipping the seedlings before transplanting reduces the carry-over of eggs from the nursery to the main rice field.

Trichogramma spp which are egg parasitoids have been identified as suitable biological control agents and are extensively used in India against lepidopteran pests where they are marketed as Tricho-cards® (Navarajan, 2007). However, use of pesticides is the best option when there are pest outbreaks or resurgences (Riba, 2007). Insecticides like Dimethoate® are used to routinely spray against *M. separatella* at Mwea irrigation scheme (National Rice Technical committee, 2011).

1.2. Statement of the problem

Agricultural practice has been described as a performance, involving the farmer making contingent responses to various events as a season unfolds. Knowledge may be used in making decisions at each point but the resulting field practice, such as pest management, is the result of interaction between underlying knowledge and a series of events, opportunities and constraints rather than a carefully planned *a priori* design (Richards, 1989).

It has also been realized that what people do and what they know are rather different (Sinclair and Walker, 1998). Improved understanding of weaknesses in farmers' technical knowledge on *M. separatella* bio-ecology and factors that influence acquisition of this knowledge by farmers at Mwea irrigation scheme will be important. This will aid in the design of appropriate management strategies against the pest, resulting in the reduction of rice yield losses and use of agrochemicals in the scheme.

Maliarpha separatella is a major pest that limits productivity of paddy rice in irrigation schemes in Kenya. It is mainly a rice pest and its' alternate hosts are few.

Usually rice ratoons support residual populations between rice crops and an increase in cropping intensity in irrigated systems increase the level of damage (Umeh *et al.*, 2000). However, information on bio-ecology of the species in the irrigated rice ecologies in Kenya is scanty. Understanding the factors that influence *M. separatella* fluctuations in flooded rice ecosystem will help in manipulation of cultural practices and the timing of insecticide treatments to manage it.

Protection against *M. separatella* at Mwea irrigation scheme is routine and primarily consists of the application of pesticides that are, for the most part, recommended by manufacturers and applied on a calendar-based schedule, rather than on a need basis. In most cases they are applied when pest levels do not justify their use. The development of economic thresholds will be an important decision tool for the farmers on when to initiate control measures against the pest. Routine pesticide spraying also has attendant problems of environment pollution, contamination of aquatic habitats and the development of resistance to pesticides. Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests and their damage through a combination of techniques such as biological control, habitat manipulation and modification of cultural practices, use of resistant cultivars and judicious use of pesticides.

Integrated pest management programs have a significant impact in minimizing the adverse effects of insecticides, and increasing the profitability of rice production. This study aims to integrate the entomopathogenic nematode, *Heterorhabtidis indica* and resistant rice cultivars in the management of *M. separatella*.

1.3. Justification

In Kenya rice is the third most important staple food crop after maize and Irish potatoes in terms of consumption. However, annual rice production is low at only 80,000 metric tonnes (MT) against consumption of 320,000 MT. This is further compounded by the fact that of the three grain staples, rice has the highest annual growth rate in per capita consumption at 12% followed by wheat at 4% and maize at 1%, making the country import 75% of total rice domestic requirements. About 95% of rice produced in Kenya is from irrigation schemes. Food security is the major output of irrigation activities; however this cannot be achieved without sustainable pests and disease management (GOK, 2009). *Maliarpha separatella* has been reported as the most important insect pest in late irrigated rice. It is also important in the ratoon crop where losses of 5-50% have been reported. Development of an Integrated Pest Management system against the pest will reduce the possibility of losses, increase food availability and incomes for small holder farmers in irrigation schemes and contribute to reduction of the country's food import bill.

1.4. Objectives

1.4.1. Overall objective

To study the bio-ecology of *M. separatella* and to develop an Integrated Pest Management (IPM) system against the pest, so as to contribute to food security and improved livelihoods of rice farmers in irrigation schemes in Kenya.

1.4.2. Specific objectives

1) To document the level of farmer knowledge on *M. separatella* and its influence in the management of the pest.

2) To determine the influence of water provision schedules and planting time regimes on spatial and temporal fluctuation of *M. separatella* at Mwea irrigation scheme.

3) To measure rice losses associated with *M. separatella* infestation and damage.

4) To evaluate the effectiveness of entomopathogenic nematodes against *M. separatella.*

5) To screen rice cultivars for resistance to *M. separatella.*

6) To assess the effectiveness of resistant rice cultivars and entomopathogenic nematodes in the management of *M. separatella.*

1.5. Hypotheses

1) Farmer's local knowledge of *M. separatella* does not influence its management practices.

2) Water provision schedules and planting time regimes do not influence the spatial and temporal fluctuations of *M. separatella* at Mwea irrigation scheme.

3) *Maliarpha separatella* does not cause substantial damage and yield loss in rice.

4) There are no effective entomopathogenic nematodes against *M. separatella*

5) Resistant rice cultivars against *M. separatella* do not exist.

6) Combination of resistant rice cultivars and entomopathogenic nematodes cannot manage *M. separatella.*

1.6. References

Food and Agricultural Organization (FAO) 2006. FAOSTAT Database [Online] fao.org/ag/magazine/060sp1.htm . Accessed 16 July 2012.

Gitu, K.W. 2004. Agricultural Development and Food Security in Kenya. Building a case for more support. *A paper prepared for the Food and Agricultural Organization of the United Nations (FAO)*: 13-14.

Government of Kenya (GOK). 2010. Economic Review of Agriculture: 15-20.

Government of Kenya (GOK). 2009. National rice development strategic plan (2008-2018). Ministry of Agriculture 25pp

Khush, S. G. 2005. What it will take to Feed 5.03 Billion Rice consumers in 2030. *Plant Molecular Biology* 59:1-6.

Navarajan, P. 2007. Insect pests of rice (*Oryza sativa*). In Insects pests and their management. www.nsdl.niscair.res.in/bitstream/123456789/493/1/. Accessed 17 August 2012.

National Rice Technical Committee, 2011. Rice insect pests and diseases. In Guidelines to rice production in Kenya (Eds Kouko, W., Wanjogu, R., Kimani, A., Mahungu, M. and Hikaru, N.): 37-39

Riba, T. 2007. Major pests of paddy and their management, Paddy Stem borers: In Integrated pest management in paddy, Krishi Vigyan Kendra College of Horticulture and Forestry, Central Agricultural University, Pasighat. http://www.earik.in/index.php?option=com_content&view=article&id=74:crop-information&catid=39. Accessed 4 August 2012

Richards, P. 1989. Agriculture as a performance. In: *Farmer first* (eds. Chambers, R., Pacey, A. and Thrupp, L.A.). Intermediate Technology Publications, London: 39-51.

Sinclair, F.L. and Walker, D.H.1998. Qualitative knowledge about complex agroecosystems. Part1: a natural language approach to representation. *Agricultural Systems* 56:341-363.

Umeh, E .D. N., Joshi, R. C and Ukwungwu, M. N. 2000. Biology, status and management of rice insect pests in Nigeria. *Crop Protection* 11(5): 408-413.

(WARDA) Africa Rice Center /FAO/SAA. 2008. NERICA®: the New Rice for Africa – A Compendium. (Eds. Somado, E.A., Guei, R.G. and Keya, S.O.) Cotonou, Benin: Africa Rice Center (WARDA); Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Association. 210 pp. ISBN 92 9113 3167.

CHAPTER 2

LITERATURE REVIEW

2.1. *Maliarpha separatella* biology and ecology

Maliarpha separatella is the most important stem borer pest species on the upland and irrigated rice ecologies in sub Saharan Africa and Indian Ocean Islands and is restricted to cultivated rice and its wild relatives (CABI, 1996). Stem borers can have multiple generations in a year (multivoltine), but the number of generations depends on environmental factors primarily temperature, rainfall, and crop availability. In different geographical areas, the borers hibernate, aestivate, or remain active throughout the year, and occur in different seasonal patterns. But in tropical conditions with the continuous cropping of rice, overlapping generations are possible throughout the year (Heinrichs and Barrion, 2004). Reports also indicate that *M. separatella* is able to survive on rice stubble of the previous harvest and wild rice (Ba *et al.*, 2008).

Studies indicate that an ecologically specialized pest species with a narrow host range like *M. separatella* is favoured by crop intensification, which involves continuous cropping of a susceptible variety due to its other desirable attributes, an increase in the use of fertilizers and pesticides, increased area under irrigation and closer spacing resulting in increased plant densities (Umeh *et al.*, 2000). It has also been shown that traditional cultural practices provide a certain degree of stability in which natural enemies play a major role of regulating the pest (Nwilene *et al.*, 2011).

2.2. *Maliarpha separatella* damage on rice and importance

In Kenya, irrigated rice yields are less than 4 tons per hectare against a potential of more than 10 tons per hectare (GOK, 2009). The low yields can be attributed to damage by a large number of insect pests from nursery to harvest, but only a few of them are considered key pests. In Kenya *M. separatella* has been reported as the most important insect pest in the ratoon crop and the late planted rice in irrigation schemes. Reports estimate losses due to *M. separatella* ranging from 7 % to 34% (CABI, 1996), but sometimes total yield loss can occur once the stems have been infested. *Maliarpha separatella* damage to the rice plant is unique among the various rice stem borer species in that larval damage seldom causes the development of dead-hearts. This is because the growing apical portion of the rice plant is not cut from the base, as the larvae dwell in the lower internodes. The damage results in empty panicles, unfilled grains and white heads. It causes substantial yield loss, by reducing plant vigour and the number of tillers and affecting yield components, which result in lower weights based on 1000 seeds (National Rice Technical Committee, 2011, 2003, Nwilene *et al.*, 2011).

Crop loss assessments are important in pests and pesticide management. Applying insecticides against Yellow Stem Borer has been recommended if there is one adult stem borer moth per square meter of rice plants in a rice field; or 5% "dead hearts" at vegetative stage, and moth or one egg mass per square meter before booting (RKMP, 2011). Litsinger *et al.*, (2006) reported that the most effective action threshold for yellow *Scirpophaga incertulas* (Walker) and white *S. innotata* (Walker) was deadhearts. The respective percentages for different rice growth stages were 5% for vegetative stage, 25% in reproductive and 10% in the ripening stages. Muralidharan and Pasalu (2006) reported that 1% dead hearts causes 2.5% yield loss, 1% whiteheads causes 4.0% yield loss, and 1% dead hearts and whiteheads result in 6.4% yield loss.

The monitoring of stem borer brood emergence through trapping by use of pheromone traps is also an important component for predicting stem borer damage in Pakistan (RKMP, 2011).

2.3. Management of *Maliarpha separatella* on rice

Methods for controlling stem borers include application of insecticides and biological agents, cultural practices and the growing of resistant crop varieties

2.3.1. Chemical control

Use of insecticides to control rice pests is the most popular method and accounts for most of insecticides use in Asia (Litsinger *et al*., 2009). Insecticides are effective at reducing stem borer infestations and yield losses in rice (Reay-Jones *et al*., 2007). However, the price of chemicals is generally high and moreover, because the larvae feed inside the stems, they cannot be controlled by non-systemic insecticides. It has also been reported that it is normally too late to initiate control measures on seeing the damage symptoms (Litsinger *et al*., 2009). Farmers are reported to use excessive applications which are not economical. Bandong *et al* (2002) in a study in Phillipines found out that 70% of the farmers growing rice under irrigation used insecticides against stem borers, with average of 3-4 applications. Farmers sprayed upon seeing some moths flying when flushed from the fields or by observing damage only on a few hills. Heong and Escalada (1999) reported that farmers tended to overuse pesticides in the belief of worst stem borer attacks in the absence of control. Repetitive advertising by pesticide manufacturers, high peer pressure from other farmers and misconception of perceived benefits from insecticide sprays directly influenced farmers' spray decisions, insecticide spending and spray frequency (Heong and Escalada, 1999).

2.3.2. Cultural control

Rice plants in the vegetative and early reproductive stages and rice fields receiving high rates of nitrogenous fertilizers are preferred for egg oviposition by stem borer moths (Heinrichs and Barrion, 2004).

Studies have also shown that the transplanted rice has higher stem borer numbers than a direct seeded crop, because the former crop matures later in the season thus allowing the stem borers to build up on earlier plantings (Litsinger *et al*., 2009). Reports indicate that moths of stem borers are attracted to water bodies and those seedlings of direct seeded rice crop which are grown without standing water during the vegetative stage are less attractive for oviposition. *Maliarpha separatella* attacks the late stages of the rice crop development and the synchrony of stem borer generations within a given rice-growing area is dependent on the synchrony of planting within the dispersal range of the moths. If in a rice-growing area there are rice fields sown at different times, there will be many oviposition periods, leading to overlapping generations. Synchronous planting is advocated for the management of stem borers because it allows a planned non-rice break to occur during the year to interrupt the pest life cycle (Heinrichs and Barrion, 2004). Previous studies indicate that pest damage from stem borers was greater in areas where farmers staggered their planting up to three months apart and used varieties that matured in 120- 210 days than in areas where farmers planted rice within one month and used 120-days varieties only (Heinrichs and Barrion, 2004). Pakmakumari and Pasalu, (2003) reported that growing one row of Pusa basmati 1 (a susceptible variety as an inter crop/ trap crop) for every 9 rows of the main crop in east- west direction reduced damage by stem borer in the main crop. However, the sowing date of Pusa basmati has to be adjusted so as to flower a week before the main crop.

Chandramani *et al*. (2010) reported that use of soil amendments containing organic silica reduced leaf folder, stem borer and gall midge populations and increased rice yields.

2.4.3. Entomopathogenic nematodes as biological control agents

Increased efforts in recent years have been focused on biological control using entomopathogenic nematodes. Most of the virulent species are in the families, Heterorhabditidae and Steinernematidae.

These two nematode families are in the order Rhabditida. They are associated with mutualistic bacteria in the genus *Xenorhabdus* for Steinernematidae and *Photorhabdus* for Heterorhabditidae. Thus, it is a nematode/bacterium complex that works together as a biological control unit to kill an insect host (Hazir *et al*., 2006). Some EPN species for example, *Heterorhabtidis bacteriophora* (HP 88), *Heterorhabtidis megidis, Steinernema carpocapsae*, *Steinernema feltiae* and *Steinernema krauseri* are available commercially as insecticides (Weeden *et al.,* 2007). Reports from Kenya Agricultural Research Institute (KARI) (2006) and Waturu (1998) indicated that *Sternenema karii* was effective against the larvae of the African boll worm *Helicoverpa armigera* Hubner and the spotted stem borer *Chilo partellus* (Swinhoe) under experimental conditions. Nderitu *et al.* (2009) reported that *Heterorhabtidis indica* was effective against sweet potato weevil, *Cylas puncticollis (*Boheman) and Nyasani *et al.* (2007) found significant efficacy of *Steinernema karii* against the Diamond back moth *Plutella xylostella* (L) in kales.

2.4.5. Host plant resistance as a component in Integrated Pest Management systems

Studies indicate that resistance to stem borer in rice can be attributed to biochemical and physical differences in different rice varieties. Padhi (2004) reported that stem borer resistant variety IR-198007-21 released antibiotic chemicals which reduced the buildup of population of stem borers while susceptible variety Basmati-370 lacked this quality and that high amount of total phenols, orthodehydroxy phenol, silica and low sugar occurred in tolerant varieties to the yellow stem borer as compared to the susceptible checks. Irrespective of varieties, the sugar content of the stem tissue was highest at maximum tillering stage, and this resulted in higher borer incidences in this stage, the amount of phenolic compounds and silica increased significantly with the age of the plant, but the survival of stem borer larvae decreased as the rice crop age advanced.

Results of studies by Ramzan *et al.* (2007) indicated that the lowest stem borer infestation was found in plots where nitrogen was not applied. Aromatic rice varieties were also reported to be more attractive and susceptible to stem borers (Dhuyo and Soomro, 2007).

Physical attributes of rice varieties like hard and narrow stem lumens were found to make rice plants less attractive to stem borers (Padhi and Sen, 2002). Zou *et al.,* (2002) found that rice cultivars with tight sheaths and short internodes had lower stem borer infestations. Short statured varieties were also reported to suffer less stem borer damage while rice cultivars with short maturation periods escape stem borer attack and those with high tillering ability compensate for stem borer damage (Ntanos and Koutroubas, 2000). Tall long maturation cultivars were reported to be more susceptible to stem borer attack and the rice plants were more vulnerable to stem borer infestation during maximum stem elongation rice growth stage (Litsinger *et al.*, 2006). In Kenya the following cultivars are reported to be resistant to stem borers, *Oryza sativa* japonica sub species LAC 23, ITA 121, TOS 4153 and New Rice for Africa (NERICA) rice cultivars, NERICA 1, NERICA 2, NERICA 4, NERICA 5 and NERICA 7 (National Rice Technical Committee, 2011).

2.4.6. Integrated Pest management

Integrated pest management (IPM) is the combination of cultural, biological and chemical methods to sustainably manage pests in flooded rice cultivation in the most effective, environmentally sound and socially acceptable manner. It involves crop management as a preventative measure to enable the crop to compensate from stem borer injury and to regularly monitor the rice crop using action thresholds (Litsinger *et al.*, 2005). Control measures include: cultural control (flooding, harrowing and ploughing to minimize population carryover; destruction of stubble and volunteer rice plants; regulating planting times; using early-maturing varieties; synchronizing planting; and removing stubble at harvest), biological control (through conservation and enhancement of natural enemies), use of host-plant resistance and pheromones to disrupt mating (RKMP, 2011). During rice stem borer outbreaks, these control tactics can be reinforced by judicious use of pesticides. Combination of resistant rice varieties, *Beuvaria basiana* isolates, neem kernel extract and early planting significantly reduced yellow stem borer *Scirpophaga incertulas* (Dhuyo, 2009). Past studies indicate that combination of biological control agents and host plant resistance can suppress the development of *M. separatella* while maintaining a high level of productivity (Nwilene *et al*, 2011).

2.5. Farmers' knowledge and management of rice insect pests

In spite of major advances made in rice science, farmers' knowledge and decision-making skills in crop management is still inadequate. A number of gaps exist between scientific achievements and farmers' practices as illustrated by a few examples, in insect management, entomologists know that damages by leaf feeding insects are of no consequence, but most farmers spray when they see these damages (Heong and Escalada, 1999). Many farmers now grow insect resistant varieties, but insecticide use does not change. Farmers either do not know the varieties have resistance or they have a different concept of resistance (Heong and Escalada, 1999). Curtis *et al*. (2005) reported that information may be delivered and received but not utilized in decisions. This is especially the case for information dealing with new opinions, attitudes and behavior, or if new enterprises or innovations 'are complex, are perceived as being risky, do not fit with existing enterprises or conflict with the existing social norms' (Curtis *et al*., 2005). It has been recognized that development initiatives that pay attention to local perceptions and socio-norms are more likely to be more sensitive to people's needs and to generate interventions that are sustainable.

Kasina *et al.* (2009) from a study on bees at Kakamega forest in Western Kenya reported that the level of knowledge of local farmers about bees and their natural history was important in instigating policies geared towards bee conservation and pollination management. Likewise it will be important to know rice farmers level of knowledge of *M. separatella* and their perceptions and attitudes to its management and possibly include this knowledge system in a holistic manner in the development of a control strategy against the pest.

2.6. References

Ba, N. M., Dakouo, D., Nacro, S., Karamage, F. 2008. Seasonal abundance of Lepidopteran stemborers and diopsid flies in irrigated fields of cultivated (*Oryza sativa*) and wild rice (*Oryza longistaminata*) in western Burkina Faso. *Journal of Tropical Insect Science*, 28 (1): 30-36.

Bandong, J.P, Canapi, B.L, Dela Cruz, C.G and Litsinger, J.A. 2002. Insecticide decision protocols: a case study of untrained Filipino rice farmers. *Crop Protection*. 21: 803–816

CABI, 1996. *Maliarpha separatella*. [Distribution map]. CAB International, Wallingford, UK, Distribution Maps of Plant Pests, December (1st Revision), Map 271 http://www.cabdirect.org/abstracts/20046600271.html. Accessed on 12 September 2012

Curtis, A., Byron, I. and MacKay, J. 2005. Integrating socio-economic and biophysical data to underpin collaborative watershed management. *Journal of the American Water Resources Association* 41 (3): 549-563.

Chandramani, P., Rajendran1, R., Muthiah, C. and Chinniah, C. 2010. Organic source induced silica on leaf folder, stem borer and gall midge populations and rice yield. *Journal of Biopesticides* 3(2): 423 – 427

Dhuyo, A. R. 2009. Integrated control of yellow rice stem borer *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae). Department of Zoology PhD thesis. University of Sindh, Jamshoro, Pakistan 152 pp.

Dhuyo, A. R. and Soomro, N. 2007. The response of different rice varieties to infestation of yellow rice stem borer, S*cirpophaga incertulas* (Walk.) under field and green house conditions. *Pakistan Entomology* (29): 27-32

Government of Kenya. 2009. National rice development strategic plan (2008-2018). Ministry of Agriculture 25pp

Hazir, S., Kaya H. K., Stock, S. P. and Keskün, N. 2006. Entomopathogenic Nematodes (Steinernematidae and Heterorhabditidae) for Biological Control of Soil Pests. *Turkish Journal of Biology* 27: 181-202

Heinrichs, E.A.and Barrion, A.T. 2004. Rice-Feeding Insects and selected natural Enemies in West Africa Biology, ecology, identification Eds G.P. Hetel 247pp.

Heong, K. L and Escalada, M. M. 1999. Quantifying rice farmers' pest management decisions: beliefs and subjective norms in stem borer control. *Crop Protection* 18(5): 315-322

KARI, 2006. Field evaluation of entomopathogenic nematodes for efficacy against cotton pests. Kenya Agricultural Research Institute 2006 Annual Report: 85-86.

Kasina, M., Kraemer, M., Martius, C and Wittmann, D. 2009. Farmers' knowledge of bees and their natural history in Kakamega district, Kenya. *Journal of Apicultural Research and Bee World* 48(2): 126-133.

Litsinger, J.A, Bandong, J.P, Canapi, B.L, Dela Cruz, C.G, Pantua, P.C, Alviola, A.L,Batay-An III, E. H. 2006. Evaluation of action thresholds against chronic insect pests of rice in the Philippines: IV. Stemborers. *International Journal of Pest Managanament* 52: 194–207.

Litsinger, J.A, Bandong, J.P, Canapi, B.L, Dela Cruz, C.G, Pantua, P.C, Alviola, A.L and Batay-An III, E.H. 2005. Evaluation of action thresholds for chronic rice insect pests in the Philippines. I. Less frequently occurring pests and overall assessment *International Journal of Pest Management* 51(1): 45-61

Litsinger, J.A, Canapi, B.L., Bandong, J.P., Lumaban, M.D., Raymundo, F.D. and Barrion, A. T. 2009. Insect pests of rain-fed wetland rice in the Philippines: Population densities, yield loss, and insecticide management. *International Journal of Pest Management* 55, 3: 221-242.

Muralidharan, K., and Pasalu, I.C. 2006. Assessments of crop losses in rice ecosystem due to stem borer damage. Crop *Protection* 25: 409-417.

National Rice Technical Committee, 2011. Currently cultivated varieties main characteristics. In Guidelines to rice production in Kenya (Eds Kouko, W., Wanjogu, R., Kimani, A., Mahungu, M. and Hikaru, N.): 16-17

Ntanos, D.A. and Koutroubas, S.D. 2000. Evaluation of rice for resistance to pink stem borer. *Field Crops Research* 66: 63-71.

Nderitu, J., Sila, M., Nyamasyo, G. and Kasina, M. 2009. Effectiveness of entomopathogenic nematodes against sweet potato weevil, *Cylas punctifollis* Boheman, (Coleoptera:Apionidae). *Journal of Entomology* 6 (3): 145-154

Nyasani, J.O., Kimenju, J.W., Olubayo, F.M. and Wilson, M.J. 2007. Potential of using entomopathogenic \ nematodes in the management of diamond back moth, *Plutella* xylostella(L.) (Lepidoptera: Plutellidae) in Kenya. *African Crop Science conference proceedings* (8): 1063-1066

Nwilene, F.E., Onasanya, A., Togola, A., Oyetunji, O., Semon, M., Tamo, M., Bright, E.O and Ofondile, S. 2011. Effect of intercropping maize and cassava with upland NERICA rice varieties on stem borer attack in South West Nigeria. *Journal of Entomology*. 8(5): 417-428.

Padhi, G. and Sen, P. 2002. Evaluation of wild rice species against yellow stem borer (*Scirpophaga incertulas* Walk.). *Journal of Applied Zoology Research* 13(2/3): 147-148

Padhi, G. 2004. Evaluation of rice cultivars for yellow stem borer resistance in lowland rice. *Journal of Applied Zoology Research* 13(2/3): 188-189.

Padmakumari, A.P. and Pasalu. I.C. 2003. Influence of planting pattern of trap crops on yellow stem borer, *Scirpophaga incertulas* (Walker) damage in rice. *Indian Journal of Plant Protection* 30 (1): 78-83.

Ramzan, M., Hussain, S. and Akhter, M. 2007. Incidence of insect pests on rice crop under various nitrogen doses. *Journal of Animal and Plant science* 173: 3- 4

Reay-Jones, F.P.F., Way, M.O. and Reagan, T.E. 2007. Economic assessment of controlling stem borers with insecticides. *Texas rice Crop Protection* 26: 963-970.

Richards, P. 1989. Agriculture as a performance. In: *Farmer first* (eds. Chambers, R., Pacey, A. and Thrupp, L.A.). Intermediate Technology Publications, London: 39-51.

Rice knowledge management portal (RKMP), 2011. Integrated Pest management in Rice, Technical bulletin No. 15, Directorate of rice research, Rajendranagar, Hyderabad 16pp

Sinclair, F.L. and Walker, D.H. 1998. Qualitative knowledge about complex agroecosystems. Part1: a natural language approach to representation. *Agricultural Systems* 56: 341-363.

Umeh, E., Joshi, R. and Ukwungwu, M. 2000. Biology, status and management of rice insect pests in Nigeria. *Crop Protection* 11(5): 408-413.

Waturu, C.N. 1998. Entomopathogenic Nematodes (Steinernematidae and Heterorhabditidae from Kenya. PhD thesis, University of Reading191pp.

Weeden, C.R., Shelton, A. M. and Hoffman, M. P. 2007. Biological Control: A Guide to Natural Enemies in North America. http://www.nysaes.cornell.edu/ent/biocontrol/ Accessed on 12 July 2012.

Zou, L. 2004. Integration of management tactics for the rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) with particular emphasis on use of plant resistance (tolerance) PhD thesis Louisiana State University and Agricultural and Mechanical College 127 pp.

CHAPTER 3

FARMERS KNOWLEDGE AND MANAGEMENT PRACTICES OF *MALIARPHA SEPARATELLA* AT MWEA IRRIGATION SCHEME, KIRINYAGA COUNTY, CENTRAL PROVINCE, KENYA

Abstract

In Kenya, rice is the third most important cereal crop after maize and wheat and of the three grain staples, has the highest per capita consumption. It is an important cash and food crop at Mwea irrigation scheme where this study was carried out. However production is constrained by many factors including the African white rice stem borer *Maliarpha separatella* which is a major rice pest. In order to bridge an existing knowledge gap and guide further research on the improvement of rice production a survey was conducted with specific objectives of analyzing the current rice production constraints, farmers' level of knowledge on *Maliarpha separatella* and its management. A structured questionnaire was administered to a random sample of 119 rice farmers in 17 villages at Mwea irrigation scheme. Farmers were requested to provide information about rice, its importance, pests and *M. separatella* management. The study was carried out from 17 to 20 February 2011. The survey results revealed that rice is grown both for food and as a cash crop as indicated by 87% and 71% of respondents respectively. The average age for the majority (62%) of farmers was 42 years. Most farmers had about eight years rice farming experience and their main sources of information was from other farmers. The percentage farmers who used pesticides to control *M. separatella* were 77%. About 60% of the respondents indicated that substantial loss of rice grain yield would occur if the pest is not controlled. Age (p=0.005), rice farming experience (p=0.000) and rice farming as the only occupation (p=0.000) had a highly positive significant influence on *M. separatella* knowledge.

Being a female (p=0.004) significantly increased the probability of having less knowledge on *M. separatella* when compared with men. This study suggests that there is need for specific training on the management of *M. separatella*, so as to reduce the possibility of losses and use of agro-chemicals at Mwea irrigation scheme.

3.1. Introduction

Pest management in irrigated rice production systems is compromised by intensive cultivation practices, such as cropping large areas with varieties from similar genetic backgrounds or a single variety in extreme monocropping conditions and with high chemical inputs (Heinrichs.and Barrion 2004). These practices increase farmers' vulnerability to invading pests such as stem borers. In addition, farmers pay high production costs and have increased the risk of pesticide exposure. Therefore in order to develop practices that are viable, we need to understand the local farmers' attitudes, beliefs and practices. This information can be used to develop communication strategies and policy dialogue, and to initiate changes in attitudes that would create a better environment for adoption (Kasina *et al.*, 2009).

Many studies report that farmer knowledge is important to smallholder farmers' decision making (Belaineh, 2003). In pest management the main issues are how to respond and adapt to minimize possibility of damage to crops and the resulting losses in yield, quality and monetary value. Belaineh (2003) reported that social demographic factors like, age, religious beliefs, myths, experience and education affected acquisition, application and retention of risk information in a farming community in Ethiopia. Mahdi *et al.* (2006) found a positive correlation between the knowledge-score and attitude-score for sustainable agriculture among rural farmers in Iran. It has been argued that, interpersonal sources such as friends and neighbours play a significant role in the distribution of information from formal and other sources more widely throughout the agricultural community (Belaineh, 2003).

This study sought to investigate and to document rice production constraints and farmers' knowledge on the African white rice stem borer *Maliarpha separatella* and to determine how such knowledge influences management of this pest at Mwea irrigation scheme.

3.2. Materials and methods

3.2.1 Study site

The study was conducted at Mwea rice irrigation scheme (0° 40'South; 37° 18'East) which is in Kirinyaga County, Central Province, Kenya. The scheme is situated approximately 100 km North East of Nairobi at an elevation of 1,100-1200 M above sea level (Onjala, 2001).

3.2.2. Study design

During the study, Mwea irrigation scheme had 9,226 households. The area under rice cultivation was 10,400 ha and farmers were settled in 70 communal villages (Mwangi, 2011). These villages were distributed in 13 sub locations within nine locations in Mwea division. A multistage random sampling was done, whereby a sample of 17 villages was drawn from the 70 villages and then from each village, seven homesteads were selected making a total of 119 households. All the respondent villages had their latitudinal and longitudinal positions as well as altitude determined with the help of a Garmin® e-trex hand held monochrome Geographic Positioning System (GPS) device (Table 3.1).

Table 3.1: Respondent sub locations, villages and GPS coordinate at Mwea irrigation scheme in February 2011.

Section	Sub location	Village	Longitude in degrees	Latitude in degrees	Altitude in meters
Mwea	Nguka	Karira	37.34085E	0.66166S	1183
	Nguka	Kiuria	37.31394E	0.66298S	1190
	Nguka	Nyakio	37.31538E	0.66383E	1187
	Nguka	Nguka	37.32372E	0.66349S	1181
Tebere	Kiarukungu	Nderwa	37.35240E	0.62820S	1190
	Kiratina	Karima	37.32736E	0.69204S	1162
Mwea	Thiba	Thiba	37.34068E	0.6929S	1154
	Thiba	Thiba North	37.33891E	0.69229S	1155
	Thiba	Maendeleo	37.34375E	0.68721S	1150
	Kiratina	Githunguya	37.34000E	0.68880S	1153
Tebere	Kathigiriri	Murubara	37.36823E	0.65775S	1168
	Mahigaini	Kirogo	37.39490E	0.66856S	1154
	Mathangauta	Mathangauta	37.36857E	0.63629S	1172
	Mathangauta	Nineveh	37.36672E	0.62588S	1184
	Mwathaini	Mwathaini	37.37636E	0.65068S	1186
Tebere	Nyangati	Kimbimbi	37.36502E	0.62153S	1217
	Nyangati	Kiorugari	37.35019E	0.61810S	1201

Geographic information System (GIS) coordinate digital map linked software (Arc GIS) was used to map the villages (Figure 3.1)

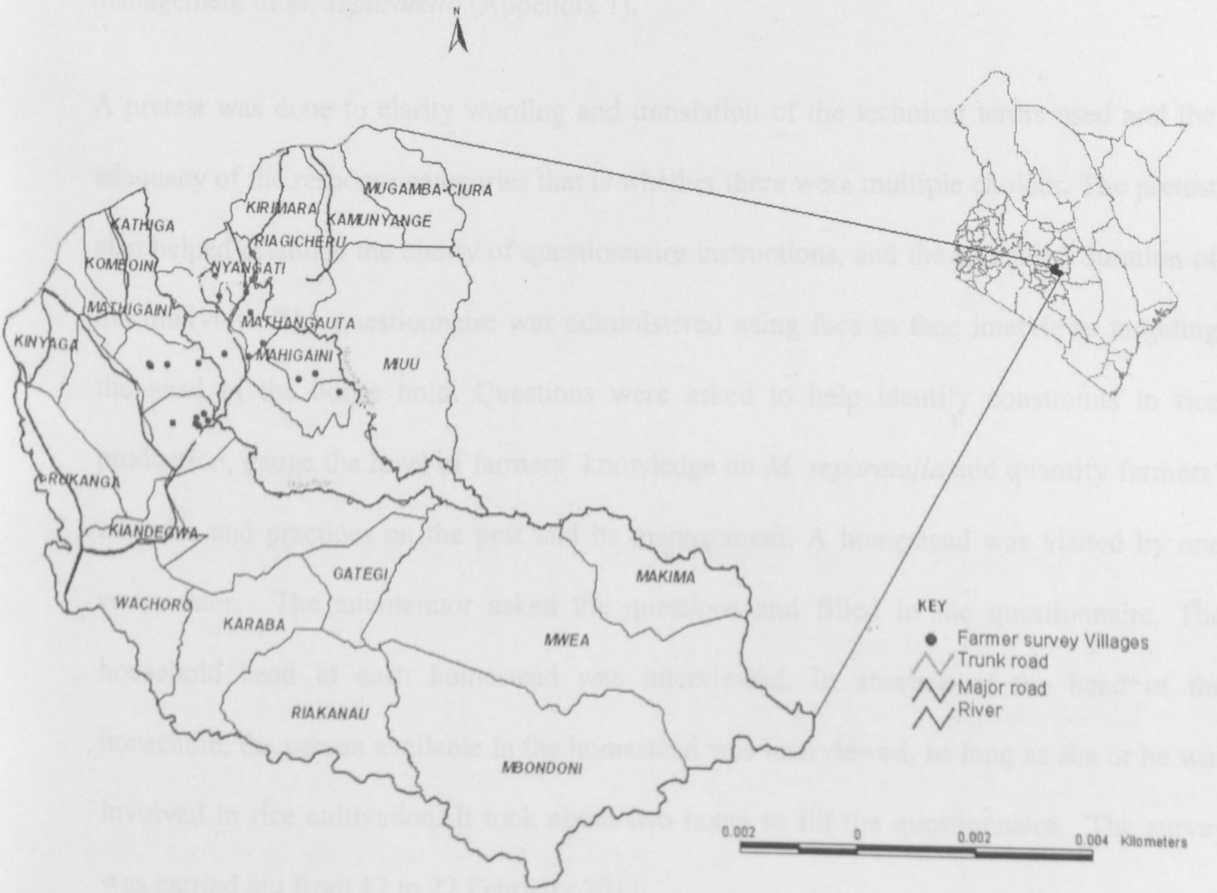

Figure 3.1: Map of Kenya showing sites and sub locations at Mwea irrigation scheme (0° 40'S; 37° 18'E) where socio-cultural questionnaires were administered in February 2011.

3.2.3. Data collection

Eight enumerators with no training in agriculture were recruited from Mwea division to collect the data. Individual farmers were interviewed through a semi- structured questionnaire.

The questionnaire was organized in the following sections: Background information, demography and socio-economic characteristics, rice production constraints, investment and financing, types and sources of information, farmer knowledge on rice pests and farmer management of *M. separatella* (Appendix 1).

A pretest was done to clarity wording and translation of the technical terms used and the adequacy of the response categories that is whether there were multiple choices. The pretest also helped establish the clarity of questionnaire instructions, and the estimated duration of the interview. The questionnaire was administered using face to face interviews targeting the head of the house hold. Questions were asked to help identify constraints in rice production, gauge the level of farmers' knowledge on *M. separatella* and quantify farmers' attitudes and practices on the pest and its management. A homestead was visited by one enumerator. The enumerator asked the questions and filled in the questionnaire. The household head in each homestead was interviewed. In absence of the head of the household, the person available in the homestead was interviewed, so long as she or he was involved in rice cultivation. It took about two hours to fill the questionnaire. The survey was carried out from 17 to 22 February 2011.

3.2. 4. Data analysis

The collected data was subjected to descriptive statistics, which included means, standard deviation and frequencies. These were computed by use of SPSS version 16.0 for windows (SPSS, 2007).

The statistics described the characteristics of Mwea rice farmers and were also used to answer some of the specific research questions in the study. Logit regression was used to elucidate the determinants of *M. separatella* knowledge.

3.2.5. Logit regression and the study hypothesis

Logistic regression is categorized under Limited Dependent variable model and is used in social research when the dependent variable is discrete and takes a binary value of either 0 or 1, for example know versus Do not know or dead versus alive. The logistic function is useful because it can take as an input any value from negative infinity to positive infinity, whereas the output is confined to values between 0 and 1. The mean of a binary distribution so coded is denoted as P, the proportion of 1s. The proportion of zeros is (1-P), which is sometimes denoted as Q. The variance of such a distribution is PQ, and the standard deviation is Square root (PQ) (Wright, 1995).

Logistic regression equation was derived following the method of Kasina *et al*. (2009). In this study, farmers were grouped as those who had the knowledge of *M. separatella* (0) and those who did not have the knowledge of *M. separatella* (1). Thus the dependent variable took the value of 0 (yes) with a probability of success (the respondent knew *M. separatella*) *P* or value of 1 (no) with the probability of failure (not having knowledge of *M. separatella*) 1-*P*. Logistic regression calculates the probability of success (P) over the probability of failure (1-P), and the model is in non-linear form, thus for better interpretation, the coefficients are transformed into Odds' ratio or

$$odds = \frac{P}{1-P} \tag{3.1}$$

The relationship between the predictor and response variables is not a linear function in logistic regression; instead, the logistic regression function which is the natural logarithms of odds is used.

This is the logit transformation of P:

$$logit[P(x)] = \log\left[\frac{P(x)}{1-P(x)}\right] = \propto + \beta_1 x_1 + \beta_2 x_2 + .. + \beta_i x_i \tag{3.2}$$

where $P(x)$ is probability of having knowledge of *M. separatella*, α is the constant of the equation and β is the coefficient of the predictor variables (x) or the socio cultural variables in this study, $\beta_0 ......\beta_r$ are the parameters to be estimated or the coefficient of the predictor variables (Padaria *et al*., 2009). The analysis provides transformed (antilog) value as exponential logistic coefficient of the respective original coefficient, the "logit" (Hair *et al*., 2007).

In this study it was expected that the following socio-demographic characteristics of the respondents would influence the probability of having knowledge of *M. separatella* knowledge; 1) age, the older the respondent was, the more likely one would have come across the pest and thus a high chance of having knowledge of the pest, 2) gender, one particular gender would be involved more closely with rice cultivation and hence would most likely have knowledge of *M. separatella,* 3) rice farming experience, the more years a farmer was involved in rice cultivation the higher the probability of having come across *M. separatella* and thus more likely to have the knowledge of it 4) occupation (rice cultivation as the only occupation) meant that the farmer was in close and constant touch with the crop and thus high chances of having come across *M. separatella* and hence a high probability of having knowledge of the pest. Therefore, it is possible to deduce the probability of a respondent with known values of these characteristics, having knowledge of *M. separatella*. If β_i (the original coefficient) is positive, its transformation (the exponential coefficient) would be greater than 1, meaning that the odds of an event happening increases for any positive change in the independent variable (Hair *et al*, 2007). The best fit logit model is based upon the likelihood ratio, denoted as -2 log likelihood (-2LL).

The minimum value of -2 log likelihood is 0, which corresponds to a perfect fit, hence; the lower its value, the better the model (Padaria *et al.*, 2009). Chi-square test of significance and Nagelkerke R^2 value provide the basis to represent the overall model fit. Wald statistics provides the statistical significance for each estimated coefficient (β) (Padaria *et al.*, 2009). In this study the estimated coefficients (β_o β_i .... β_n) represented the influence of gender, age, rice farming experience, occupation, training, sources of information and type of information on farmer knowledge of *M. separatella.*

3.3. Results

About 52.5% of the rice farmers were males while 47.5% were females. The average age of the farmers was 41.9 years and they had 9.8 years of formal schooling. The rice farming experience of the farmers was 8.1 years (Table 3. 2).

Table 3.2: The general characteristics of rice farmers at Mwea irrigation scheme in February 2011.

Variable	Mean	SD
Gender (percent) Male 52.5 Female 47.5		
Age in years	41.9	12.0
Number of years in formal school	9.8	3.1
Rice farming experience (years)	8.1	6.1

The main occupation of most respondents at Mwea irrigation scheme was rice farming. About 47.9% of sample respondents were solely involved in rice cultivation whereas the remaining 52.1 % indicated that they had other occupation in addition to cultivating rice such as salaried employment; cultivation of horticultural or field crops, motor cycle taxi (*Boda boda*), hiring out of ox driven rotavation and being employed as a casual labourer (Table 3.3).

Table 3.3: Occupation of rice farmers at Mwea irrigation scheme in February 2011.

Occupation	Percent
Rice cultivation alone	47.9
Salaried employment	13.7
Horticultural crops farming	12.8
Rice trader	8.4
Field crops farming	7.7
Casual labourer	4.3
Motor cycle" boda boda" taxi driver	2.6
Hiring out ox- driven rotavation	2.6

The main source of cash for rice cultivation for 71.2% of the respondents was rice sales from the previous season. However, farmers had other sources of cash for rice cultivation. These included, savings from other sources, 14% of respondents, loans 6%, casual wages 5% and remittances from relatives (3%) (Table 3.4)

Table 3.4: Main sources of cash for rice cultivation at Mwea irrigation scheme in February 2011.

Source of capital	Percent
Rice sales from previous season	71.2
Own savings from other sources	14.4
Loans	5.9
Casual wages	5.1
Remittances from relatives	3.4

Food crop was defined as the crop which a farmer grew solely for supplying his house hold food requirements. A cash crop was a crop which farmers grew specifically for selling. Rice was important as a food item and also as a cash crop in Mwea irrigation scheme households. It was ranked first as a cash crop by 32.3% of the farmers and tied in second position with beans as a food crop as reported by 20.4% of farmers. The other cash crops were French beans and tomatoes while maize and bananas were the other important food crops, the latter was also an important source of cash income for the households (Table 3.5).

Table 3.5: Farmer ranking of rice crop as food and as a cash crop at Mwea irrigation scheme in February 2011

Food				Income			
Crop	N	Percent	Rank	**Crop**	N	Percent	Rank
Beans	19	20.4	1	**Rice**	**30**	**32.3**	**1**
Rice	**19**	**20.4**	2	French beans	22	23.7	2
Maize	17	18.3	3	Tomatoes	15	16.1	3
Bananas	14	15.1	4	Bananas	10	10.8	4
Arrow roots	6	6.5	5	Mangoes	8	8.6	5
Cowpea	4	4.3	6	Maize	6	6.5	6
Kales	4	5.7	6	Cowpeas	1	1.1	7
Spinach	4	4.3	6	Sugar cane	1	1.1	7
Tomatoes	3	3.2	7				
Pigeon peas	2	2.2	8				
Sorghum	1	1.1	9				

Farmers ranked marketing as the most important constraint in rice farming followed by the availability of irrigation water. There were very many brokers in the marketing node of the rice chain thus affecting the profitability of the exercise to the farmers.

Lack of irrigation water availability impacted negatively on rice productivity by limiting the land to be cultivated and the number of times per year that rice can be cultivated. Pests were ranked number three (Figure 3.2).

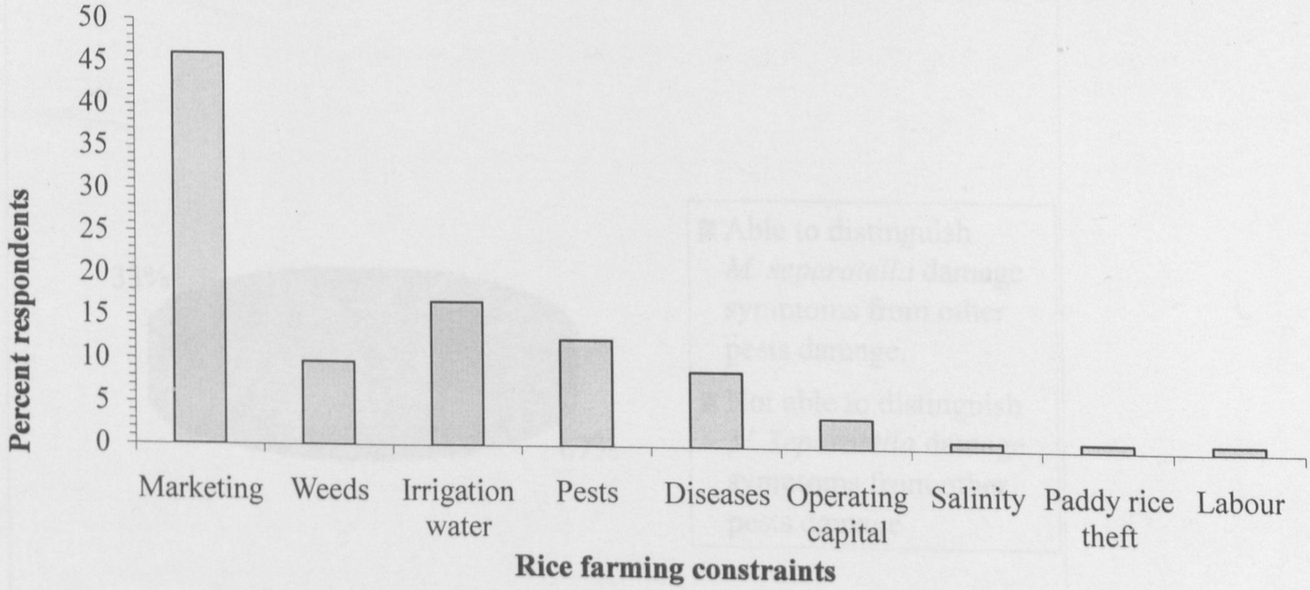

Figure 3.2: Farmer's ranking of the important constraints to rice farming at Mwea irrigation scheme in February 2011

About 58% of the respondents gave arthropod pests as the most important pests in rice and 0.6% gave slugs as important. About 30.4% of farmers identified *M. separatella* as the most important arthropod pest. Slightly less than half the number of respondents (46.3%) reported that maximum tillering stage was the crop growth stage where most damage occurred as a result of *M. separatella* infestation (Table 3.6).

Table 3.6: Pests of rice at Mwea irrigation scheme and the stage where *M. separatella* inflicts most damage as reported by farmers in February 2011.

Rice pests	Percent response	Rice crop growth stage where *M. separatella* inflicts most damage	Percent response
Athropod pests	58.0	Maximum tillering	46.3
Maliarpha separatella	30.4	Nursery	22.4
Stalk eyed fly	10.0	Booting	17.9
Slugs	0.6	Heading	7.5
		Maturity	6

About 67% of the farmers were able to identify white rice stem borer symptoms (Figure 3.3).

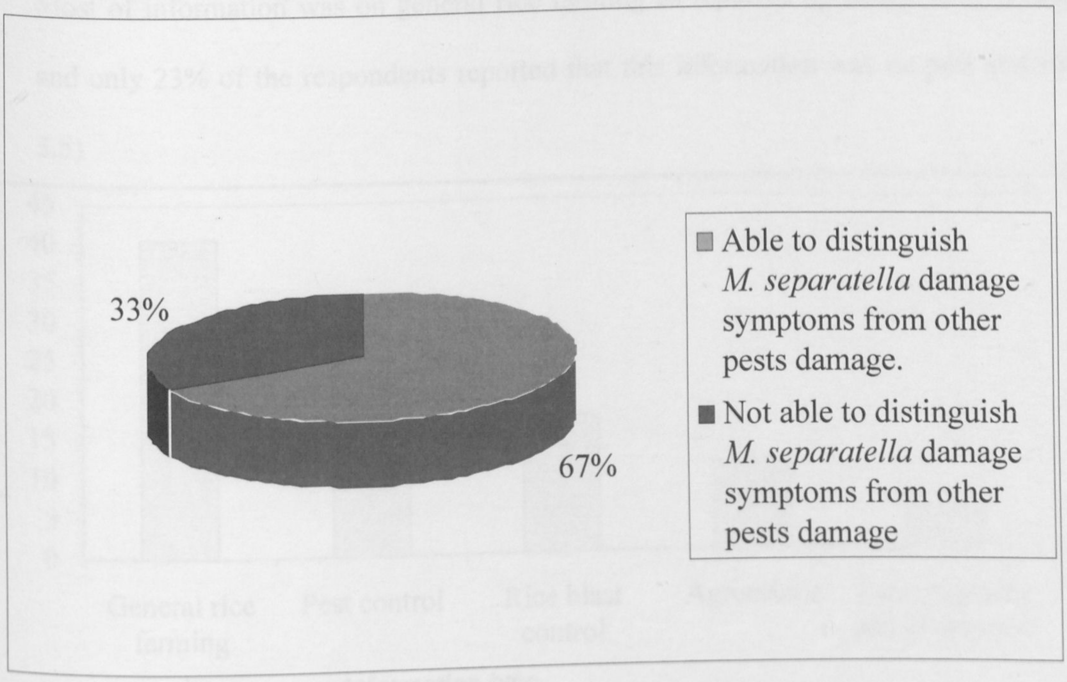

Figure 3.3: Percentage number of farmers able to distinguish stem borer damage symptoms at Mwea irrigation scheme in February 2010.

About 36% of the respondents reported that they had obtained agricultural information from other farmers while 19% gave National Irrigation Board (NIB) as the main source of information (Figure 3.4).

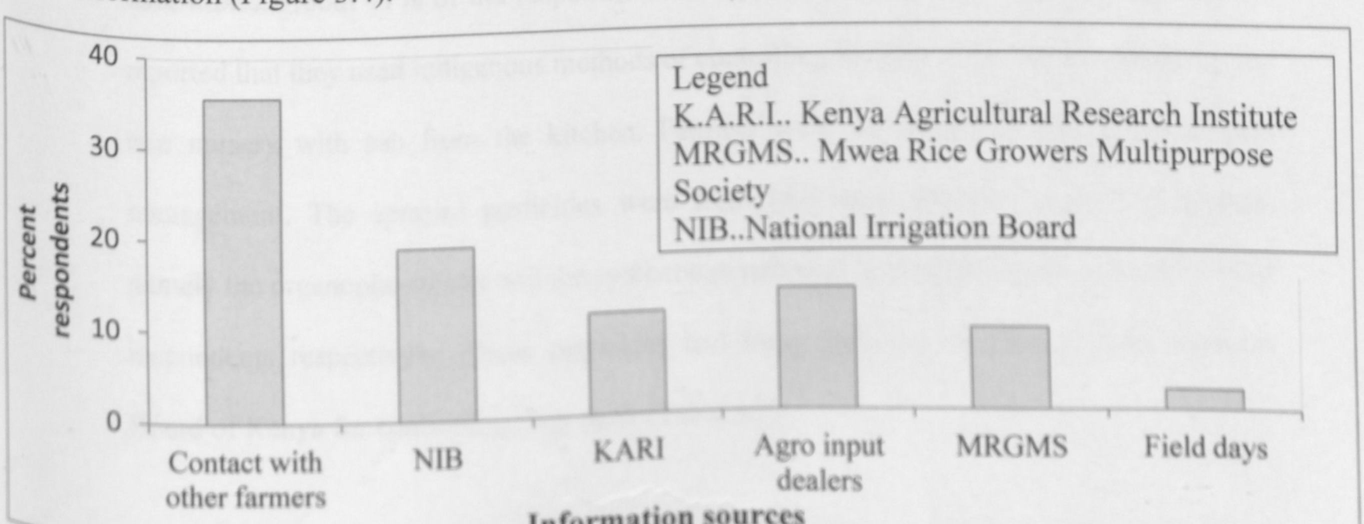

Figure 3.4: Sources of *M. separatella* information for the farmers at Mwea irrigation scheme in February 2010

Most of information was on general rice farming as reported by about 41% of respondents and only 23% of the respondents reported that this information was on pest control (Figure 3.5)

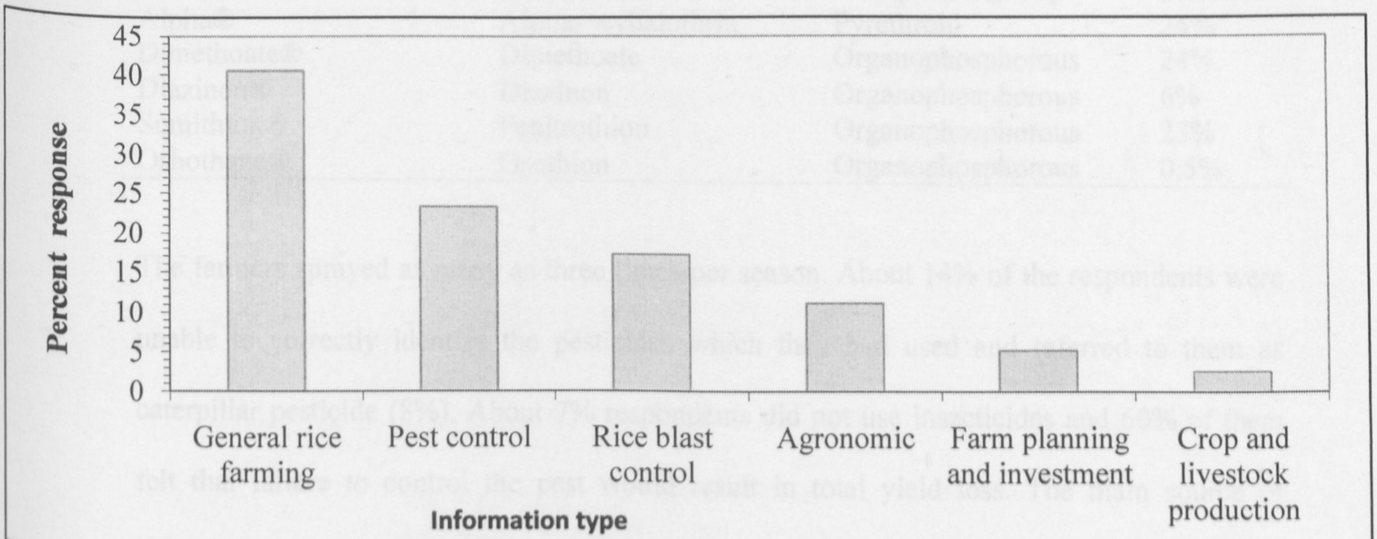

Figure 3.5: Type of information available to the rice farmers at Mwea irrigation scheme in February 2011

The main control method which was applied was the spraying of pesticides by using a 15 liter knapsack sprayer. In most cases the spraying was for a single compound and there were no tank mixes. About 77% of the respondents used pesticides and only 7% of the respondents reported that they used indigenous methods of controlling the pest. This was by sprinkling the rice nursery with ash from the kitchen. Farmers were not aware of the integrated pest management. The sprayed pesticides were from two main chemical compound groups, namely the organophosphates and the synthetic pyrethroids as reported by 53.5% and 24 % of respondents respectively. These pesticides had been approved by Pest Control Products Board of Kenya for controlling crop pests (Table 3.7).

Table 3.7: Pesticides and chemical groups used by farmers to control *M. separatella* at Mwea irrigation scheme in February 2011.

Pesticide trade name	Chemical name	Compound group	Percent
Alpha®	Alpha- cyhalothrin	Pyrethroid	24%
Dimethoate®	Dimethoate	Organophosphorous	24%,
Diazinon®	Diazinon	Organophosphorous	6%
Sumithion®	Fenitrothion	Organophosphorous	23%
Oshothane®	Osothion	Organophosphorous	0.5%

The farmers sprayed as many as three times per season. About 14% of the respondents were unable to correctly identify the pesticides which they had used and referred to them as caterpillar pesticide (8%). About 7% respondents did not use insecticides and 60% of them felt that failure to control the pest would result in total yield loss. The main source of information on the choice of pesticides was from other farmers and the National irrigation Board. The majority of farmers bought pesticides from the Agro- chemical shops while a few of them received pesticides together with other farm inputs, in a form of farm input advances with the rice crop as collateral. This was from Mwea Rice Growers Multipurpose Cooperative society. The decision to spray was made by the husband (52% of respondents), and spraying was done by men. About 36% of the respondents indicated the husband and 30% gave male casual labourer as the ones who sprayed against *M. separatella*. The cost of spraying one acre of the rice crop by Dimethoate® was Kes 2,500 per single spray.

The *apriori* expectation was that eight variables will affect farmer knowledge on *M. separatella* in different but specific ways. These variables were age, gender, education, training, rice farming experience, sources of information, type of information and occupation. The variables are explained in (Table 3.8).

Table 3.8: Variables identified as determinants of *M. separatella* knowledge at Mwea irrigation scheme in February 2011.

Variable	Description
AGE	Age of the respondent, years
GENDER	Gender of the respondent, 1 Male, 0 Female
EDU	Years of formal schooling of the respondents in years
TRAIN	Attended agricultural training, 0 Yes 1 No
RICE EXP	Rice farming experience, 0 Yes 1 No
INFO_SOR	Source of information about *M. separatella,* 1 extension services, 0 otherwise
INFO_TYPE	Information on *M. separatella* ,0 Yes 1 Otherwise
OCCU	Occupation, 0 Rice farming alone ,1 Otherwise
BORER_KNO	Knowledge of *M. separatella*, 0 Yes, 1 No

The variables: age (p=0.05), rice farming experience (p=0.00) and rice farming as the only occupation (p=0.00), had a positive significant influence on *M. separatella* knowledge and being a female (p=0.04) significantly increased the probability of not having *M. separatella* knowledge. Contrary to *apriori* expectation, education (p=0.78), training (p=0.47), sources of information (p=0.56) and information type (p=0.60), were found not to have any significant influence on *M. separatella* knowledge (Table 3.9).

Table 3.9: Factors that determined farmer knowledge of *M. separatella* at Mwea irrigation scheme in February 2011.

Variable	B	S.E.	Wald	Df	Significance (p-value)	Exp(B)
AGE	0.04	0.01	7.91	1	0.005	0.96
GENDER	-0.94	0.33	8.12	1	0.004	0.39
OCCU	2.23	0.56	15.83	1	0.000	9.30
RICE EXP	0.11	0.02	25.26	1	0.000	0.90
EDU	0.50	0.078	0.413	1	0.78	0.82
TRAIN	0.16	0.53	0.085	1	0.47	0.30
INFO_SOR	0.224	0.50	0.20	1	0.56	0.67
INFO_TYPE	0.33	058	0.43	1	0.60	0.73
Constant	2.720	0.80	11.42	1	0.001	15.13

-2log likelihood=380.00, chi-square= 84.11, probability *(chi-square)* = 0.00, *Nagerkeke* R^2=0.30

3.4. Discussion

Majority of the farmers were in the middle age group and had about eight years of rice farming experience. This finding is in agreement with previous study in the area by Kuriah *et al*. (2003), who reported that majority of rice farmers were middle aged, but contradicts their report of farmers having less than 2 years experience of rice cultivation. Possibly this was as a result of an influx of young migrant rice farmers into the scheme immediately after Mwea rice farmers through their cooperative society took over the management of the scheme from the National Irrigation Board. Results from this study indicated that farmer - farmer contacts were important sources of information. This is similar to the findings by Kamau (2007) who noted that the important channels of agricultural information were the self help groups which were formed as a result of the diminished role of the National Irrigation Board.

The negative influence of gender on *M. separatella* knowledge was unexpected, since the medium aged farmers have had equal development of knowledge in Kenya. Possible reasons for this anomaly may be that men are in close contact with the rice crop more than women as they are the ones that rotavate, spray against pests and harvest, while the majority of women are involved in the retailing of the milled and polished rice in the trading centers within the scheme (Emorgor *et al*., 2010). Farmer's depth of knowledge of rice pests is also related to the importance and visibility of the pests. Bentley and Thiele (1999) reported that farmers had difficulties of attributing damage to pests that were not easily visible thus underpinning the importance of close association with the rice plant with levels of *M. separatella* knowledge reported in this study.

There was no significant effect on age and education ($p>0.05$) on *M. separatella* knowledge from the results of the study suggesting that farmers provide an efficient platform of knowledge sharing among themselves irrespective of age and the level of formal schooling.

This is in agreement with studies of Buthelezi *et al.* (2010), who in a study on the influence of scientific and indigenous knowledge on agricultural land evaluation and soil fertility in South Africa, found that knowledge on these two aspects was easily transmitted between old and young people, despite the disparities in age and the level of education; but this is contrary to the belief that educated people have access to better information (Belaineh, 2003). The level of knowledge may also vary between different types of farmers. For example a previous study at Mwea irrigation scheme found that horticultural crop farmers knew more pests and were more knowledgeable in pest management than the rice farmers (Sithanantham *et al.*, 2002).

The use of pesticides against *M. separatella* is in agreement with earlier findings in the area which indicated that insecticide spraying against pests was common in the area and was not based on any economic threshold levels (Sithanantham *et al.*, 2002). About 60% of the respondents felt that 90% yield loss would result from failure to spray against pests. These results are consistent with the findings of Heong and Escalada (1999), who reported that rice farmers in Philippines spent an average of KE Sh 1440 per acre on insecticides and believed that if they did not spray against the pest they would lose about KE sh 32,160. Escalada *et al.* (2007) also found out that farmers' reliance on pesticides as the main means of pest control in Vietnam was due to constant repetition, a strategy used in pesticide advertising which resulted in farmers' pest control decisions being biased towards spraying against rice pests.

Barkat *et al*. (2006) also reported that 86% of the rice farmers used chemical control on pests and only 3.3 % of the farmers in High Barind tract area of Bangladesh were aware of the integrated pest management. From this study it appears that Mwea rice farmers do not have any method of deciding on when to spray against *M. separatella*, the type of pesticides to choose, how many times to spray and have no information on the use of integrated pest management. Therefore, there is need to address these gaps in order to develop appropriate management options for the pest.

3.5. References

Barkat, A., Sayeedul, H.K., Mohib, K.A., Ahaduzzaman, S.K. and Hoque, S. 2006. A study on Knowledge, Attitude and Practice (KAP) of resource farmers of Foshol-Care human development research centre. Report prepared for CARE-Bangladesh Dhaka: December 24, 2006, 39 pp.

Belaineh, L. 2003. Smallholders' risk perception and çoping strategies: The case of Kersa and Babile, Eastern Ethiopia. Published MSc. Thesis. ISSN 1403-7998. Swedish University of Agricultural Sciences, Department of Rural Development Studies, Uppsala, pp

Bentley, J.W and Thiele, G.N. 1999. Farmer knowledge and management of crop diseases. *Agriculture and Human Values,* 16:75-81.

Buthelezi, N., Hughes, J. and Modi, A. 2010. The use of scientific and local knowledge in Agricultural land evaluation and soil fertility studies in two villages in KwaZulu-Natal, South Africa. In *19th World congress of soil science and soil solutions for a changing world, 1-6 August 2010, Brisbane Australia.*

Emongór, R.A., Mureithi, F.M. Ndirangu, S.N, Kitaka D.M and Walela, B.M. 2010. The rice value chain in Kenya with reference to rice producers. *12th KARI Biennial conference proceedings,* 7-12 November 2010 Nairobi, Kenya, 1324-1330

Escalada, M.M, Heong, K.L., Huan, N.H. and Chien, H.V. 2007. Changes in rice farmers' pest management beliefs and practices in Vietnam: an analytical review of survey data from 1992 to 2007 In Heong KL, Hardy B, editors. 2009. Plant hoppers: new threats to the sustainability of intensive rice production systems in Asia. Los Baños (Philippines): International Rice Research Institute, 447-456.

Hair, J.F.Jr., Black, W, Babin, B., Anderson, R. and Tatham, R 2007. Multivariate data analysis. Pearson Education Inc. p 23

Heinrichs E.A.and Barrion, A.T. 2004. Rice-Feeding Insects and selected natural Enemies in West Africa Biology, ecology, identification Eds G.P. Hetel 247pp.

Heong, K.L.M and Escalada, M. 1999. Quantifying rice farmers' pest management decisions: Beliefs and subjective norms in stem borer control, *Crop Protection* 18: 315-322

Kamau, G.M. 2007: *Case* 1: *Jua kali* rice-self mobilization in swamps: Battle in the swamps. In Researching with farmers. A study of KARI participatory research practices in context. PhD thesis, Wageningen University, the Netherlands: 148-157.

Kasina, M., Kraemer, M., Martius, C and Wittmann, D. 2009. Farmers' knowledge of bees and their natural history in Kakamega district, Kenya. *Journal of Apicultural Research and Bee World* 48(2): 126-133

Kuriah, J.N., Ommeh, H., Kabuage, L., Mbogo, S. and Mutero, C. 2003. Technical efficiency of rice producers in Mwea irrigation scheme. *African Crop Science Conference proceedings* (6):668-673.

Mahdi R. K, Shariat, M., Azar, A, Moharamnejad, N and Mahjub, H. 2006. Survey on knowledge, attitude and practice on sustainable agriculture among rural farmers in Hamadan province, Iran. *Sarhad J. Agric*, 22, (4): 701-705.

Mwangi, O. 2011. Rice production at Mwea irrigation scheme in Kenya. District Agricultural Officer, Kirinyaga South District internal report 8p

Onjala, J. 2001. Water Pricing Options in Kenya: Cases of Mwea and West Kano Irrigation Schemes. Centre for Development Research (CDR) Working Paper 01.9 Copenhagen 37p.

Padaria, R.N., Baldeo, S., Sivaramane, N. , Yaswant K. N., Ravi, M. and Surya, S. 2009. A Logit Analysis of Bt Cotton Adoption and Assessment of Farmers' Training Needs, *Indian Research Journal of Extension Education* 9 (2): 39-45.

Sithanantham, S., Seif, A.A., Ssenyonga, S., Matoka, C. and Mutero, C. 2002. Integrated Pest Management (IPM) issues in irrigated Agriculture: Current initiatives and future needs to promote IPM adoption by small holder farmers in Eastern Africa In The changing face of irrigation in Kenya. Opportunities for anticipating change in Eastern and Southern Africa eds. Herbert G. Blank, Clifford M. Mutero and Hammond Murray-Rust: 231-263 available on line www.iwmi.cgiar.org/.../PDF/Changing_face_of_Irrigation.pdf. Accessed on 14 April 2012.

SPSS 2007. Statistical package for social scientists (SPSS) (2007) version 16.0 for windows.

Wright, R. E. 1995. Logistic regression. In Reading and understanding multivariate statistics eds. Grimm, L. G. and Yarnold, P. R. American Psychological Association Washington, DC. : 217-244.

CHAPTER 4

SPATIAL AND TEMPORAL FLUCTUATION OF THE AFRICAN WHITE RICE STEM BORER (*MALIARPHA SEPARATELLA* RAG) AT MWEA IRRIGATION SCHEME

Abstract

The African white rice stem borer (*Maliarpha separatella* Ragonot) is a major rice pest in West Africa, islands of Comoros and Madagascar, and East Africa including Kenya. In order to develop an integrated management strategy against the pest at Mwea irrigation scheme in Central Kenya, its spatial and temporal fluctuations were studied in rice farms for two wet and two dry seasons. The experiment was arranged in a factorial design with two factors each at two levels and each treatment replicated three times. The first factor was water provision at three levels (System for Rice Intensification (S.R.I), flood, and sporadic) and the second factor was cropping system also at three levels (main season crop (conventional method), planting of a second rice crop in the same area within the year (double crop) and ratoon). Farms located in different parts of the scheme were sampled every fortnight. The average size of the sampled farms was 0.4 hectares. Sampling was done using $1m^2$ quadrants which were placed randomly in the farm. The number of white heads, tunneled tillers and larvae were counted and at harvest the weight of grains was recorded. The study was conducted from September 2010 to July 2011. The results showed that infestation by *M. separatella* varied significantly ($p<0.05$) in the scheme. The percentage number of white heads per quadrant varied from (4.3-13.7%), tunneled tillers (3.9-8.9%), number of larvae (0-3) and grain weight (20-21.3g). The highest infestation was in sporadic water provision while the lowest was in the flooded system of cultivation. The high *M. separatella* infestation occurred where a second rice crop was grown in the same area during the year.

There were no significant differences in pest infestations in the main season crop and the ratoon crop (p>0.05). The percentage number of whiteheads and tunneled tillers in farms under the SRI were not significantly different from the flood irrigated fields (p>0.05). There was interaction for the number of larvae, grain weight and productive panicles between irrigation water provision and cropping system. However, no interaction was evident for the number of white heads, tunneled tillers and empty grains per spikelet (p>0.05) between irrigation water provision and cropping system. From this study it can be concluded that double cropping of rice increases *M. separatella* infestation but ratooning does not increase the pest infestation and neither does the use of the S.R.I result in lower *M. separatella* infestation.

4.1. Introduction

Stem borer species are considered to be the most important insect pests of rice in Africa (Heinrichs and Barrion, 2004). In Kenya all stem borer species are in the noctuid and pyralid families (Lepidoptera) except for the *Diopsis* spp which belongs to the order Diptera (CABI, 1996). In flooded rice cultivation the most important species is *Maliarpha separatella* which attacks rice at full tillering stage thus preventing grains from filling up and ripening. This damage results in empty panicles known as "whiteheads"(National Rice Technical Committee, 2011). Pest management in irrigated rice production systems is compromised by cultivation practices, such as monoculture of similar varieties, intensive use of chemical inputs (fertilizers and pesticides) and asynchronous planting (CABI, 1996, Heinrichs and Barrion, 2004). It has been reported that high *M. separatella* occur in areas where two crops of rice are grown per year. It has also been found that stem borers moths are active fliers and can migrate and infest new rice fields 5 km and that they are attracted by standing water bodies (CABI, 1996). This implies that in an irrigation scheme with wide acreage it is possible to have non uniform *M. separatella* infestation.

The objectives of this study were to investigate the effect of farmer practices (water provision and cropping system) on spatial and temporal fluctuations of *M. separatella* at Mwea irrigation scheme.

4.2. Materials and methods

4.2.1. Study site

The study was carried out at Mwea Irrigation Scheme (0° 40'S; 37° 18'E) (Jaezold *et al*., 2006) in Kirinyaga County, Central Province, Kenya. It is in the low altitude agro ecological zone, Lowland Midland zone (LM 4) and 1,100 to 1200 meters above sea level (Jaezold *et al*., 2006). Rice farms were selected in the whole scheme with help from the management of Mwea Rice Growers Multi Purpose Cooperative Society.

4.2.2. Study design

The observation study was arranged as a factorial design with two factors each at three levels and each treatment replicated three times. First factor was irrigation water provision at three levels (flood, SRI and sporadic) and second factor was cropping system also at three levels (main crop, double crop and ratoon). Description of treatments (irrigation water provision and cropping system) is given in Table 4.1.

Table 4.1: Irrigation water provision and cropping system categories at Mwea irrigation scheme during the study from September 2010 to July 2011

Water provision (1st factor)	Description
Flood irrigated	Conventional method at Mwea. Rice grown under continuous flooded condition (Nyamai, 2012).
Sporadic irrigation	Frequent water shortages and application of irrigation water varied from time and in most cases with prolonged dry spells.
System of rice intensification (SRI).	Alternate wet and dry irrigation. The crop is maintained in semi aerobic conditions during the vegetative phase, followed by shallow flooding after panicle initiation (Nyamai, 2012).
Cropping system (2nd factor)	
Main season crop	Conventional crop which was planted normally and within the main cropping season with the following cropping sequence (rice-fallow period-rice)
Double crop	Rice crop planted immediately after the harvest of the main crop and in most cases was planted late in the following sequence (rice –rice-rice).
Ratoon crop	Main crop was harvested when the stems were still green and stalks cut before the main crop was fully mature, leaving main crop stubble with 2-3 nodes which sprouted to form the next crop in the following sequence (rice-ratoon-rice)

The farms were in four National Irrigation Board (NIB) sections within the irrigation scheme in four sub-locations. These farms had different water provision regimes (flood, sporadic and Systems for rice intensification). The farms under flood water provision and SRI were in areas shaded pink and sporadic water provision farms are shown in orange (Figure 4.1). The three cropping systems (main crop, double and ratoon) were present in the three irrigation water provision regimes.

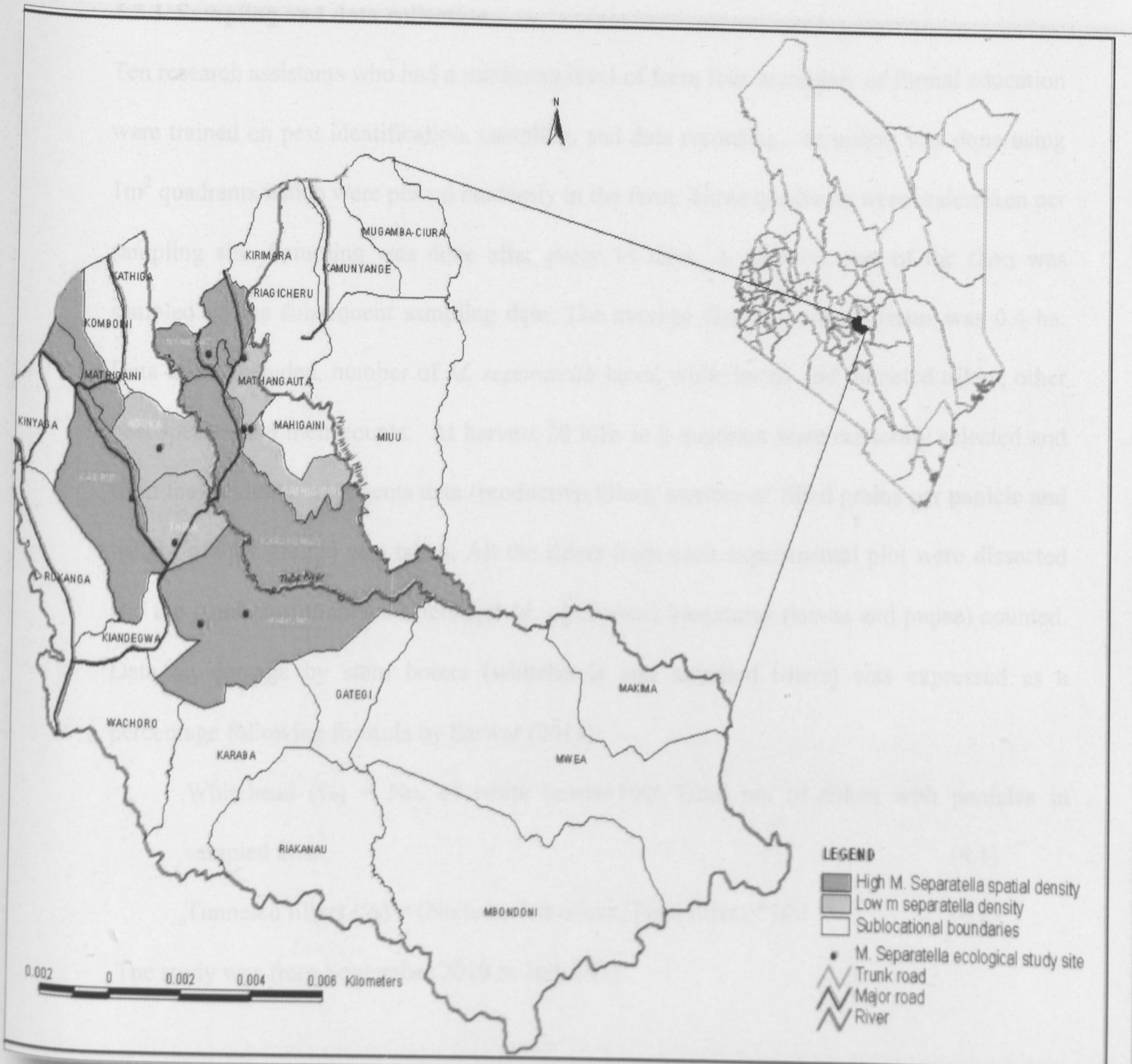

Figure 4.1: Map of Kenya showing *Maliarpha separatella* temporal and spatial fluctuation study sites at Mwea irrigation scheme (0º 40'S; 37º 18'E), Kirinyaga County, Central Province, Kenya from September 2010 to July 2011

4.2.3. Sampling and data collection

Ten research assistants who had a minimum level of form four secondary of formal education were trained on pest identification, sampling, and data recording. Sampling was done using $1m^2$ quadrants which were placed randomly in the farm. Three quadrants were undertaken per sampling site. Sampling was done after every 14 days. A different part of the farm was sampled on the subsequent sampling date. The average size of sampled farms was 0.4 ha. Data taken included, number of *M. separatella* larva, white heads and tunneled tillers, other pest species and their counts. At harvest 20 hills in a quadrant were randomly selected and from these, yield components data (productive tillers, number of filled grains per panicle and weight of 1000grains) was taken. All the tillers from each experimental plot were dissected and the number of tunneled tillers and *M. separatella* immatures (larvae and pupae) counted. Data on damage by stem borers (whiteheads and tunneled tillers) was expressed as a percentage following formula by Sarwar (2011):

Whitehead (%) = No. of white heads×100/ Total no. of tillers with panicles in sampled area. (4.1)

Tunneled tillers (%) = (No tunneled tillers /Total tillers)*100 (4.2)

The study was from September 2010 to July 2011.

4.2.4. Data analysis

Prior to analysis pest data was normalized using square root transformation (*SQRT(X+0.5)*) while percent white heads and percent stem tunneling were arcsin-square root transformed (*arc_p = arcsin(SQRT(p))*). Data were subjected to analysis of variance (ANOVA) and means separated by Fishers Least Significance Difference (LSD) at 5% significance level by use of GENSTAT Version 12 statistical soft ware.

4.3. Results

The number of white heads/m^2 was low in areas of flood water provision and in the Systems for Rice Intensification (SRI). High *M. separatella* infestation occurred in the sporadic water provision farms. The highest number of white heads occurred in areas where rice was double cropped and the lowest in the ratoon crop. Analysis of variance showed that there were no significant differences in the number of white heads between the on-season crop and the ratoon cropping system and between flood and SRI methods of irrigation water provision. It was also shown that irrigation water provision (df 2, 17, p= 0.034) and the cropping system (df 2, 17, p=0.002) had significant effect on the number of white heads and there was no interaction between irrigation water provision and the cropping system (df 2, 17, p=0.076). The cropping system (df 2, 17, p=0.028) had significant influence on the number of tunneled tillers/m^2 (Table 4.2).

Table 4.2: Number of white heads and tunnelled tillers in different irrigation water provision schedules and cropping systems at Mwea irrigation scheme.

Irrigation water provision		White heads	Tunneled tillers
	Sporadic	9.70a	8.87
	SRI	5.48ab	4.48
	Flood	4.42b	4.27
	P	0.034	0.059ns
	LSD	4.37	2.21
Cropping system			
	Late	13.66a	12.63a
	On season	6.37b	6.02b
	Ratoon	4.25b	3.78c
	P	0.002	0.028
	LSD	4.37	2.21

Means in a column with the same letter are not significantly different by Fishers LSD (P<0.05), ns, not significant

The number of *M. separatella* larvae was highest in the sporadic irrigation water provision and where rice was double cropped. Larvae were present in the double cropped rice irrespective of irrigation water provision method. There were no larvae in the on season and ratoon crop where rice cultivation was under flood water and SRI water provision. Analysis of variance indicated that irrigation water provision (df 17, 2, $p < 0.04$) and cropping system (df 17, 2, $p=0.015$) significantly influenced the number of larvae/m^2. There was significant interaction between irrigation water provision and cropping system (df 17, 2, $p=0.037$) (Table 4.3)

Table 4.3: Mean number of larvae in different irrigation water provision schedules and cropping systems at Mwea irrigation scheme.

Irrigation water provision	Cropping system	Mean number of larvae
Sporadic	Double	3.0a
Sporadic	Ratoon	2.7a
Sporadic	On season	2.1ab
Flood	Double	0.58bc
SRI	Double	0.12c
Flood	Onseason	0.0000c
Flood	Ratoon	0.0000c
SRI	On season	0.0000c
SRI	Ratoon	0.0000c
P		0.037
LSD		2.41

Means in a column with the same letter are not significantly different by Fishers LSD (P<0.05.

High *Maliarpha separatella* infestation in the scheme occurred in the double cropped rice in October 2010 (9%) and April 2011 (12%). The October peak was in the double cropped rice while the April peak was in the crop transplanted in early February. Similar trends occurred in the other two systems (Figure 4.2).

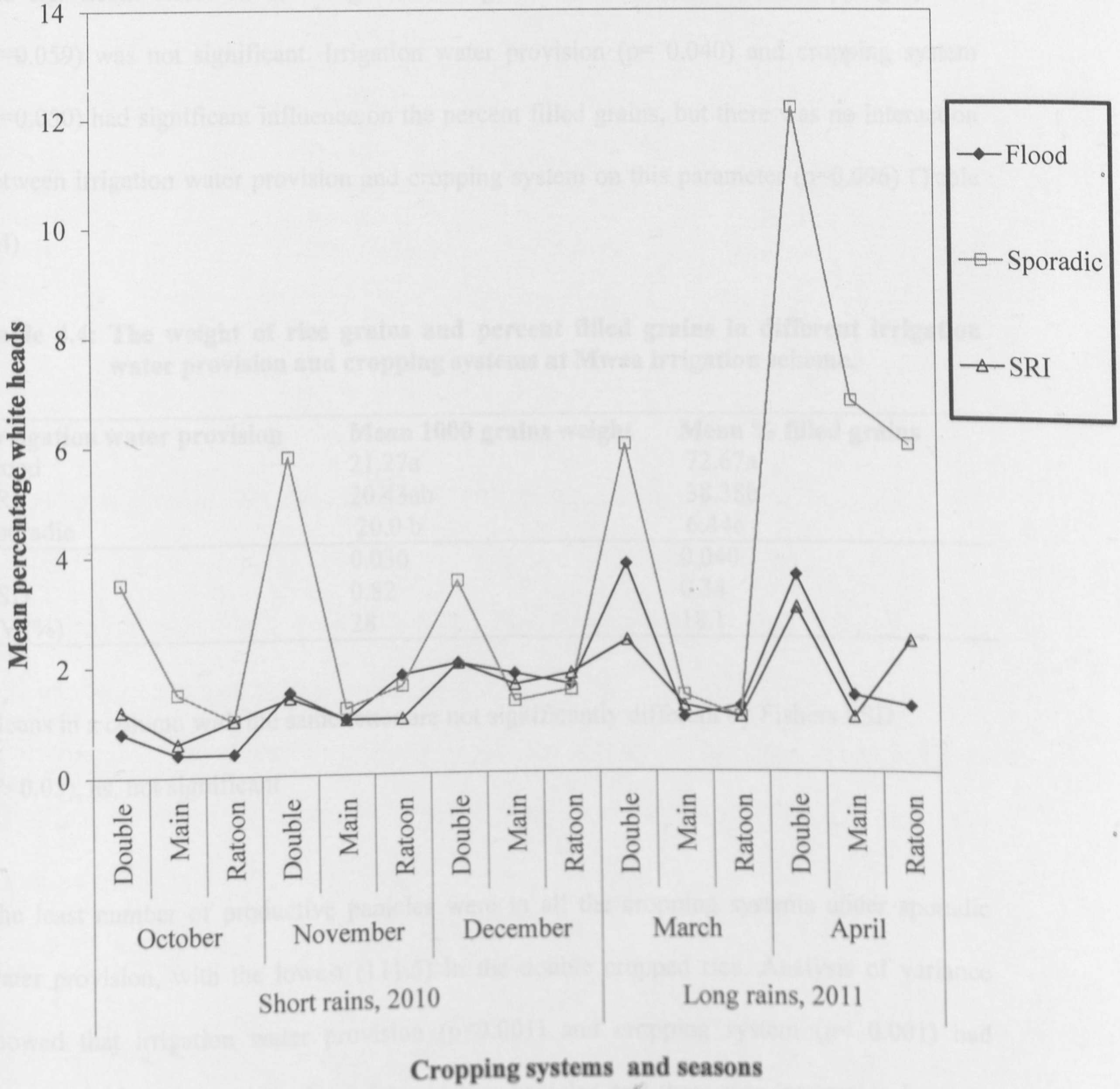

Figure 4.2: Mean number of whiteheads in different cropping systems in the 2011 short rains and 2011 long rains seasons at Mwea irrigation scheme

The lowest weight of grains and the percent filled grains were found in the sporadic irrigation water provision. The analysis of variance indicated that irrigation water provision ($p=0.030$) had significant effect on the weight of rice grains but the influence of cropping system ($p=0.059$) was not significant. Irrigation water provision ($p= 0.040$) and cropping system ($p=0.050$) had significant influence on the percent filled grains, but there was no interaction between irrigation water provision and cropping system on this parameter ($p=0.096$) (Table 4.4)

Table 4.4: The weight of rice grains and percent filled grains in different irrigation water provision and cropping systems at Mwea irrigation scheme.

Irrigation water provision	Mean 1000 grains weight	Mean % filled grains
Flood	21.27a	72.67a
SRI	20.43ab	38.38b
Sporadic	20.0 b	6.44c
p	0.030	0.040
LSD	0.82	0.34
CV (%)	28	18.1

Means in a column with the same letter are not significantly different by Fishers LSD ($P<0.05$), ns, not significant

The least number of productive panicles were in all the cropping systems under sporadic water provision, with the lowest (111.5) in the double cropped rice. Analysis of variance showed that irrigation water provision ($p<0.001$) and cropping system ($p< 0.001$) had significant effect on the number of productive panicles and there was interaction between irrigation water provision and cropping system ($p<0.001$) (Table 4.5)

Table 4.5: Mean number of productive panicles in different water provision and cropping systems at Mwea irrigation scheme.

Irrigation water provision	Cropping system	Productive panicles
Flood	On season	685.4a
SRI	On season	617.5ab
SRI	Ratoon	564.1bc
Flood	Ratoon	505.2c
SRI	Double	277.1d
Flood	Double	180.3e
Sporadic	Ratoon	168.5e
Sporadic	On season	129.9e
Sporadic	Double	111.5e
p		0.001
LSD		90.60
CV (%)		11.2

Means in a column with the same letter are not significantly different by Fishers LSD (P<0.05).

The number of white heads was high in initial stages of sampling at panicle initiation, peaked at booting and decreased slightly towards maturity.

The infestation was highest at maturity in the sporadic water provision. There were no significant difference in the number of white heads between rice crops under flood water provision and SRI (p>0.05) (Table 4.6).

Table 4.6: Mean number of white heads at different rice growth stages

Growth stage	Water provision		
	Flood	Sporadic	SRI
Panicle initiation	1.2	1.6	1.6
Booting	3.9	5.9	3.8
Heading	6.4	10.0	7.0
Flowering	8.9	14.1	10.2
Milky stage	11.4	18.4	13.2
Dough stage	13.8	22.7	16.7
Mature grain	16.1	26.7	18.9
p	0.13	0.09	0.20
S.E	0.50	1.2	0.63
CV (%)	35.5	26.2	46.5

4.4. Discussion

The influence of different planting regimes at Mwea irrigation scheme was evident, high pest infestations were in the areas where rice has been double cropped. These results are consistent with the findings from other studies which indicate that if a rice-growing area is a mixture of farms sown at different times, there will be many oviposition periods, leading to overlapping generations (Umeh *et al.,* 2000). Litsinger *et al* (2009) reported that insect pest damage particularly from stem borers was greater in areas where farmers staggered their planting up to 3 months apart and used a set of varieties that matured in 140-210 days than where farmers planted rice within 1 month, used 120-d varieties and planted at the start of the rainy season. These cultural practices are similar to those of Mwea where farmers cultivate rice throughout the year and use medium duration varieties like Basmati 370 which has a maturity period of 115 days and (BW 196) which takes 110 days to mature (National Rice Technical Committee, 2011).

The high *M. separatella* infestation in the sporadic double crop is in agreement with the work of Litsinger *et al*. (2009) who reported that the expanded growth period favoured vegetative pest build up in flooded rice cultivation. They also found out that the rain fed wetland rice system which may be equated with sporadic irrigation at Mwea was more prone to physiological stresses than the flood irrigated crop and this minimizes crop compensation and accentuates losses (Litsinger *et al*., 2009). It was reported from Philippines that losses of 5–71% were highest in the sites with the smallest rice area in which pests were concentrated and in the poorest soils which constrained yield compensation (Litsinger *et al*., 2009). Similarly high *M. separatella* occurred in the sporadic irrigated areas at Mwea which were areas with unsuitable soils for rice growing and inadequate supply of water for the flooded rice cultivation.

Findings in this study of the two *M. separatella* population peaks at Mwea are consistent with the reports of (CABI, 1996) of a major peak in November and a minor peak in April. However, in this study, the major peak was in April while the minor peak was in October. This shift is possibly due to the continuous cropping of rice which was not previously the case before 1998 (Kuriah *et al*., 2003), which resulted in the presence of the pest throughout the year. The presence of low pest infestations in the ratoon contradicts the previous findings of high *M. separatella* infestation in the study area (CABI, 1996). Possible reasons for this may be that due to the recent importance of rice straw as fodder for livestock, there has been a reduction of straw being left standing or stacked in the fields, and thus a substantial reduction of the reservoirs for the pest. The ratoon crop also matures much earlier than the double crop and thus may escape attack.

The evidence of reduction in the weight of the grains and productive panicles and increase in the number of empty panicles is consistent with other findings that *M. separatella* infestations cause a reduction in productive tillers and yield components (Litsinger *et al*., 2006). The 15% white heads damage in this study is within the range observed by Sarawar (2011) on stem borer damage on aromatic rice. The presence of high *M. separatella* infestations in the double crop planted rice irrespective of whether the rice culture was conventional or SRI, underpinned the importance of the "double cropping" which can be equated to the late planting on stem borer infestations. This is consistent with findings from a study that tested three planting times; first planting 14 days before farmers' planting time; the second simultaneous with farmers and the third, 14 days after farmer planting. They found out that at three weeks after transplanting, stem borer infestation in the third planting time was significantly higher than the other two (Suharto and Usyati, 2005).

Reports have also been made of low stem borer infestation in the rice grown under the System of Rice Intensification (SRI) (Uphoff, 2007). However, in this study there was no evidence that *M. separatella* population infestation was lower in the SRI system than in the conventional flooded method of growing paddy rice. Results of the present study indicate that there is a need to synchronize rice planting within the scheme and to include a rice break between two consecutive rice seasons by growing a suitable dry land crop. Attempts should also be made to research on the influence of System for Rice Intensification on *M. separatella* infestations.

4.5. References

CABI, 1996. *Maliarpha separatella*. [Distribution map]. CAB International, Wallingford, UK, Distribution Maps of Plant Pests, December (1st Revision), Map 271 http://www.cabdirect.org/abstracts/20046600271.html. Accessed on 12 September 2012

GENSTAT, 2009 . Genestat statistical package for windows version 12.0.

Heinrichs, E.A. and Barrion, A.T, 2004. Rice-Feeding Insects and selected natural enemies in West Africa . Biology, ecology, identification Eds G.P. Hetel 247pp.

Jaetzold, R., Schimdt, H., Hornetz, B. and Chisanya, C. 2006. Kirinyaga District Agroecological zones and subzones. Ministry of Agriculture, Farm management Hand book of Kenya Vol.II. Natural conditions and Farm management information 2nd Edition Part B, Central Kenya, Sub part B2, Central Province: 434-438

Kuriah, J.N., Ommeh, H., Kabuage, L., Mbogo, S. and Mutero, C. 2003. Technical efficiency of rice producers in Mwea irrigation scheme. *African crop science conference proceedings* 6: 668-673.

Litsinger,J.A., Bandong, J.P., Canapi, B.L., Dela Cruz, C.G. Pantua, P.C. Alviola, A.L. and Batay- An III, E.H. 2006. Evaluation of action thresholds for chronic rice insect pests in the Philippines. IV. Stemborers, *International Journal of Pest Management* 52(3): 195-207.

Litsinger, J.A, Canapi, B.L., Bandong, J.P., Lumaban, M.D., Raymundo, F.D. and Barrion, A. T. 2009. Insect pests of rainfed wetland rice in the Philippines: population densities, yield loss, and insecticide management. *International Journal of Pest Management* 55 (3): 221-242.

National Rice Technical Committee, 2011. Currently cultivated varieties main characteristics. In Guidelines to rice production in Kenya (Eds Kouko, W., Wanjogu, R., Kimani, A., Mahungu, M. and Hikaru, N.): 16-17

National Rice Technical Committee, 2011. Rice insect pests and diseases. In Guidelines to rice production in Kenya (Eds Kouko, W., Wanjogu, R., Kimani, A., Mahungu, M. and Hikaru, N.) 37-39

Nyamai, M. 2012. A comparative assessment of SRI and conventional rice production in Mwea irrigation scheme, Kenya. Msc Jomo Kenyatta University of Agriculture and Technology 109 p.

Sarwar, M. 2011. Effects of Zinc fertilizer application on the incidence of rice stem borers (*Scirpophaga* species) (Lepidoptera: Pyralidae) in rice (*Oryza sativa* L.) crop. *Journal of Cereals and Oilseeds* 2 (5): 61-65

Suharto,M. and Usyati, N. 2005. Stem borer infestation on rice cultivars at three planting times, *The Indonesian Journal of Agricultural Science* 2: 39-45.

Umeh, E .D. N., Joshi, R. C and Ukwungwu, M. N. 2000. Biology, status and management of rice insect pests in Nigeria. *Crop Protection* 11(5): 408-413.

Uphoff, N.T. 2007. System of rice intensification (SRI): An efficient, economical and ecologically-friendly way to increase production. Pesticide Action Network Asia & Pacific PANAP Rice sheets, 5-6

CHAPTER 5

ASSESSMENT OF YIELD LOSS CAUSED BY *MALIARPHA SEPARATELLA* RAG. ON RICE AT MWEA, KIRINYAGA COUNTY, KENYA

Abstract

Injury to stems of rice plants by *Maliarpha separatella* Rag larvae causes serious yield reductions in rice at Mwea irrigation scheme. In order to develop an integrated control strategy, there is need to establish the level of losses attributable to the pest. This study was set up to determine the level of losses caused by the pest and establish economic injury levels for use in the management of the pest. The study was carried out in an insect proof screen house at Kenya Agricultural Research Station, Mwea. The experiment was arranged as a 2x6 factorial design and each treatment replicated three times. First factor was time of infestation at two levels, early and late which was 3 and 6 weeks after transplant date (WAT) respectively. The second factor was infestation rate at six levels (0, 1, 2 4, 6 and 8 egg batches). Sampling was done seven days after each infestation and thereafter at weekly intervals until harvest. The study was from 13 April to 24 September 2011. The results showed that the maximum yield reduction of 91% occurred to the plants which were infested with 8 egg batches at the early infestation. There were no significant differences ($p>0.05$) with the plants infested with 6 egg batches from those infested with 8 egg batches at both infestation times. On the basis of cost benefit ratio, the economic injury level per m^2 was 6 egg batches and 8 egg batches for the early and late infestation times respectively. The corresponding economic threshold level was 4 egg batches/ m^2 tillers at the early infestation and 6 egg batches/ m^2 tillers for the late infestation.

This study suggests that continuous pest scouting and monitoring, through observing the number of egg batches should form an integral component of managing *M. separatella* and that the time to treat should commence earlier than 3 WAT.

5.1. Introduction

For most cultivated crop species herbivory by insect pests increases with increasing pest densities. Farmers need to know the levels of losses to allow them respond appropriately to pest infestations and reduce possibility of losses. It is generally thought that young plants are more prone to insect pests due to their succulence. However some pests such as *Maliarpha separatella* Rag prefer mature stems as compared to young tillers (Litsinger *et al*., 2011). Reports indicate that rice plants are more susceptible at vegetative and early stages of the reproductive phase which result in the reduction of productive tillers and grain yield components, leading to grain yield reduction (Nwilene *et al* 2011, Litsinger *et al*., 2011).

The development and implementation of effective pest management strategies rely on accurately defined economic injury levels (EIL) and economic thresholds (ET) for that pest, developing relevant monitoring and management procedures and providing a means for practical implementation of the control program within the rice crop production system (RKMP, 2011). Crop loss assessments are also important in pesticide management. Applying insecticides against Yellow Stem Borer has been recommended if there is one adult stem borer moth per square meter of rice plants in a rice field; or 5% "dead hearts" at vegetative stage, and moth or 1 egg mass per square meter in the heading stage of the rice plant (Navarajan 2007, RKMP, 2011). Litsinger *et al.*, (2006) reported that the most effective action threshold for yellow stem borer (*Scirpophaga incertulas* (Walker)) and white stem borer (*S. innotata* (Walker)) was deadhearts.

The respective percentages for different rice growth stages were, 5% for vegetative stage, 25% in reproductive and 10% in the ripening stages. Ritchie and Hunt (2009) found economic threshold for *Scircopophaga incertulas* to be 2 egg masses/20 hills up to panicle initiation stage and one egg mass thereafter. They recommended that egg masses be counted on 20 random hills along the diagonal of the field. When the threshold is reached the egg masses need to be collected and reared in vials or jars. If more parasitoids emerge than *S. incertulas* larvae there is no need to apply insecticides. However, if the larvae are more numerous than the parasitoids then insecticides need to be applied. It has also been reported that *M. separatella* does not attack young leaves on tillers in the nursery and that adult moths oviposit eggs on mature leaves approximately three weeks after transplanting (Nwilene *et al*., 2008). The objectives of this study were to investigate the influence of *M. separatella* infestation and damage on rice yields and monetary value and to determine economic injury level for the pest.

5.2. Materials and methods

5.2.1. Study site and experimental design

The study was carried out in an insect proof screen house at Kenya Agricultural Research Station, Mwea (37.36502 E, 0.62153 S, 1210 A.S.L). Rice (Basmati 370 (*Pishori*) variety) was seeded on raised beds in the insect proof screen house which was divided into different compartments at KARI-Mwea on 14 March 2011. The seedlings emerged seven days later and after one month, they were transplanted in 20 liter plastic buckets which had a rim diameter of 30 cm and were 32 cm high. A single seedling was transplanted in each bucket. Seven days after transplant date, thinning was done leaving 25 tillers per bucket. This was equivalent to number of rice plants per square meter in the field when spaced at 20x20cm.

The treatments were then superimposed on these plants as a 2x6 factorial design and each treatment replicated three times. First factor was time of infestation at two levels, early and late which was 3 and 6 weeks after the transplant date (WAT) respectively.

Second factor was infestation rate at six levels, zero egg batches (no *M. separatella* infestation), one egg batch (approximately 50 *M. separatella* eggs), two egg batches (100 eggs), 4 egg batches (200 eggs), six egg batches (300 eggs) and eight egg batches (400 eggs). Early infestation coincided with the period of panicle initiation while late infestation was equivalent to the booting stage of the rice plant. The treatments were randomized within the different insect proof units and each treatment was under a different screen house unit. The plants were maintained in the insect proof screen house until 25th August 2010 when the experiment was harvested.

5.2.4. Sampling

Sampling started seven days after artificial infestation of the test plants at each infestation period and continued at weekly sampling intervals up to harvesting. Data on number of productive tillers, non productive tillers and number of white heads was taken weekly. At harvest, data on yield and yield components (number of panicles, and number of filled grains per panicle, number of unfilled grains per panicle and 1000 grains weight) was taken. The rice stems were also dissected and the number of larvae and pupae recorded. Yield per screen house unit was weighed and monetary loss under different *M. separatella* infestation rates and time determined. Total yield loss was calculated both in terms of grain weight and percentage. Total yield loss was the difference between the control treatment and yield from different treatments.

5.2.5. Economic injury level (EIL) assessment and the study hypothesis

Yield loss due to *M. separatella*/m^2 was determined as follows:

$$\%w=P-A/P*100 \tag{5.1}$$

where w= percentage yield loss, P=potential yield (without loss due to *M. separatella*) i.e. *M. separatella* free plants or the control and A= actual yield loss (yield of infested plants at different infestation rates).

Yield loss of the plants was used to calculate the slope of the graph that was used to estimate loss per *M. separatella* egg mass.

Before calculating EIL, the net monetary loss or gain due to the different *M. separatella* infestation rates in different infestation periods was calculated. The monetary loss took into account the monetary value if insecticide control was used at the recommended rates and EIL was derived from the decision criterion in partial budget analysis, R (N) ≥ C(N), where R were the returns if *M. separatella* pest population (N), was managed and (C) was the management cost (Pedigo, 1986). The underlying assumption was that loss was directly proportional to *M. separatella* infestation, that is, loss was a linear function of *M. separatella* population (N) (Pedigo, 1986). Economic injury levels were determined according to procedure outlined by Pedigo (1986), using the following formula;

$$\text{EIL} = C/\,(VID) \tag{5.2}$$

where;

C = Cost of management per unit of production and was measured as total costs of inputs and management in shillings (Kenya currency, 1 US$ is equivalent to 80 shillings), the average Central Bank of Kenya exchange rate for third week in the month of August 2011 (www.currencies.com.pk);

I=Injury units per insect per production unit measured as *M. separatella* white heads/ha

V= Market value per unit of produce, that is the utility per unit of produce and was measured as shillings per kg which was KES50 or US$ 0.63(www.currencies.com.pk) per kg at time of study;

D=Damage per unit of injury which was measured as reduction in yield (kg/ha).

5.2.6. Data analysis

Data on stem tunneling, white heads, yield components, yield and monetary value was subjected to analysis of variance. Correlation and regression analyses were conducted to establish the relationship between grain yield and monetary value with *M. separatella* infestation. All analyses were done by use of GENSTAT Version 12 statistical software. Least significant difference (LSD) at 5% confidence interval was used to separate the means that were significant.

5.3. Results

Percent white heads, tunneled tillers and the number of empty grains per spikelet increased with increasing levels of infestation. White heads increased from zero percent at 0 infestation rate to 28.42% at 400 neonates infestation for the early infestation. Similarly, for late infestation percent white heads increased from 0% at zero infestation rates to 22.05 in the 400 neonate infestation rate. The highest percentage number of white heads was in 400 neonate infestation in the early infestation and the lowest was at zero infestation rates in both infestation periods. The percentage tunneled tillers followed a similar trend with the lowest tunneled tillers at zero infestation rates at the two infestation periods. The number of empty grains per spikelet increased with increasing infestation in both infestation periods. The highest increase was in the late infestation with an increase from 2.27% at the one egg batch infestation to 39.97%. There was significant effect on the percent tunneled tillers by the rate of infestation ($p<0.03$) but this was not significant on the percent white heads ($p>0.05$).

There were no significant differences on the number of the tunneled tillers between the plants infested with 50 neonates and those with zero infestation in the two infestation periods (Table 5.1).

Table 5.1: Percent white heads, tunneled tillers and the number of empty grains per spikelet in different *M. separatella* infestation rates and time.

Infestation time	Infestation rate (egg batches)	%whiteheads	% tunneled tillers	Number of empty grains per spikelet
Early	8	28.42a	16.7a	39.97a
Late	8	22.05b	12.3b	39.35a
Late	6	21.63b	9.7b	11.49b
Early	6	17.85c	9.7b	12.81b
Late	2	8.82e	4.3c	9.34b
Early	4	16.24c	4.0c	11.93b
Late	4	14.49d	3.3cd	10.64b
Early	1	3.581e	3.2de	7.12b
Early	2	5.411e	1.20de	7.91b
Late	1	2.27e	1.0e	5.68b
Early	0	0e	0e	2.31c
Late	0	0e	0e	3.64c
p		0.05	0.03	0.016
LSD		3.42	3.24	2.01
CV (%)		37.8	32.4	10.7

Means in a column followed by the same letter are not significantly different by Fishers protected LSD (p<0.05)

DT refers to days after transplant date

White heads (2%) first appeared after panicle initiation which was at six weeks after transplant date (WAT). This indicated tunneling of the tillers which disrupted the plants nutrient transport system resulting in unfilled grains. The highest percentage of white heads (28) was recorded at 8 WAT which corresponded to the booting stage of the rice plant. As the plants aged into the late booting to heading and eventually to maturity, the percentage white heads decreased with the lowest percentage at harvest which was 20 WAT (Figure 5.1).

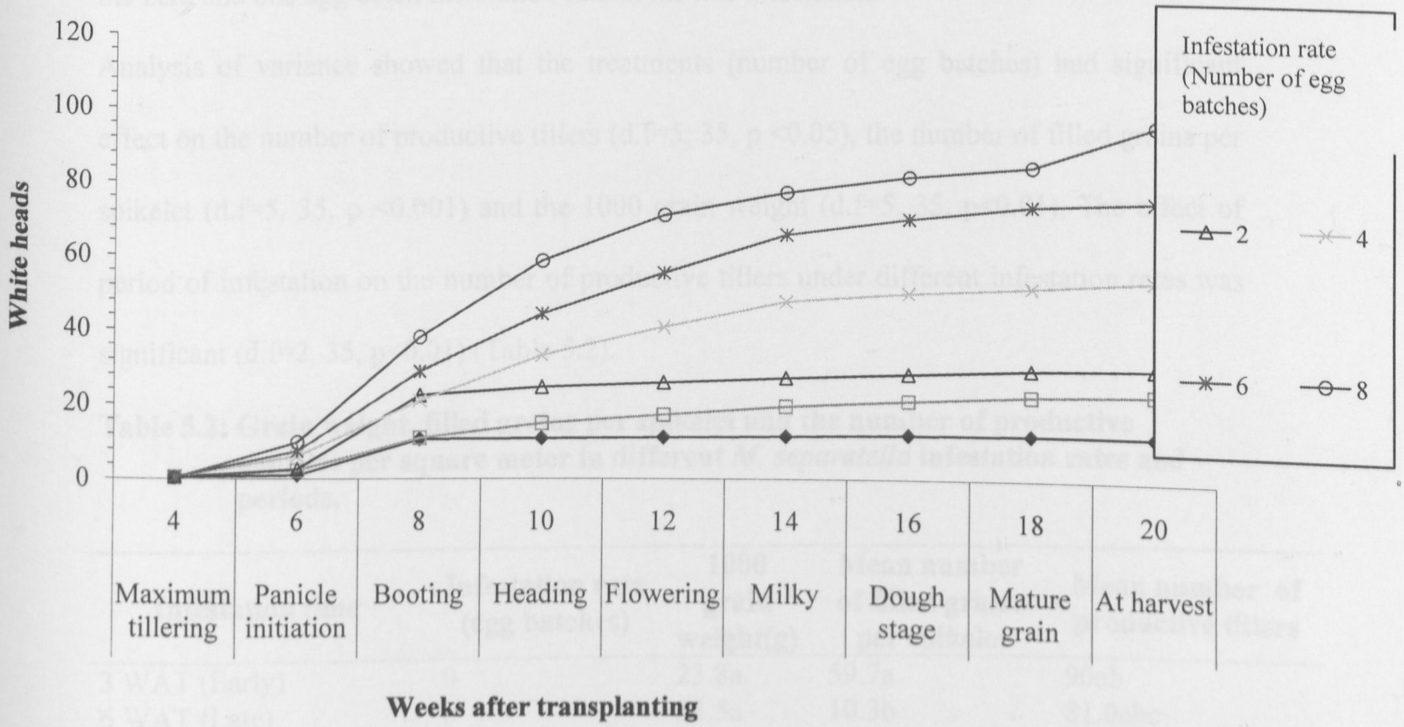

Figure 5.1: Number of white heads *M. separatella* under different infestation rates in the different reproductive phases and weeks after transplanting.

The productive tillers were 90 at zero infestation in the early infestation (3 WAT) but increased to 100 at 1 egg batch infestation rate, possibly due to compensatory tillering. The number of filled grains decreased from 60 at 1 egg mass infestation to 2 in the 8 egg batch infestation rate. Infestation by four egg batches at the early infestation resulted in equal 1000 grain weight in the plants infested late (6 WAT) with two egg batches. There were no differences in the weight of grains in 8 egg batches in the late infestation to those which were infested with 6 egg batches in the early infestation. The weight of grains dropped from 23.8g at zero infestation to 19.1 at the 8 egg mass infestation rate in the early infestation. The lowest grain weights occurred in the late infested plants and the decrease was from 21.4 g at zero infestation to 19 g in the 8 egg mass infestation rate.

There were no differences in the number of filled grains per spikelet and productive tillers in the zero and one egg batch infestation rate in the late infestation.

Analysis of variance showed that the treatments (number of egg batches) had significant effect on the number of productive tillers (d.f=5, 35, $p < 0.05$), the number of filled grains per spikelet (d.f=5, 35, $p < 0.001$) and the 1000 grain weight (d.f=5, 35, $p < 0.01$). The effect of period of infestation on the number of productive tillers under different infestation rates was significant (d.f=2, 35, $p < 0.01$) (Table 5.2).

Table 5.2: Grain weight, filled grains per spikelet and the number of productive panicles per square meter in different *M. separatella* infestation rates and periods.

Infestation time	Infestation rate (egg batches)	1000 grain weight(g)	Mean number of filled grains per spikelet	Mean number of productive tillers
3 WAT (Early)	0	23.8a	59.7a	90ab
6 WAT (Late)	0	23.5a	10.3b	81.0abc
6 WAT(Late)	1	21.4b	10.0b	77.3abc
3 WAT(Early)	1	21.4b	9.0bc	100.0a
6 WAT(Late)	2	21.3bc	8.67bc	43.3cd
3 WAT(Early)	4	21.1bc	6.33cd	84.7ab
6 WAT(Late)	4	20.9cd	5.33d	62.7abc
3 WAT(Early)	2	20.4de	5.33d	64.7abc
6 WAT(Late)	6	20.2e	5de	75.7abc
3 WAT(Early)	6	20.0e	4.0def	52.7bcd
6 WAT(Late)	8	19.1f	2.33ef	59.3abc
3 WAT(Early)	8	19.1f	2f	14.7d
p		0.01	0.001	0.05
LSD		0.48	2.68	40.8
CV (%)		1.3	14.7	35.7

Means in a column followed by the same letter are not significantly different from each other by Fishers LSD ($p < 0.05$).

Overall *M. separatella* infestation levels had significant negative effects on grain yield and yield components. The number of white heads had a significant negative influence on yield, while number of productive panicles and 1000 grain weight had a significant positive influence on this parameter. The number of empty grains had no significant effect on grain yield, but had a significant negative influence on 1000 grain weight (Table 5.3).

Table 5.3: Correlations between white heads, yield components and grain yield.

	Number of white heads	1000 grains weight in grams	Number of productive panicles	Number of empty grains	Grain yield in kgs/ha
Number of white heads	1				
1000 grains weight	0.-324 (0.099)	1			
Number of productive panicles	-0.270 (0.173)	0.253 (0.202)	1		
Number of empty grains	0.216 (0.280)	0.402* (0.038)	-0.181 (0.367)	1	
Grain yield	-0.280 (0.157)	0.302 (0.126)	0.998** (0.00)	-0.176 (0.379)	1

N= 36, significance level is indicated in brackets, *, **. Correlation is significant at 5 and 1% level respectively, ns not significant.

5.3.4. Grain yield net value and monetary loss

In the early infestation, grain yield was significantly reduced from 2495kg/ha in the control with un infested plants to 1004, 418, 380, 245, 227 where 1, 2, 4, 6, and 8 *M. separatella* egg batches were introduced respectively. These corresponded to 59.8, 83.2, 84.8 90.2 and 90.9% reductions in yield.

For the late infestation, yield was reduced from 2072 in the control with un infested plants to 1361, 993, 758, 377 and 398 at 1, 2, 4, 6, and 8 *M. separatella* infestation rates and this corresponded to 34.3, 52.1, 63.4, 81.8, and 80.8% yield reductions. Reduction in monetary value followed similar trend with no loss at the zero infestation rate in the two infestation periods. The highest loss in net value was where the plants were infested with 8 egg masses in the early infestation period (Table 5.4).

Table 5.4: Grain yield and net value loss in different *M. separatella* infestation rates and periods.

Infestation period	Infestation rate(egg batches)	Grainyield (kg/ha)	Net value(Kes)	Reduction in grain yield/ha	% Yield reduction/ha	Net loss(Kes/ha)
3WAT (Early)	0	2495a	124750a	0a	0.0f	0.0e
WAT (Late)	0	2072b	103600b	0a	0.0f	0.0e
6 WAT(Late)	1	1361c	68050c	711b	34.3d	35550.0d
3 WAT(Early)	1	1004d	50200c	1491bc	59.8e	74550.0b
6 WAT(Late)	2	993cd	49650c	1079cd	52.1c	53950.0c
6 WAT(Late)	4	758d	37900e	1314de	63.4b	65700.0b
6 WAT(Late)	6	377e	18850ef	1695e	81.8c	84750.0b
6 WAT(Late)	8	398e	19900f	1674fg	80.8b	83700.0b
3 WAT(Early)	2	418e	20900f	2077g	83.2b	103850.0b
3 WAT(Early)	4	380e	19000f	2115g	84.8a	105750.0a
3 WAT(Early)	6	245e	12250f	2250g	90.2a	112500.0a
3 WAT(Early)	8	227e	11350f	2268g	90.9a	113400.0a
p		0.01	0.01	0.01	0.05	0.02
LSD		254	12,700	488.6	5.34	18,100
CV (%)		26.3	28.9	11.9	37.8	23.4

Means in a column followed by the same letter are not significantly different by Fishers LSD ($p<0.05$)

WAT refers to weeks after transplant date

Data on grain yield at different infestation rates was used to calculate a regression equation (y = -0.214.29 □ + 1693.4, $r^2 = 0.8416$), where y was the weight of paddy rice and □ was the infestation level in number of egg batches. This described the overall relationship between yield and *M. separatella* infestation levels. There was a significant strong negative relationship between infestation levels and grain yield at different infestation levels. The linear relationship indicated that relatively high yield loss, up to 100% at infestation level of 8 egg batches was possible (Figure 5.2).

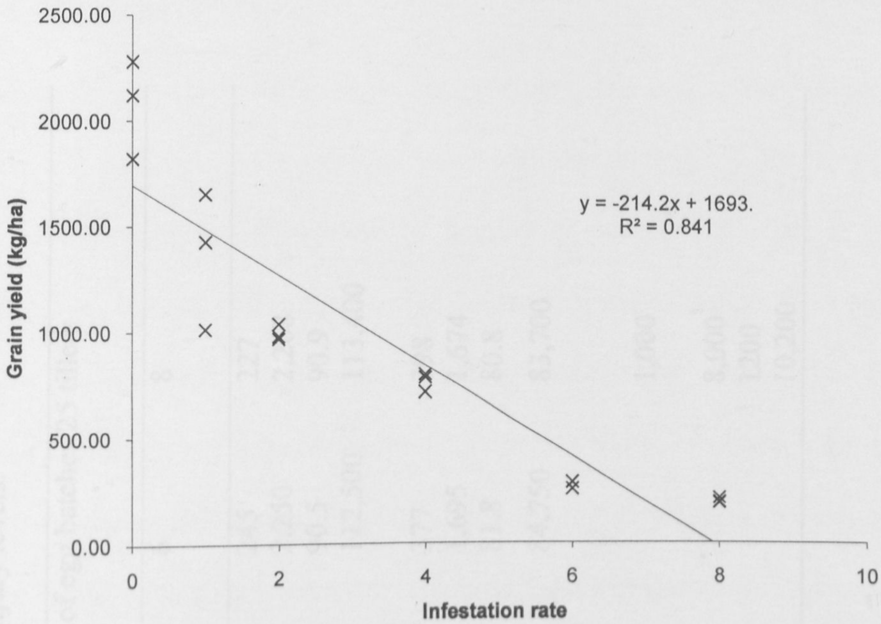

Figure 5.2: Linear regression relationship between grain yield and *M. separatella* infestation rates.

5.3.5. Economic Injury Level (EIL)

Infestation data on losses attributed to rice plants infestation by *M. separatella* egg batches and costs of management were used to calculate Economic Injury level (EIL). The resultant EIL was 6 and 8 egg batches/ m^2 tillers for early and late infestation respectively (Table 5.5).

Table 5.5: Monetary net loss of Basmati 370 rice caused by *M. separatella* infestation and economic injury levels.

		M. separatella infestation level in number of egg batches/25 tillers					
Time of infestation	Parameter	0	1	2	4	6	8
3 WAT(Early)	Grain yield	2,495	1,004	418	380	245	227
3 WAT	Reduction in grain yield	0	1,491	2,077	2,115	2,250	2,268
3 WAT	% yield reduction	0	59.8	83.2	84.3	90.5	90.9
3 WAT	Net revenue loss (KES/ha)	0	40,666	103,850	105,750	112,500	113,400
3 WAT	Average loss per *M. separatella* egg batch				283.5 kg/ha		
6 WAT (Late)	Grain yield	2,072	1,361	993	758	377	398
6 WAT	Reduction in grain yield	0	711	1,079	1,314	1,695	1,674
6 WAT	% yield reduction	0	34.3	52.1	63.4	81.8	80.8
6 WAT	Net revenue loss (KES/ha)	0	35,550	53,950	65,700	84,750	83,700
6 WAT	Average loss per *M. separatella* egg batch	0			209.3 kg/ha		
	Type of cost	Labour					1,000
		Sprayer and depreciation					8,000
		Insecticide					1200
		Total (KES)					10,200
	EIL(21DT)	5.72 or 6 egg batches/25 tillers					
	EIL(42DT)	7.80 or 8 egg batches/25 tillers					

1KES=0.0125USD (Central Bank of Kenya rates of 25th August 2011)

5. 4. Discussion

The findings that the number of productive tillers increased at low infestation levels in the early infestation period are in agreement with the findings by Asghar *et al*. (2009) who found a corresponding increase in number of productive tillers at 1% white head infestation, but this was not evident at the late infestation period. This could be attributed to the fact that the rice plant is able to compensate for low levels of stem borer attacks that occur during the early stages of the plant growth stage, by producing more tillers. It has been suggested that enhancing plant compensating mechanism to stem borer injury may be a better strategy for stem borer management compared with insecticide application (Asghar *et al*. 2009). The results of two egg batches at the early infestation periods causing an equal loss of productive tillers with 8 egg batches at the late infestation are in agreement with Litsinger *et al.* (2011) findings who reported that compensatory tillering of the rice plant was low at high infestation rates in the late stages of the rice plant growth. The results of high grain yield at early infestation were suggestive of compensatory tillering and enhancement of the yield components by the rice plants, when infested at young stages. This is in agreement with Asghar *et al*. (2009) who reported an increase of grain yield at 1% white head infestation at the early stage of the rice plant growth. The decrease in the number of white heads as the rice plant aged into the reproductive and ripening phases is consistent with the findings of Bandong and Litsinger (2005) which indicated that rice is resistant to stem borer damage when very young, at mid-growth, and after panicle initiation, but is more susceptible at booting stage. These authors suggested that during booting the stems swell and leaf husks loosen thus making it easy for stem borer neonates to gain entry into the rice plant.

The number of filled grains per spikelet and 1000 grain weight were affected significantly in a negative way by increasing infestation levels. This effect may be attributed to the fact that *M. separatella* damage disrupts translocation of nutrients to the growing floral parts as reported by Asghar *et al.* (2009).

The grain yield decrease with increase in infestation levels across the infestation periods is consistent with findings by Asghar *et al.* (2009) and Litsinger *et al*. (2011) of negative correlation between grain yield and infestation levels. However there was a huge magnitude of losses and this is supported by reports that stem borers cause heavy losses (Riba, 2007). Grain yield losses of 20 to 50 % due to yellow stem borer (YSB) damage have been reported in India (Riba, 2007). In Ganado, Texas, rice yield losses of up to 60%, were reported in untreated fields (Way *et al*., 2006). The results of negative correlation of *M. separatella* damage with yield and yield components in this study was expected and is consistent with several reports from other authors (Litsinger *et al*., 2006, Sherawat *et al*., 2007, Asghar *et al.,* 2009, Litsinger *et al*., 2011) which indicate that grain yield decreases with increasing stem borer infestations.

The economic threshold of 4 egg batches per square meter of rice plants at the early infestation in this study is consistent with recommendations by RKMP (2011) of applying insecticides against stem borers if there is one adult stem borer moth per square meter of rice plants in a rice field. These results are also in agreement with the findings of Muralidharan and Pasalu (2006) that one white head can cause 4.0% yield loss. Ritchie and Hunt (2009) found economic threshold for *Scircopophaga incertulas* to be 2 egg masses per 20 hills up to panicle initiation stage and one egg mass thereafter. They recommended that egg masses be counted on 20 random hills along the diagonal of the field. When the threshold is reached the egg masses need to be collected and reared in vials or jars. If more parasitoids emerge than *S. incertulas* larvae there is no need to apply insecticides. However, if the larvae are more numerous than the parasitoids then insecticides need to be applied. It has also been reported that *M. separatella* does not attack young leaves on tillers in the nursery and that adult moths oviposit eggs on mature leaves approximately three weeks after transplanting (Nwilene *et al*., 2008).

Results of this study suggest that pest monitoring of *M. separatella* by routine scouting for egg batches before the 3 WAT equivalent to maximum tillering would aid in initiating insecticide control measures early enough. Further scouting up to the 6 WAT will help in making decisions to spray against subsequent infestations at booting stage. Insecticides should be applied if 4 egg batches/ m^2 at the 3 WAT (early infestation) are seen and a subsequent application if 6 egg batches/ m^2 are seen at the 6 WAT (late infestation) for Basmati 370 variety at Mwea.

5.5. References

Asghar, M., Suhail, A., Faisal, M. and Khan, M.A. 2009. Determination of economics threshold levels for the stem borers (*Scirpophaga* sp.) and leaf folder (*Cnaphalocrosis medinalis*) of rice (*Oryza sativa*) in the Kallar tract of Punjab, Pakistan. *Internattonal Journal of Agricultural Biology* 11: 717–720.

Bandong, J.P. and Litsinger, J.A. 2005. Rice *crop stage susceptibility to the rice yellow stem borer Scirpophaga incertulas (Walker). International Journal of Pest Management 51* (1): 37–43.

Central Bank of Kenya, 2011. Exchange rates-Forex rates. Business flap 25th August 2011. http://www.currencies.com.pk.central-bank-of-kenya Accessed 25 August 2011

GENSTÀT, 2009 . Genestat statistical package for windows version 12.0.

Litsinger,J.A., Bandong, J.P., Canapi, B.L., Dela Cruz, C.G. Pantua, P.C. Alviola, A.L. and Batay- An III, E.H. 2006. Evaluation of action thresholds for chronic rice insect pests in the Philippines. IV. Stemborers, *International Journal of Pest Management* 52(3): 195-207.

Litsinger, J.A, Canapi, B.L., Bandong, J.P., Lumaban, M.D., Raymundo, F.D. and Barrion, A. T. 2009. Insect pests of rainfed wetland rice in the Philippines: population densities, yield loss, and insecticide management. *International Journal of Pest Management*. 55 (3): 221-242.

Litsinger, J.A., Bandong, J.P. and Canapi, B.L. 2011. Effect of multiple infestations from insect pests and other stresses to irrigated rice in the Philippines: II. Damage and yield loss. *International Journal of Pest Management* 57 (2): 117-131.

Muralidharan, K., and I.C. Pasalu. 2006. Assessments of crop losses in rice ecosystem due to stem borer damage. *Crop Protection* 25: 409-417.

Navarajan, P. 2007. Insect pests of rice (*Oryza sativa*). In Insects pests and their management. www.nsdl.niscair.res.in/bitstream/123456789/493/1/. Accessed 17 August 2012.

Nwilene, F.E., Onasanya, A., Togola, A., Oyetunji, O., Semon, M., Tamo, M., Bright, E.O. and Ofondile, S. 2011. Effect of intercropping maize and cassava with upland NERICA rice varieties on stem borer attack in South West Nigeria. *Journal of Entomology* 8(5): 417-428.

Nwilene, F.E, Sanyang, S., Traore, A.K., Goergen, G. and Agunbiade, T.A. 2008. Rice stem borers: Biology, Ecology and Control-*Field guide and Technical Manual, Cotonou, Benin, Africa Rice Centre (WARDA)* 28p

Pedigo, L.P., Hutchins, F.H and Higley, L.G. 1986. Economic injury levels in theory and practice. *Annual Review of Entomology.* 31: 341-368.

Riba, T. 2007. Major pests of paddy and their management, Paddy Stem borers: In Integrated pest management in paddy, Krishi Vigyan Kendra College of Horticulture and Forestry, Central Agricultural University, Pasighat 7pp http://www.earik.in/index.php?option=com_content&view=article&id=74:crop-information&catid=39. Accessed 4 August 2012

Rice knowledge management portal (RKMP), 2011. Integrated Pest management in Rice, Technical bulletin No. 15, Directorate of rice research, Rajendranagar, Hyderabad 16pp

Ritchie, B.J and Hunt, B. 2009. Yellow stem borer (YSB) , *Scirpophaga incertulas*, Dark headed stem borer (DHSB), *Chilo polychrysus* & pink stem borer (PSB) *Sesamia inferens* CABI/IKSL/HAFRICE/AUG09/1 CABI,UK Europe centre p5

Sherawat, S.M., Inayat, M. Ahmad, T. and Maqsood, M.K. 2007. Determination of economic threshold levels (ETL) for the chemical control of rice stem borers. *Journal of Agricultural Research,* 45: 55–59.

Way, M.O., Reay-Jones, F. P F. and Reagan, T. E. 2006. Resistance to stem borers among Texas rice cultivars. *Journal of Econonomic Entomology* 99(5): 1867-1876

CHAPTER 6

EFFECTIVENESS OF ENTOMOPATHOGENIC NEMATODES AGAINST THE AFRICAN WHITE RICE STEM BORER *MALIARPHA SEPARATELLA* RAG

Abstract

The efficacy of three entomopathogenic nematodes (EPN) species *Steinernema carpocapsae* Weiser, *Steinernema karii* Waturu, Hunt & Reid, *Heterorhabdtids indica* Poinar, Karunaka & David and two EPN isolates collected from Coastal Kenya (*EX MOMBASA*) and Rift valley (*EX NAKURU*) was evaluated against larvae of African white rice stem borer, *Maliarpha separatella* Rag. The experiment was carried out using no-choice modified filter paper bioassay at KARI-Mwea. Whatman filter paper was substituted with white cotton cloth discs. The activity of the biological agents under study was determined at 25°C and 65% relative humidity, with concentrations of 50, 100 and 200 infective juveniles (IJs) per one *M. separatella* third instar larva. The larvae were confined in 60mm plastic petri dishes in darkness as the larvae spend their entire life inside the rice stems. The mortality rate was determined at 24, 48, 72 and 96 hours after application of the nematode suspension. Significant virulence was obtained with all the nematode species at 200 infective juveniles (IJs). There was low mortality at 50 and 100 concentration rates. All the EPNs significantly reduced *M. separatella* larvae after 48 hours in the following order *H. indica> EX NAKURU> S. carpocapsae> EX MOMBASA* >S. *karii*. The number of nematodes from the infected cadavers after 48 hours post infection was *H. indica* (553), *EX –MSA* (294), *EX-NKU* (242), *S .karii* (168) and *S. carpocapsae* (157). *S. karii* took the longest time (96 hours) to kill all the test insects. In conclusion, the study shows that EPNs are effective against *M. separatella* and could be used within an integrated pest management strategy for the pest. There is need to carry out further studies to determine effective dosages under field conditions.

6.1. Introduction

The control of pests and diseases including *Maliarpha separatella* at Mwea irrigation scheme is through use of pesticides following a calendar based spraying regime developed by Mwea Integrated Agricultural Development Centre (MIAD). However, use of pesticides is associated with various problems. For farmers, the most serious are the acquisition of pest resistance to the chemicals, secondary pest outbreaks, and health hazards associated with the application of chemicals. For consumers, the main problems are pesticide residues in food and environmental degradation (Ooi, 2005). Due to these factors, research towards developing alternative control strategies is warranted and the use of entomopathogenic nematodes (EPNs) in irrigated rice ecologies offers a viable alternative. Most of EPN formulations used in biological control of insect pests are from two Families namely Steinernematidae and Heterorhabditidae in order Rhabtida (Adams and Nguyen, 2002). The formulations consist of third stage infective juvenile (sometimes referred to as IJ or dauer). It is non-feeding, developmentally arrested and the only EPN life stage that exists outside the host insect. The IJ seeks insect hosts, and after entering, they release an associated mutualistic bacterium, *Xenorhabdus* for Steinerernematids and *Photorhabdus* for Heterorhabditids, respectively (Adams and Nguyen, 2002). The nematode-bacterium complex usually cause host mortality within 24- 48 hours (Burnell and Stock, 2000). The nematodes provide shelter to the bacteria, which, in turn, kill the insect host and provide nutrients to the nematode (Adams and Guyen, 2002). The bacteria produce pigments so that insects infected by Heterorhabtidis turn brick red or maroon colour and those infected with Steinernematids turn ochre, tan or brown (Greenwood and Rebek, 2008). All nematode-infected insect cadavers have a distinct firm and rubbery consistency, and stay intact for more than a week, while the nematodes complete their life cycle (Greenwood and Rebek, 2008).

In Kenya EPNs have been used to control insect pests (Waturu, 1998; K.A.R.I., 2006; Nderitu *et al.* 2009; Nyasani *et al,* 2008) but none have been tested against *M. separatella.* The aim of this research was to determine the efficacy of three EPN species, *Steinernema carpocapsae, Steinernema karii, Heterorhabditis indica* and two strains collected from Coastal Kenya (*EX MOMBASA*) and from Rift valley (*EX NAKURU*), against the larvae of *M. separatella.*

6.2. Materials and methods

6.2.1. Study site and entomopathogenic nematodes production

The study was carried out at Kenya Agricultural Research Station, Mwea (37.36502 E, 0.62153S) entomology laboratory on 25-28 October 2010. Cultures of three entomopathogenic nematode species and two isolates were used. These were from colonies maintained in the laboratory and included *S. carpocapsae, S. karii, H. indica* and two EPN isolates collected from Coastal Kenya *(EX MOMBASA*) isolate (Waturu (1998) and from Rift valley *(EX NAKURU)* isolate (Mwaniki, 2008). Infective juveniles (IJs) of the five isolates were cultured in the last in- star of the greater wax moth, *Galleria mellonella* L. at 20-22^{0}C 60-65% relative humidity. The emerging IJs were harvested from White traps and stored in distilled water at 10^{0}C.

6.2.2. Insect colony

Maliarpha separatella third instar larvae were used for the assay. They were maintained on an artificial diet modified by the author at KARI-Katumani insectary. The colony had been established by collecting *M. separatella* eggs from rice fields at Mwea rice irrigation scheme and rearing on an artificial stem borer rearing diet.

6.2.2. Stem borer artificial rearing diet preparation

The diet ingredients and procedure for diet preparation was adopted from the method by Songa *et al.* (2001) for artificial rearing of cereal stem borers. Diet was modified by substituting sorghum leaf powder by rice leaf powder prepared from leaves of six weeks old rice plants which were dried and ground into a fine powder. The ingredients and the ratios used for 1.5 liter diet were: distilled water (80.1%), Brewer's yeast (2.3%), sorbic acid (0.13%), methyl-p-hydroxylbenzoate (0.2%), ascorbic acid (0.25%), vitamin E capsules (0.2%), rice leaf powder (2.5%), Bean (*Phaseolus vulgaris*) powder (8.8%), sucrose (3.5%), agar (Tech No 3) powder (1.3%), formaldehyde 40% (0.2%). and Grabacin (0.2%).

Maliarpha separatella larvae collected from infested rice fields were then introduced into diet at the rate 20 larvae per jar, where they developed up to adult moth emergence. The emerging moths were sexed and five pairs introduced into oviposition cages which were lined with wax paper. The female moths laid eggs on the wax paper. The sections of the wax paper with eggs were then cut out, put in sterilized Sterlin® plastic petridishes and incubated at 30^0 C for 24 hrs up to black head egg stage. The black heads were surface sterilized by 70% ethanol and introduced into the artificial rearing diet. They were then allowed to develop into 3rd instar larvae and used in the bioassay.

6.2.3. Entomopathogenic nematodes evaluation

Contact filter paper bioassays against *Maliarpha separatella* using the five entomopathogenic nematodes isolates were set up at KARI-Mwea entomology laboratory. Standard filter paper bioassays have been used before to evaluate EPNs (Woodring and Kaya, 1988) but in the present study white cotton cloth discs were used instead of the Whatman® filter paper.

Suspensions of EPNs were first agitated by blowing into the suspension by a pipette and the equivalent aliquots of nematode concentrations were drawn.

Treatments consisted of three concentrations of entomopathogenic nematodes (EPN), 50, 100 and 200 IJs and an untreated control. One ml of nematode suspension was added to each Sterlin ® 60mm plastic petridish containing a folded cotton cloth disc using a pipette, with the tip being changed after every treatment. In the control treatments 1 ml of distilled water without nematodes was added to the cotton cloth discs. One *M. separatella* 3rd instar larva was then introduced on top of cloth disc which was already moist with the nematode suspension making sure that the larvae did not drown. They were closed and incubated at temperatures of $25^0C\pm2^0$ and 65-75% relative humidity. The experiment was laid out in a completely randomized design with 10 replicates for each nematode isolate at the test concentrations. Observations were done on 24, 48, 72 and 96 hours after *M. separatella* larva introduction. On each of these observations mortality was measured and *M. separatella* cadavers observed for firm rubbery consistency and colour change (brick red or maroon colour for Heterorhabtidis and ochre, tan or brown for Steinernematids (Greenwood and Rebek, 2008) which indicate nematode infectivity. They were then put in 1% Ringer's salt solution and dissected under a binocular microscope in an engraved Petri dish. The number of first generation nematodes was counted using a tally counter under low power binocular microscope.

6.2.4. Statistical analysis

Analysis of variance (ANOVA) was conducted to determine the differences in mortality rates. Least significant differences were used to separate means when found significant at p=0.05. The statistical analysis was performed using Genstat Version 12 statistical software. Probit regression analysis was performed on the data to estimate effective concentration and lethal periods.

6.2.6. Probit regression analysis and the study hypothesis

Probit analysis is used to analyze dose-response curves especially to determine the relative toxicity of pesticides to living organisms. This is done by testing the response of an organism under various concentrations of the pesticide and then comparing the concentrations at which one encounters response. The assumption is that in population of units to be used in the study, there is a normal distribution of concentration which each unit will tolerate. The assumption of a normal distribution of tolerance levels is most reasonable when the concentrations are transformed to a log scale. The underlying model uses the procedure developed by Finney (1971). From their work, probit *P* is a percentage of population responding and the model is;

$$\text{Probit}(p)=\alpha+\beta(\log_{10}[\text{Concentration}]) \quad (6.1)$$

The estimates of α and β were obtained using the iterative procedure outlined by Finney (1971) and an approximate standard error for the estimate of the EPN log dose 50 (LC_{50}) was obtained by using the formula from Mead *et al.* (1993);

$$S.E(LD_{50})=\sqrt{Var(a)-2.LD_{50}.Cov(a,b)+LD_{50}^{2}Var(b)/b^{2}} \quad 6.2$$

where a and b are the estimates of α and β and the variances and covariances are obtained from the variance-covariance matrix of the parameter estimates. The approximation is reasonable if the standard error of the slope is relatively small (Mead *et al*., 1993)

6.3. Results

Probit curve showed *Heteterorhabitidis indica* as the EPN requiring the least concentration to cause 100% *M. separatella* mortality while *S. karii*, *S. carpocapsae* and *EX MOMBASA* required slightly higher than 200 IJs to kill all the test insects. The order of virulence was *H. indica*> *EX NAKURU*> *S. carpocapsae*> *EX MOMBASA* >*S. karii* (Fig 6.1)

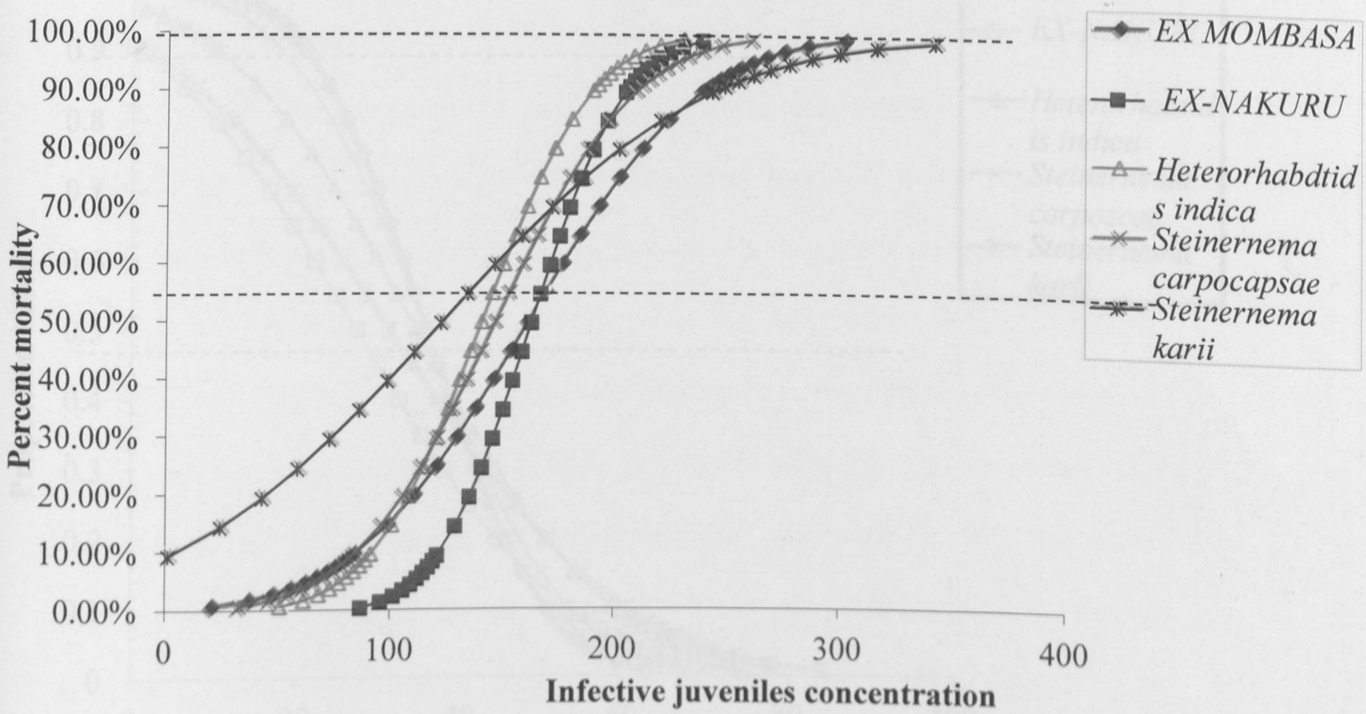

Figure 6.1: Median lethal concentration (LC_{50}) and LC_{90} of different EPN isolates to *M. separatella* larvae.

All EPNs were effective against *M. separatella* within 48 hours of infection. *EX-NAKURU* had the earliest median LT50, while *S. karii* took the longest time to kill all the test insects (Figure 6.2)

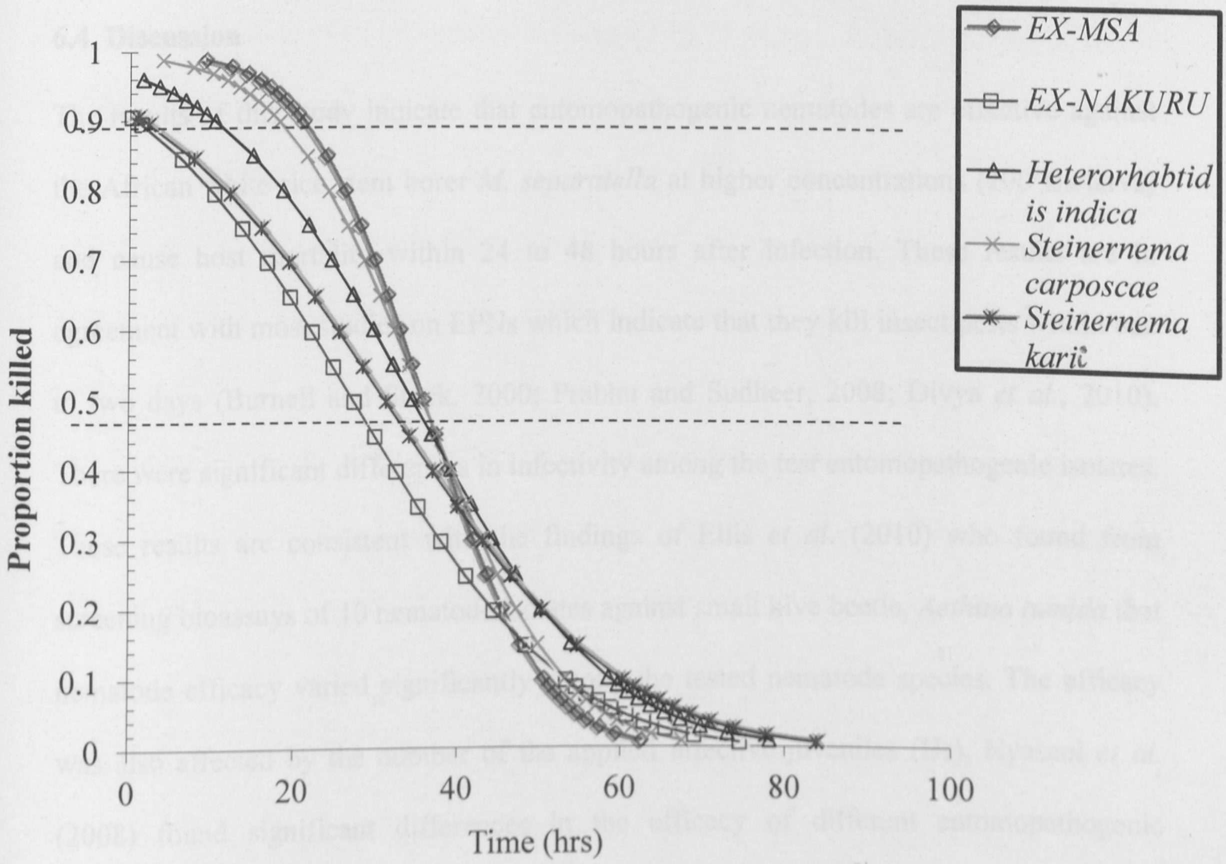

Figure 6.2: Median lethal time (LT 50) and LT 90 of *M. separatella* larva after infection by different EPN isolates.

Heterorhabtidis indica had the highest number of first generation EPNs in *M. separatella* cadavers after 48 hours post infection followed by EX-MSA, while the least number of EPNs was in *Steinernema carpocapsae* (Table 6.1).

Table 6.1: The mean number of first generation Entomopathogenic nematodes in *M. separatella* host cadavers after 48 hours post infection.

Isolate	Number of EPNs per *M. separatella* cadaver (Mean±SE)
Steinernema carpocapsae	157.23±0.64
Steinernema karii	168.19±0.81
Heterorhabdtidis indica	552.93±0.74
EX-NKU	242.00±0.90
EX-MSA	293.56±0.66
P	0.33
CV (%)	48.7

6.4. Discussion

The results of this study indicate that entomopathogenic nematodes are effective against the African white rice stem borer *M. separatella* at higher concentrations (200 IJs/larva) and cause host mortality within 24 to 48 hours after infection. These results are in agreement with most studies on EPNs which indicate that they kill insect pests within one to two days (Burnell and Stock, 2000; Prabhu and Sudheer, 2008; Divya *et al.*, 2010). There were significant differences in infectivity among the test entomopathogenic isolates. These results are consistent with the findings of Ellis *et al.* (2010) who found from screening bioassays of 10 nematode isolates against small hive beetle, *Aethina tumida* that nematode efficacy varied significantly among the tested nematode species. The efficacy was also affected by the number of the applied infective juveniles (IJs). Nyasani *et al.* (2008) found significant differences in the efficacy of different entomopathogenic nematodes against diamond back moth. Past studies indicate that EPNs are effective when well matched with host arthropod pests (Gaugler, 1999) and that different species of entomopathogenic nematodes vary in the range of the insects which they attack and their environmental needs (Shapiro-Ilan and Gaugler, 2010).

The high mortality caused by *H. indica* which also had the highest multiplication rate in *M. separatella* host cadavers is in agreement with the findings of Shapiro-Ilan and Gaugler (2010) who demonstrated that invasion and reproduction in hosts by different nematode species varied quantitatively. Menti *et al*. (2000) reported that *Heterorhabditis spp* often infect at lower rates than *Steinernema spp* but comparative mortality is often similar or higher as was found out in this study. The discrepancy in infectivity between Heterorhabditids and Steinernematids may be attributed to differences in the time of establishment of the symbiotic bacteria in the insect host.

The most effective entompathogenic nematode was *H. indica*. It is heat tolerant, infecting insects at 30°C or higher. The nematode produces high yields *in vivo* and *in vitro*, but shelf life is generally shorter than most of the other nematode species. Nderitu *et al.* (2009) also found this EPN to have significant efficacy against *Cylas puncticollis* in sweet potato fields at Kibwezi in Kenya. Similarly, Mahar *et a*l. (2006) in a study to control nymphs of desert locust *Schistocerca gregaria* found that Heterorhabditids (*H. indica* and *H. bacteriophora*) were more effective as compared to Steinernematids (*S. carpocapsae*, *S. feltiae*) at 30 degrees centigrade and that the highest concentration of each isolate (200 IJs per ml) proved to be most appropriate for maximum insect death.

The period of exposure and concentration were important factors for the activity of the nematodes. This can possibly be explained by the fact that the number of EPNs penetrating the host is influenced by the number of invasive nematodes which earlier managed to penetrate it. In the current study most of the nematodes had high chances of penetrating the host and this is supported by studies by Declan *et al.* (2006) who when screening *S. feltiae* and *S. carpocapsae* against *Plectrodera scalator* reported that filter paper bioassays killed 50-58% of larvae but the mortality in diet cup bioassay was less than 10%. The results of this research show that application of entomopathogenic nematodes might be a possible efficient way for controlling *M. separatella*, but the optimization of environmental factors and application by the most appropriate method under field conditions would further improve their efficacy.

6.5. References

Adams, B. J. and Nguyen, K. B. 2002. Taxonomy and Systematics: General biology. In. *Entomopathogenic Nematology* (ed. R. Gaugler) CABI Publishing, CAB *International*:1-2.

Burnell, A. M. and Stock, S. P. (2000). *Heterorhabditis, Steinernema* and their bacterial symbionts as lethal pathogens of insects. *Nematologica* (2, 1): 31-42.

Declan, J.F., Leellen, F.S., Leah, S.B., Deborah, L.M., James, R.C. and Michael, L.M. (2006). Effect of entomopathogenic nematodes on *Plectrodera scalator* (Fabricius) (Coleoptera: Cerambycidae). *Journal of Invertebrate Pathology*. 92 (2006):55–57

Divya, K., Sankarb, M., and Marulasiddesha, K.N. 2010 Efficacy of Entomopathogenic Nematode, *Heterorhabditis indica* against three lepidopteran insect pests. *Asian Journal of Experimental Biology and Science* (1, 1): 183-188.

Ellis, J.D, Spiewok, S., Delaplane, K., Buchholz, S., Neumann, P., and Tedders, W. 2010. Susceptibility of *Aethina tumida* (Coleoptera: Nitidulidae) larvae and pupae to entomopathogenic nematodes. *Journal Econonmic Entomology* 103(1): 1-9.

Finney, D.J. 1971. Probit analysis 3rd edition Cambridge University Press, Cambridge, U.K

GENSTAT, 2009 . Genstat statistical package for windows version 12.0.

Gaugler, R. 1999. Matching nematodes and insects to achieve optimal field performance. *Optimal Use of Insecticidal Nematodes in Pest Management Workshop Proceedings:* 9–14. Edited by S. Polavarapu, Rutgers University

Greenwood, C. M. and Rebek, E. J. 2008. Detection, Conservation, and Augmentation of Naturally Occurring Beneficial Nematodes for Natural Pest Suppression. *Oklahoma*

Cooperative Extension Fact Sheets, Oklahoma Cooperative Extension Service EPP-7670 p6 http://osufacts.okstate.edu. Accessed on 5 July 2012.

KARI, 2006. Field evaluation of entomopathogenic nematodes for efficacy against cotton pests. Kenya Agricultural Research Institute 2006 Annual Report: 85-86.

Mahar, A. N., Jan, N. D., Gowen, S. R., Hague, N. G. M., Al-Siyabi, A. A. , Mahar, A. Q. 2006. A comparative study on the effectiveness of laboratory bioassays of entomopathogenic nematodes against desert locust nymphs *Schistocerca gregaria* (Acrididae:Orthoptera). *Pakistan Journal of Nematology* 24: 151-161.

Mead, R., Curnow, R.N., Hasted, A.M. 1993.Statistical methods in agriculture and experimental biology, second edition. Chapman and Hall, London, United Kingdom

Menti, H., Wright, D.J., Perry, R.N., 2000. Infectivity of populations of the entomopathogenic nematodes *Steinernema feltiae* and *Heterorhabditis megidis* in relation to temperature, age, and lipid content. *Nematology* 2: 515–521.

Mwaniki, S.W., Nderitu, J.H., Olubayo, F., Kimenju, J.W., and Nguyen, K .2008. Factors influencing the occurrence of entomopathogenic nematodes in the Central Rift Valley region of Kenya. *African Journal of Ecology* 46: 79-84.

Nderitu, J. Sila, M. Nyamasyo, G. and Kasina, M. 2009. Effectiveness of Entomopathogenic Nematodes against Sweet Potato Weevil (*Cylas puncticollis* Boheman (Coleoptera: Apionidae)] under semi-field Conditions in Kenya. *Journal of Entomology* 6: 145-154.

Nyasani, J.O., Kimenju, J.W., Olubayo, F.M., Shibairo S.I. and Mutua G.K. (2008). Occurrence of entomopathogenic nematodes and their potential in the management of Diamond Back Moth in kale. *Asian journal of plant sciences* 7(3): 314-318.

Ooi, P. A. C, 2005. Some Non-Pesticide Methods for Managing Crop Insect Pests-Present Status, Issues and Strategies. *Non pesticide Methods for Controlling Diseases and Insect Pests. Report of the APO Seminar on Non pesticide Methods for Controlling Diseases and Insect Pests held in Tokyo, Japan, 10–17 April 2002 (Eds Ooi, P.A.C) Asian Productivity Organization (APO) ISBN: 92-833-7037-6:* 15-24.

Prabhu, S. and Sudheer, M. J. 2008. Evaluation of two native isolates of entomopathogenic nematodes *Steinernema sp.* and *Heterorhabditis indica* from Andhra Pradesh against *Amsacta albistriga* Walk in groundnut, *Journal of Biopesticides* 1(2):140 – 142.

Shapiro-Ilan, D.I., and Gaugler, R. 2010. Nematodes: Rhabditida: Steinernematidae & Heterorhabditidae. In: *Biological Control: A Guide to Natural Enemies in North America*. Edited by A. Shelton, Cornell University. http://www.biocontrol.entomology.cornell.edu/pathogens/nematodes.html. Accessed 26 July 2012.

Songa, J.M., Bergvinson, D. and Mugo, S. (2001). Mass rearing of the maize stem borers *Chilo partellus, Busseola fusca, Sesamia calamistis, Chilo orichalcociliellus* and *Eldana saccharina* KARI-Katumani. *In proceedings of Seventh Eastern and Southern Africa Regional maize conference 12-15 February 2001:* 120-124.

Waturu, C.N. (1998). Entomopathogenic Nematodes (Steinernematidae and Heterorhabditidae) from Kenya, PhD thesis, University of Reading 191pp.

Woodring, J. L., and Kaya, H. K. 1988. Steinernematid and Heterorhabditid nematodes: handbook of biology and techniques. *Southern Cooperative Series Bulletin 331*. A publication of the nematode subcommittee of the Southern Research Project S135-Entomopathogens for use in Pest Management Systems. Arkansas Agricultural Experiment Station, Fayetteville, AR.

CHAPTER 7

EVALUATION OF RICE CULTIVARS FOR RESISTANCE TO *MALIARPHA SEPARATELLA*

Abstract

It has long been recognized that pesticide spraying cause environment pollution, contaminate aquatic habitats and insect pests may develop resistance to pesticides. An accepted fact is that the development of host plant resistance and the supply of resistant varieties are crucial to the development of an Integrated Pest Management. An experiment was set up at KARI-Mwea field testing site to evaluate 23 rice cultivars for their resistance against the African white rice stem borer (*Maliarpha separatella*). The experimental design was a randomized complete block design with three replications. The collected data included plant height, days to maturity, number of white heads, tunnelled tillers, yield and yield components. Sampling was done weekly starting two weeks after transplanting. Results showed that short stature and short maturation periods had significant influence on *M. separatella* damage as shown by the number of white heads and tillered tunnels. Cultivar M27615 was 80 centimeters tall and had the lowest number of whiteheads. Cultivar M27608 was the earliest to mature at 78 days, had the highest number of tillers and out-yielded all the other cultivars. These results suggest that rice cultivars with short stature and shorter growth duration may suffer less damage from *M. separatella* infestation compared with tall, long growth duration cultivars. In addition short growth duration cultivars seem to compensate for stem borer damage through increased tillering. Such cultivars offer potential possibilities for resistance breeding. Thus cultivars M27615 and M27608 can be incorporated in breeding programmes for resistance against *M. separatella*.

7.1. Introduction

Concerns over environment and food safety in flooded rice ecosystems from conventional chemical pest controls has led to the development of Integrated Pest Management (IPM) to reduce dependence on chemical pesticides and make pest control more environmentally sustainable (Speight *et al.*,2008). An accepted paradigm is that the development of host plant resistance and the supply of resistant varieties are the central element and foundation of the integrated pest management (Abro *et al.* 2003). Stem borer resistance can be due to antibiosis (reduced longevity and reproduction, increased mortality of insect), antixenosis (reduced plant attractiveness), and tolerance (ability to withstand and recover from damage (Kogan and Ortman, 1978). Seed with improved host resistance is an easy fit in farming systems and the most cost effective approach in protecting crops against insect herbivory. Resistant varieties control even a low pest density, whereas insecticide use is justifiable only when the density reaches the economic injury level (Shafiq *et al.*, 2000).

Breeding for resistance to insects has two steps. The first one is to create novel genetic variation and the second one is to select the improved variants. This depends on the screening of rice germplasm to identify novel donors of resistance. The second step involves the use of these donors in sexual hybridization with commercial varieties to create novel combinations of genes (El - Malky *et al.*, 2008). One of the main objectives of any breeding program is to produce high yielding and better quality lines for release as cultivars to farmers. The prerequisite to achieve this goal is the presence of sufficient amount of variability; in which desired lines are to be selected for further manipulation to achieve the desired target, may it be yield or any other desirable trait like stem borer resistance (El - Malky *et al.*, 2008). The objective of this study was to evaluate rice cultivars for resistance against the African white rice stem borer (*Maliarpha separatella*).

7.2. Materials and methods

7.2.1. Study site and experimental field layout.

The experiment was set up at KARI-Mwea field testing site (Kirogo) (037.22760E, 0039.00E, altitude 1150 m A.S.L). The whole rice area which was 100x10m was divided into 3 main blocks. Each block comprised of 23 plots of 2.5 × 2.5 m with one meter paths between the blocks and 0.5m between the plots.

7.2.2. Experimental design and planting

The experimental design was randomized complete block design with 3 replications. Twenty three cultivars including two commercial checks were evaluated. Fourteen of these cultivars were obtained from the rice germplasm collection maintained at the National Gene Bank of Kenya, KARI-Muguga and seven from the rice breeding programme at KARI-Mwea. Two cultivars, Basmati 370 and BW 196 which are common cultivars in the area were purchased from Mwea Rice Growers Cooperative society and were included in the study as commercial checks. Cultivars BW 196 is reported to be resistant to *M. separatella* while Basmati 370 is highly susceptible (National Rice Technical Committee, 2011) All the cultivars were seeded in the nursery and later transplanted in the experimental plots after 30 days. Transplanting was done at the rate of one seedling per hill. A single rice seedling was transplanted at 20 cm spacing between the plants and inter-row spacing of 20cm.

The crop was raised following standard agronomic practices for paddy rice cultivation. Nitrogen (N_2) and Phosphorus (P_2O_5) fertilizer were applied at the recommended ratio of 150:80 kg/ha (N_2: P_2O_5). All Phosphorous and half of Nitrogen was applied at the time of transplanting and rest of Nitrogen applied at the panicle initiation stage. Cultural practices were performed uniformly and equally to all the plots. Two rows of the susceptible rice variety, Basmati 370 were planted as border rows round all the plots.

7.2.2. Sampling

Data collection on agronomic traits started three weeks after transplant date and thereafter weekly till harvesting. Data collected included the number of tillers and plant height taken from the soil surface to the tip of the tallest panicle, awns excluded. The cultivars were then classified into three categories based on the International Rice Research Institute (IRRI) Standard Evaluation system for Rice (SES, 2002). This was on a scale of 1-5, (Semi Dwarf < 110 cm (1), Intermediate, 110-130 cm (5) and Tall, >130 cm (9) (SES, 2002). Days to maturity were also recorded. Maturity days were counted from seeding to when 85% of grains on panicle were mature (SES, 2002). The number of white heads from 20 panicles randomly selected in each plot was also recorded using a scale of 0 (No damage), 1-5% (1), 6-10% (3), 11-15 % (5), 16-25 % (7) and ≥26% (9). At harvest, all the stems were dissected and the number with tunnels, number of larvae and pupae recorded. The number of productive panicles, filled grains, empty grains and 1000 grain weight from 20 randomly selected tillers was also recorded.

Data analysis

Analysis of variance (ANOVA) was conducted to determine the differences in height, number of tillers, pest infestation, yield and yield components across different cultivars. Correlation analysis was done to elucidate the influence of plant height and maturity periods on *M. separatella* infestation.

Least significant differences were used to the separate means when found significant ($p \leq 0.05$). The statistical analysis was performed using Genstat Version 12 statistical software.

7.3. Results

There were significant differences among cultivars in terms of plant height (d.f=68, p<0.01). Plant height data at harvest showed that 21out of 23 cultivars were short statured (semi dwarf) with plant heights ranging from 77 to 99 cm. Two cultivars were intermediate with a height of 124 cm (Table 7.1).

Table 7.1: Mean plant height (cm) at the harvest of different rice cultivars at KARI-Mwea in 2010.

Cultivar	Height (cm)	SES scale
PUSA BASMATI	124a	5
BASMATI 370	123.74a	5
M27638	98.98b	1
IR 2793-80-1	94.14bc	1
M27608	92.9bcde	1
ITA302	91.05bcde	1
M27628	89.45bcde	1
ITA 304	88.91bcde	1
M27626	88.8bcde	1
WAT 317-WAS-B-5-11-3-5	87.38bcde	1
M27610	87.35bcde	1
IR13240-105-105-2-2-3(SAHEL 108)(FKR)	86.28cde	1
M27612	85.87de	1
M27633	85.56de	1
M27634	85.56de	1
M27611	85.54de	1
ITA 310	82.71de	1
M27613	82.38de	1
M27627	80.73e	1
M27615	77.82e	1
M27623	77.56e	1
BW196	77.17e	5
M27607	76.91e	1
P	0.01	
LSD	17.48	

Means in a column followed by the same letter are not significantly different from each other by Fishers LSD (p<0.05).

Plant height scale 1, Semi-dwarf (< 110 cm), 5, Intermediate (110-130 cm), 9, Tall (> 130 cm) (SES, 2002).

The results of days to maturity showed that Cultivar M27608 was the earliest and matured in 78 days. Most of the cultivars took between 100 to 140 days. Cultivar BW 196 took the longest time to mature at 139 days (Table 7.2).

Table 7.2: Mean number of maturity days of different rice cultivars at KARI-Mwea in 2010

Cultivar	Mean number of days to maturity
IR 2793-80-1	141.67
BW196	137.82
PUSA BASMATI	122.14
BASMATI 370	121.71
M27623	118.67
M27613	110.33
ITA302	110.21
M27607	106.41
M27638	104.33
IR13240-105-105-2-2-3(SAHEL 108)(FKR)	102.33
M27633	98.67
M27628	96.24
M27626	95.67
ITA 304	95.33
M27611	95.11
M27610	93.67
M27627	92.21
M27615	91.33
ITA 310	90.10
WAT 317-WAS-B-5-11-3-5	89.00
M27612	88.12
M27634	85.67
M27608	78.32
P	0.06
S.E	9.61
CV (%)	16.8

The highest number of tillers was in cultivar M27615 (24.9) while IR 2793-80-1 had the lowest number of tillers (8.84). There were no significant differences in the number of tillers among the cultivars ($p>0.05$) (Table 7.3).

Table 7.3 Mean number of tillers in different rice cultivars at KARI-Mwea in 2010

Cultivar	Mean number of tillers
BW 196	13.60
BASMATI 370	19.6
IR 2793-80-1	7.9
IR13240-105-105-2-2-3(SAHEL 108)(FKR)	20.4
ITA 304	14.2
ITA 310	11.7
ITA302	18.2
M27607	16.9
M27608	20.4
M27610	18.8
M27611	19.9
M27612	11.8
M27613	15.2
M27615	24.9
M27623	15.6
M27626	18.2
M27628	17.8
M27633	17.8
M27634	14.2
M27638	19.0
PUSA BASMATI	13.9
WAT 317-WAS-B-5-11-3-5	20.2
p	0.12
S.E	3.32
CV (%)	33.38

Percent white heads, tunneled tillers and the number of larvae varied between the different cultivars. All cultivars except M27615 were susceptible to *M. separatella* infestation with Basmati 370 recording 23% white heads. Cultivar M 27608 was second with 22% white heads. The most resistant was Cultivar M27615 with 0% whiteheads. Cultivar BW 196, the second commercial check was second in resistance with 4% white heads and was rated 1 (SES-IRRI,2002). The number of tunneled tillers followed a similar trend with Basmati with 21.3% tunneled tillers.

The highest numbers of larvae per tiller (11.3) were recovered from IR2793-80-1. There were no significant differences in the percent white heads, percent tunneled tillers and the number of larvae (p>0.05) among the cultivars (Table 7.4).

Table 7.4: Mean percentage of white heads, tunneled tillers and the number of larvae in different cultivars at KARI-Mwea in 2010

Cultivar	Percent white heads	Percent tunneled tillers	Mean number of larvae	White heads scale
BASMATI 370	23	21.3	8.3	7
M27608	22	19.5	10	7
M27611	18	16.3	10	7
M27607	17.3	10	6.7	7
ITA 304	15.7	14	5	7
M27612	15.3	13	10.7	5
IR 2793-80-1	15	12.7	11.3	5
M27627	15	14.3	7.3	5
PUSABASMATI	14.7	14.3	6	5
M27610	14.67	12	9.7	5
M27634	13	12.6	6	5
M27633	12.7	11.3	5.7	5
M27638	12	9	5	5
IR13240-105-2-3(SAHEL 108)(FKR)	11.7	11	5	5
ITA 310	11.3	9.7	6.3	5
WAT 317-WAS-B-5- 11- 3-5	11.3	8.3	4.7	5
M27628	10.7	9.7	6.7	5
ITA302	9.3	7	4	3
M27613	9.3	9	4.7	5
M27626	9.3	8.3	5	5
M27623	7	7	2.7	3
BW 196	4	3	1	1
M27615	0	0	0	0
P	0.078	0.094	0.087	
S.E	4.39	4.33	2.88	

Whiteheads scale
0= No damage, 1= 1-5%, 3= 6 10%, 5= 11-15%, 7 =16-25%, 9= 26% and above (SES, 2002)

There was negative correlation between plant height, percent white heads and the tunneled tillers at 5 % significant level. There was no correlation between plant height and the number of larvae (Table 7.5).

Table 7.5: Pearson correlation between plant height and *M. separatella* damage parameters.

	Mean plant height	Mean number of Larvae	Percent tunnelled tillers	Percent white heads
Plant height	1			
Mean number of larvae	0.130ns	1		
Percent tunnelled tillers	-0.244*	0.630**	1	
Percent white heads	-0.23*	0.777**	0.914**	1

N= 69, *, **. Correlation is significant at 5 and 1% level respectively, ns not significant (2-tailed)

There was a positive correlation between the days to maturity; percent tunneled tillers and the percent white heads. However, there was no correlation between the days to maturity and the number of larvae (Table 7.6).

Table 7.6: Pearson correlation between plant height and *M. separatella* damage parameters.

	Mean number of days to maturity	Mean number of larvae	Percent tunnelled tillers	Percent white heads
Mean number of days to maturity	1			
Mean number of larvae	0.152ns	1		
Percent tunnelled tillers	0.184	0.630**	1	
Percent white heads	0.0172*	0.777**	0.914**	1

N= 69, significance level is indicated in brackets, *, **. Correlation is significant at 5 and 1% level respectively, ns not significant (2-tailed)

There was positive correlation at 5% level between the number of tillers per hill and the grain yield, but there was no correlation between the number of tillers per hill and the weight of 1000 grains (Table 7.7).

Table 7.7: Pearson correlation between number of tillers per hill, 1000 grains weight and yield.

	Mean number of tillers/hill	1000grain weight (g)	Yield (kg)
Mean number of tillers/hill	1		
1000 grain weight (g)	0.638ns	1	
Yield (kg)	0.329^{**}	0.080 ns	1

N= 69, **. Correlation is significant at 1% level, ns not significant (2-tailed)

There were significant differences in yield between the cultivars (d.f=68, F=<0.001). The highest yield was by cultivar M27608 (3724 kg/ha) followed by cultivar M27607 (3372kg/ha). Cultivar M27615 yielded 2367kg/ha. The commercial checks, BW 196 and Basmati 370 had yields of 3323 and 2540 kg/ha respectively. There were significant differences in grain yield among the cultivars ($p<0.05$) (Table 7.8).

Table 7.8: Grain yield of different rice cultivars at KARI-Mwea in 2010

Cultivar	Yield kgs/ha
M27608	3724a
M27607	3372ab
BW 196	3323abc
M27610	3129abc
M27623	3049abcd
ITA302	2815abcde
M27628	2725abcde
Bamati 370	2540abcde
M27626	2537abcdef
M27611	2431abcdef
M27615	2367abcdef
M27634	2338abcdef
WAT 317-WAS-B-5-11-3-5	2306abcdef
PUSA BASMATI	2164abcdef
IR13240-105-105-2-2-3(SAHEL 108)(FKR)	2127abcdefg
M27613	2104 abcdefg
M27627	2066 bcdefg
M27638	1768 bcdefg
M27612	1727 bcdefg
IR 2793-80-1	1705 bcdefg
ITA 310	1405 bcdefg
M27633	1320efg
ITA 304	992 efg
P	0.05
LSD	1656.9
CV (%)	44.3

Means in a column followed by the same letter are not significantly different from each other by Fishers LSD ($p<0.05$).

The heaviest grains were from cultivar M27623 with 1000 grain weight (26.2g) while cultivars M27627 and M27634 had the lowest 1000 grain weight (20.1g). The cultivar with the highest percent filled grains was M27608 (97.8%), which also had the highest percent productive panicles (95.2%). The lowest number of productive panicles was recorded in M27627 (64.5%). Results indicated significant differences in 1000 grain weight between the cultivars (d.f=68, $p<0.05$) (Table 7.9).

Table 7.9: One thousand grains weight, filled grain ratio and productive panicles of different rice varieties at KARI-Mwea in 2010

Variety	Percent filled grains	Percent productive panicles	1000 grain weight
M27623	90.93	84.1	26.2a
ITA302	91.96	90.0	25.4b
BW 196	90.74	84.5	25.2b
ITA 310	90.97	75.7	25.2b
M27626	95.91	65.2	24.9ab
M27615	75.6	75.7	24.1ab
M27613	92.54	83.0	24.1ab
M27612	93.22	87.5	24.1ab
M27607	96.46	86.7	24abc
M27611	89.63	89.4	23.9abc
IR 2793-80-1	86.65	88.8	23.8abc
M27610	89.85	84.9	23.6abcd
IR 13240-105-105-2-2-3 (SAHEL 108) (FKR)	82.62	90.9	23.6abcd
PUSA BASMATI	92.96	85.1	23.5abcde
M27633	91.98	87.0	23.1 bcde
M27638	94.08	83.1	22.8bcde
M27608	97.87	95.2	22.6bcdef
ITA 304	87.6	86.8	22.27cdef
WAT 317-WAS-B-5-11-3-5	91.51	76.9	21.1cdef
M27628	90.1	77.6	20.7ef
M27634	90.37	89.1	20.1f
M27627	90.93	64.5	20.1f
P	0.3	0.737	0.028
S.E	5.45	7.09	$LSD_{0.05}$=6.67
CV (%)	41.4	44.6	46

Means in a column followed by the same letter are not significantly different from each other by Fishers LSD ($p<0.05$)

7.4. Discussion

Statistical analysis revealed significant differences among the cultivars for plant height. There were also differences in the maturity periods. This is consistent with the findings of (El – Malky *et al*. (2008) who in a study of 46 rice lines from four populations reported that maximum range of variation was observed for the number of filled grains per panicle followed by white head, grain yield per plant, plant height and maturity days. The findings in this study of few white heads in M27615 which was 78 cm is in agreement with the results of Ntanos and Kourtoubas (2000) who in a study on resistance of 257 lines for the yellow stem borer, *Scirpophaga incertulas* (Walker) found that resistance was negatively correlated with plant height and that low infestations occurred on semi dwarf plants which were less than 100 cm.

The positive correlation between days to maturity with the percentage tunneled tillers and percentage white heads is similar to the findings of Ntanos and Kourtoubas (2000) who reported that stem borer resistance was correlated with the heading date and that low stem borer infestations occurred in the mid-season rice cultivars (80-85 days to heading). Dhuyo (2009) reported that the medium maturing coarse rice varieties were more susceptible than the early maturing coarse rice entries to *Scirpophaga incertulus* Walker and (El – Malky *et al*. (2008) found highly significant positive correlation between white head percentage and heading date. Possible reason for this is that when a crop is harvested before a generation is completed as happens in the early maturing cultivars; mortality in a stem borer population is heavy. The findings of the increased number of empty panicles and lower 1000grain weight in susceptible cultivars are in agreement with Sarawar (2011) findings who reported that stem tunneling by stem borers cuts the plants transport system resulting in death of panicles.

Grain yield potential is one of the most important breeding objectives in rice. The results of this study indicated that the resistant genotype M27615 compared favourably with other test cultivars thus indicating its potential in stem borer resistance breeding work. Cultivar M27608 had the highest yield of all the genotypes evaluated despite the high number of white heads and stem tunneling. This suggests that this genotype was able to compensate when attacked in early growth stages and this is in agreement with Asghar, *et al.* (2009) who reported the ability of some rice varieties to compensate for stem borer infestations. Litsinger *et al.* (2011) in an experiment investigating how cultural practices mitigate irrigated rice insect pest losses in the Philippines found that there was yield increase in tolerant cultivars despite the high stem borer pressure and that this was as a result of increased panicle density and filled grains per panicle, similar to M27608 in this study. El – Malky *et al*. (2008) suggested that selection of yield in genotypes would be most effective if accompanied by observation of the number of tillers per plant, number of grains per panicle, the weight of the grains and through cluster analysis, they confirmed the usefulness of these traits for selecting stem borer resistant lines. The results of this study indicate that the two cultivars M27615 and M27608 possess some traits that can be exploited in breeding for resistance against *M. separatella*. It can be concluded from this study that rice cultivars that were of short stature and had shorter growth duration suffered less damage from stem borer damage than tall, long growth duration cultivars and that the early cultivars compensated for stem borer damage. Such genotypes offer potential possibilities for breeding for *M. separatella* resistance.

7.5. References

Abro, G.H., Lakho, G.M. and Syed, T.S. 2003. Relative resistance of some rice cultivars to Yellow, *Scirpophaga incertulus* and pink *Sesamia inferens* stem borers. *Pakistan Journal of Zoology* 35(2): 85-90.

Asghar, M., Suhail, A., Afzal, M. and Khan, M.A. 2009. Determination of economics threshold levels for the stem borers (*Scirpophaga* sp.) and leaffolder (*Cnaphalocrosis medinalis*) of rice (*Oryza sativa*) in the kallar tract of Punjab, Pakistan. *International Journal of Agricultural Biology* 11: 717–720.

Dhuyo, A. R. 2009. The reaction of yellow rice stem borer, *Scirpophaga incertulas* (walker) to different rice varieties under field and green house conditions. In Integrated control of yellow rice stem borer *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae) PhD thesis University of Sindh, Jamshoro, Pakistan: 44-56

El - Malky, M.M., El-Habashy, M.M. and Abdelkhalik, A.F. 2008. Rice germplasm evaluation for agronomic traits and their influence on stem borer (*Chilo agamemnon* Bles.) resistance. *Journal of Agricultural Research* 46(3): 203-213.

GENSTAT, 2009 . Genstat statistical package for windows version 12.0.

Kogan, M. and Ortman, E.F. 1978. Antixenosis-a new term proposed to replace Painter's non-preference' morality of resistance. *Bulletin of the Entomological Society of America* 24: 175-176.

Litsinger J.A, Canapi B.L. and Bandong J.P. 2011. Crop compensation from rice insect pest Damage: Cultural practices mitigate irrigated rice insect pest losses in the Philippines. *Philippine Journal of Science* 140: 179-194.

Ntanos, D.A. and Koutroubas, S.D. 2000. Evaluation of rice for resistance to pink stem borer. *Field Crops Research* 66: 63-71.

National Rice Technical Committee, 2011. Currently cultivated varieties main characteristics. In Guidelines to rice production in Kenya (Eds Kouko, W., Wanjogu, R., Kimani, A., Mahungu, M. and Hikaru, N.): 16-17

Sarwar, M. 2011. Effects of Zinc fertilizer application on the incidence of rice stem borers (*Scirpophaga* species) (Lepidoptera: Pyralidae) in rice (*Oryza sativa* L.) crop. *Journal of Cereals and Oilseeds* (2,5): 61-65 http://www.academicjournals.org/jco. Accessed 26 April 2012

SES, Standard Evaluation System for Rice 2002, International Rice Research Institute 56pp

Shafiq, M., M. Ashraf, Bux, M. and Tofiq, M. 2000. Screening of rice genotypes for resistance to stem borers. *Pakistan Journal of Zoology* 32 (2): 135-137

Speight M.R., Hunter M.D., Watt A.D. 2008. Ecology of Insects: Concepts and Applications. Blackwell Science, London, 350pp.

CHAPTER 8

MANAGEMENT OF *MALIARPHA SEPARATELLA* RAG USING EFFECTIVE ENTOMOPATHOGENIC NEMATODES AND RESISTANT CULTIVARS

Abstract

Current pest control methods rely on single-technology pesticide dominated paradigm and there is need to adopt a more ecological approach based on renewable technologies such as host plant resistance and natural biological control which are available even to resource poor farmers. Resistant cultivars complement natural enemy action in lowering pest infestation while intrinsic rate of increase of pest species on resistant varieties is lower. A field experiment was set up at KARI-Mwea to test whether the African white rice stem borer (*Maliarpha separatella*) can be managed by use of resistant rice varieties in combination with entomopathogenic nematodes (EPNs). The study was arranged as a 4x4 factorial design and each treatment replicated three times. First factor was rice cultivars at four levels, resistant cultivar (M27615), second resistant cultivar (M27628), the highly susceptible but tolerant cultivar (M27608) and commercial check Basmati 370 variety, which were planted in 1x1m experimental plots. Second factor was application of EPN (*Hetrerorhabitidis indica)* as a suspension in distilled water to the cultivars at four different times after they were transplanted (no application, 3 weeks after transplant date (WAT), 5 WAT and 6 WAT. Results showed that *M. separatella* infestation was lowest on cultivar M27615 where *H. indica* was applied at 3 WAT, while cultivar M27608 had the highest yield despite the high number of white heads and stem tunneling indicative of high levels of *M. separatella* infestation. The findings showed that host-plant resistance and EPNs can be integrated to manage *M. separatella* infestation.

8.1. Introduction

Evolution of insect pests in response to mortality factors makes reliance on single control strategies unsustainable in the long term. Integrated pest management (IPM) entails use of combination of host plant resistance, cultural methods and biological agents. It advocates minimal use of insecticides especially with known action thresholds. Reports from (Litsinger *et al*. (2009) indicated that rice hoppers *Nilaparvata lugens* bred slowly on rice cultivars which were recognized as very resistant and there was no yield loss even with infestations of 30 hoppers per plant. Koppenhofer and Kaya (1998) described a strong synergistic effect on the mortality of two scarab species, *Cyclocephala hirta* LeConte and *C. pasadenae* with combinations of imidacloprid insecticide and entomopathogenic nematodes. It has been reported that inoculative release which involve releasing small numbers of natural enemies into a crop cycle in combination with resistant varieties is able to protect the crop from pest infestations (Litsinger *et al*., 2011). Gassmann *et al*. (2008) found that improved resistance management for *Bacillus thuringiensis* crops was achieved with IPM strategies that incorporated entomopathogenic nematodes in non-*Bt* refugia, while Cory & Hoover (2006) reported that host plants can influence susceptibility of insects to pathogens including entomopathogenic nematodes. Thus the use of resistant rice cultivars in combination with a biological control agent may be a useful tool for integrated pest management programs that reduces pesticide input. This study was conducted to evaluate a combination of resistant rice cultivars and entomopathogenic nematodes for efficacy against *M. separatella* in flooded rice cultivation.

8.2. Materials and Methods

8.2.1. Study site and experimental plots lay out.

The experiment was set up at KARI-Mwea field testing site (Kirogo) (037.22760E, 0039.00S, Altitude 1150 A.S.L). The study was arranged as a 4x4 factorial design and each treatment replicated three times. First factor was rice cultivars at four levels, resistant cultivar (M27615), second resistant cultivar (M27628), the highly susceptible but tolerant cultivar (M27608 (chapter 7 in thesis) and a commercial check Basmati 370 variety. The experimental field (30x30m) was divided into 72 plots of 1x1m with 0.5m between the plots. The cultivars were planted in the field in a randomized complete block design at a spacing of 20x20cm. Second factor was application of EPN (*Hetrerorhabitidis indica)* to the cultivars at four different times after they were transplanted (no application, 3 weeks, 5 and 6 weeks after transplant date (WAT).

8.2.2. Entomopathogenic nematodes application

Heterorhabitidis indica rate of application in infective juveniles (IJs) per square meter was calculated as:

$$N = h^* (p^*.t\_i) * k \qquad (8.1)$$

where N= Number of IJs required

h=number of hills per plot (25 at 20cmx20cm spacing) in 1M^2 plot

p= *H. indica* IJs concentration from probit curve in chapter 6

t_i= estimated number of *M. separatella* infested tillers (Mean number of tillers) in chapter 7

k= Number of experimental plots to be applied with nematodes

which gave; N=25(157*17) or 66725 IJs per square meter.

Heterorhabitidis indica nematode suspension from the laboratory was then diluted to 6.7 x10^4 IJs per liter of distilled and applied to the cultivars at 3, 5 and 6 WAT.

Before EPNs application soil samples from the experimental plots were baited with *Galleria mellonela* L to determine whether there were any EPNS in the plots before application of the treatments. Application was by spraying the mixture of *H. indica* suspension in cool sterile water with a 15 liter knapsack sprayer. Application was done at 5.30PM, just before sunset as EPNs are rapidly inactivated by ultraviolet light (Greenwood and Rebek, 2008). Control plots were sprayed with distilled water without EPNs. The study was carried out from 18 August 2010 to 21 December 2010.

8.2.3. Sampling and data collection

Data was collected on *M. separatella* infestation (number of egg batches, white heads, tunnelled tillers and larvae/pupae) *M. separatella* damage (numbers of non-productive panicles, empty panicles, unfilled grains and 1000 grains weight) and yield (grain weight, dry matter weight and harvest index). At harvest, all stems were dissected and number with tunnels, number of larvae and pupae recorded. The number of productive panicles, filled grains, empty grains and 1000 grain weight from 10 randomly selected tillers was also recorded. The infestation was expressed as number of egg batches, larvae, and% white heads calculated by the formula;

Percent whiteheads =

No. of tillers with whiteheads/ Total No. of tillers x 100 (8.2)

(Shafiq *et al.*, 2000).

8.2.4. Data analysis

Analysis of variance (ANOVA) was conducted to determine the differences in pest infestation, damage levels, yield components and yield between the different treatments. Least significant differences ($P \leq 0.05$) were used to the separate means when found significant. The statistical analysis was performed with Genstat Version 12 statistical software.

8.3. Results

The highest number of egg batches was on Basmati 370 while the lowest was on M27615 where no *H. indica* had been applied. Analysis of variance indicated that cultivar had significant influence on the number of egg batches (d.f 47, 3, p<0.001), while effect of the time of EPN application was not significant (d.f 47, 3, p= 0.547) and there was no interaction between cultivar and the time of EPN application (d.f 47, 9, p=0.064). Basmati 370 cultivar had significantly high number of egg batches than the other cultivars (p<0.05). (Table 8.1)

Table 8.1: The effect of cultivar and time of *H. indica* application on the number of egg batches at KARI-Mwea field station in 2010 short rains season.

Cultivar	Mean number of egg batches
Basmati 370	20.27a
M27608	17.07b
M27628	15.53b
M27615	15.40b
p	0.001
L.S.D	3.14
CV (%)	18.4

The percent white heads and tunneled tillers were low in all cultivars where *Heterorhabtidis indica* was applied at 3 WAT and the lowest number of whiteheads was on cultivar M27615.

The highest number of percent white heads and the percent tunneled tillers were in Basmati 370 where there was no application of *H. indica.* Analysis of variance showed that cultivar and time of *H. Indica* application did not have any significant influence on the percent white heads and percent tunneled tillers (p>0.05) (Table 8.2)

Table 8.2: The influence of cultivar and time of *H. indica* application on the percent white heads and percent tunneled tillers at KARI-Mwea field station in 2010 short rain season.

Cultivar	*H. indica* application date (WAT)	Percent white heads	Percent tunneled tillers
M27615	0	12.8	10.8
	3	9.3	8.3
	5	10.3	9.7
	6	10.3	9.7
M27628	0	14.8	12.9
	3	11	10.3
	5	12.3	11.3
	6	13.3	12.7
M27608	0	17.7	16.8
	3	12.5	11.5
	5	13	13
	6	17.7	15.7
BASMATI 370	0	19.2	16.7
	3	11.3	11.3
	5	12.3	12.3
	6	13	12.5
p		0.053	0.059
S.E		5.88	6.52
CV (%)		45.7	47.4

The heaviest grains were in cultivar M27608 (24.42g) where *H. indica* was applied at 3 WAT. It also had the highest percentage of empty grains (27%) in the absence of *H. indica* application. The lowest 1000 grains weight (19.44) was in Basmati 370 cultivar where *H. indica* was applied at 6 WAT. The results indicated that cultivar M27615 had 21.89 % empty grains in the treatment where there was no *H. indica* application.

This cultivar did not show any *M. separatella* damage as it has been reported in chapter 7 (Table 8.3).

Table 8.3: The effect of cultivar and application time of *H. indica* on the percent empty grains and 1000 grain weight at KARI Mwea field station in 2010 short rains season.

Cultivar	*H. indica* application date (WAT)	Mean percent empty grains	Mean 1000 grains weight(g)
M27615	0	21.89	20.48
	3	14.33	22.05
	5	15.67	21.88
	6	16.00	21.16
M27628	0	20.33	19.56
	3	15.33	21.85
	5	17.67	21.17
	6	19	20.56
M27608	0	25.33	20.58
	3	17.67	23.00
	5	19.33	21.57
	6	19.67	20.02
BASMATI 370	0	22.11	19.72
	3	18	21.63
	5	21.00	20.82
	6	24.33	19.44
p		0.098	0.052
S.E		7.47	1.88
CV (%)		37.2	29.87

Grain yield and dry weight of straw in the different cultivars were influenced by *H. indica* application at different periods. Harvest index was generally low in all the cultivars. However it was highest in cultivar M27615 where *H. indica* was applied at 3 WAT and was lowest in cultivar M27608 where there was no *H. indica* application (Table 8.4).

Table 8.4: The effect of cultivar and application time of *H. indica* on the weight of grain, straw and harvest index KARI Mwea field station in 2010 short rains season.

Cultivar	*H. indica* application date (WAT)	Mean grain yield (g/m^2)	Mean straw dry weight (kg/ m^2)	Harvest index (%)
M27615	0	107.67	9.33	12.15
	3	128.6	9.61	25.09
	5	124.6	9.10	19.40
	6	109.6	9.30	15.04
M27628	0	97.27	8.5	10.36
	3	217.8	10.1	14.31
	5	188.0	9.13	11.31
	6	175.9	8.9	11.14
M27608	0	85.6	8.7	13.93
	3	148.4	10.4	18.09
	5	136.33	9.73	15.73
	6	132.2	8.8	15.55
BASMATI 370	0	113.68	8.93	12.26
	3	153.3	11.4	18.08
	5	146.8	8.9	16.38
	6	130.3	9.4	14.05
p		0.07	0.096	0.089
S.E		3.10	1.13	6.86
CV (%)		46.8	42.1	49.28

8.4. Discussion

White heads and stem tunneling data indicated that there was consistently low *M. separatella* damage in plots where *Heterorhabtidis indica* was applied at three weeks after transplanting (WAT). High levels of damage occurred where treatment was applied at 5 and 6 WAT. These results suggest that late application of the entomopathogenic nematodes after 5 WAT may have been too late to reverse the damage already inflicted by *M. separatella*.

The subsequent reduction in grain yield and increase in dry straw weight is consistent with similar findings, where the pest infestations at the early stages of plant growth stage lead to production of many nodal tillers which may have few productive panicles (Nwilene *et al.,* 2011). It was found in this study that there were low levels of infestations on resistant cultivars and this contradicted the results in chapter 7 where there were no white heads in M27615. This finding is consistent with the reported lack of complete resistance and that only partial resistance to stem borers exist in most rice genotypes. (Shafiq *et al*., 2000). The cultivar M27615 in this study indicated partial resistance while M27608 indicated tolerance and this is supported by findings of (Litsinger *et al*., 2009) who reported that host plant resistance to stem borers in rice is highly variable.

The effectiveness of the combination of resistant cultivars and EPNs in the control of *M. separatella* is supported by the results of Thomas (1999) which showed that host plant resistance and natural enemies were able to reduce aphid populations and that the effectiveness of individual mechanisms in suppressing pest population growth rate depended on the pest life history. He also showed that biological control and host plant resistance can be compatible and can combine additively or synergistically to improve pest control. It has been argued that partial resistance, like host-plant tolerance, is potentially important for host plants for it allows retention of natural enemies. In contrast, a very high level of resistance could be detrimental because it could lead to extinction of natural enemies which is similar to the effects of insecticides leading to ecological imbalances which is contrary to the tenets of Integrated Pest Management (Sandler, 2010).

The results of low levels of infestation on resistant cultivars where *Heterorhabitidis indica* was applied is supported by the results of Gassman *et al.* (2008) which indicated that presence of entomopathogenic nematodes in refugia increased the fitness cost of *Bacillus thuringiensis* resistance, indicating that their presence may slow pest adaptation to *B. thuringiensis* crops. They suggested that the presence of Entomopathogenic nematodes in refugia may delay resistance by pests to *B. thuringiensis* crops.

Host plants can influence susceptibility of insects to pathogens (Cory and Hoover 2006) including entomopathogenic nematodes. As such, it would be important to know the fitness and fecundity of the adult moths of *M. separatella* emerging from cultivars where antibiosis and antixenosis is high. Information on fitness and fecundity of entomopathogenic nematodes infecting the larvae of *M. separatella* feeding on resistant rice varieties will also be important. These studies including the effects of these cultivars on *Trichogramma sp* which is an important *M. separatella* egg parasitoid would shed light on the compatibility of *H. indica* and resistant rice cultivars in the management of the pest. While this study has demonstrated that an integration of entomopathogenic nematodes and resistant or tolerant cultivars can reduce *M. separatella* infestation, it also suggests that their efficacy can be improved by modifying cultural practices to allow for their integration in flooded rice cultivation.

8.5. References

Cory, J.S. and Hoover, K. 2006. Plant-mediated effects in insect–pathogen interactions. *Trends in Ecology and Evolution* 21: 278–286.

Gassmann, A. J., Stock, S. P., Sisterson, M. S. Carrière, Y. and Tabashnik, B. E. 2008 Synergism between entomopathogenic nematodes and *Bacillus thuringiensis* crops: integrating biological control and resistance management *Journal of Applied Ecology* 45: 957–966.

GENSTAT, 2009 . Genstat statistical package for windows version 12.0.

Greenwood, C. M. and Rebek, E. J. 2008. Detection, conservation, and augmentation of naturally occurring beneficial nematodes for natural pest suppression. *Oklahoma Cooperative Extension Fact Sheets, Oklahoma Cooperative Extension Service EPP-7670* p6 http://osufacts.okstate.edu. Accessed on 5 July 2012

Koppenhofer, A. M., and Kaya, H. K. 1998. Synergism of imidacloprid and an entomopathogenic nematode: a novel approach to white grub (Coleoptera: Scarabaeidae) control in turfgrass. *Journal of Economic Entomology* 91: 618-623.

Litsinger, J.A, Canapi, B.L., Bandong, J.P., Lumaban, M.D., Raymundo, F.D. and Barrion, A. T. 2009. Insect pests of rainfed wetland rice in the Philippines: population densities, yield loss, and insecticide management. *International Journal of Pest Management*. 55 (3): 221-242.

Litsinger J.A, Canapi B.L. and Bandong J.P. 2011. Crop compensation from rice insect pest Damage: Cultural practices mitigate irrigated rice insect pest losses in the Philippines. *Philippine Journal of Science* 140: 179-194.

Litsinger J.A, Canapi B.L. and Bandong J.P. 2011. Crop compensation from rice insect pest Damage: Cultural practices mitigate irrigated rice insect pest losses in the Philippines. *Philippine Journal of Science* 140: 179-194.

Nwilene, F.E., Onasanya, A., Togola, A., Oyetunji, O., Semon, M., Tamo, M., Bright, E.O and Ofondile, S. 2011. Effect of intercropping maize and cassava with upland NERICA rice varieties on stem borer attack in South West Nigeria. *Journal of Entomology* 8(5): 417-428.

Sandler, H.A. 2010. "Integrated Pest Management". Cranberry Station Best Management Practices (1): 12–15.

Shafiq, M., M. Ashraf, Bux, M. and Tofiq, M. 2000. Screening of rice genotypes for resistance to stem borers. *Pakistan Journal of Zoology* 32 (2): 135-137

Thomas, M. B. 1999. Population Dynamics of Plant Resistance–Biocontrol Interactions. Ecological approaches and the development of "truly integrated" pest management. Proceedings of the National Academy of Siences of the United States of America (96) 11: 5944–5951

CHAPTER 9

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

9.1. General discussion

Rice cultivation at Mwea irrigation scheme is carried out on small holding ranging from 0.25 to 1.6 hectares of land (Mwangi, 2011). *Maliarpha separatella* Rag infestation is one of the major factors that limit production. Farmer knowledge of *M. separatella* and its management was found to be inadequate and there was a tendency to routinely spray pesticides. Farmers also used the least expensive and most toxic compounds to spray against the pest, in disregard to their health and the effect on natural enemies. The decision to spray was guided by the belief that huge losses would occur from stem borer infestation in the absence of control. This finding was consistent with the findings of Heong and Escalada (1999) who reported that farmers in Phillipines spent heavily on pesticides in the belief that lack of controlling pests would result in total loss of the rice crop and that perceived benefits from insecticides were directly related to insecticide use.

It has been reported that crop intensification increases stem borer infestations. Intensification involves planting large areas with varieties that have similar genetic backgrounds, increased plant densities and intensive use of pesticides and fertilizers (Heinrichs and Barrion, 2004). Likewise the results from this study indicated that *M. separatella* density was influenced by water provision and planting regimes which favoured crop intensification and asynchrony in rice fields and suggests a study on rice-based inter/relay cropping systems, which may ensure reduced *M.separatella* infestations.

The high rice yield losses in this study even at low infestations is consistent with reports of Umeh *et al* (2000), who indicated that the economic threshold for 2 ton ha^{-1} rice yield should be 8.6 egg masses per 100 tillers which was equivalent to an infestation of 59% at the end of the critical infestation period. The findings in this study of economic injury level of 6 egg batches and 8 egg batches per square meter of rice plants for the early infestation (3WAT) and the late infestation (6WAT) respectively are lower than the thresholds of Ritchie and Hunt (2009) of 2 egg masses per 20 hills for *Scircopophaga incertulas* in irrigated rice fields, a pest that causes damage similar to damage from *M. separatella* infestations. Possible reasons for this might have been the absence of natural enemies as the study was in an insect proof screen house and about three kilometers from the nearest rice fields and it was likely that natural enemies of *M. separatella* were absent.

The high mortality caused by *H. indica* which was the species with the highest reproductive rate in *M. separatella* host cadavers is consistent with the findings of Shapiro-Ilan and Gaugler (2010) that showed quantitive variation in reproduction by different EPN species. Efficiency of *H. indica* is also demonstrated by the findings of Nderitu *et al*., (2009) of significant efficacy of this EPN species against *Cylas puncticollis* in sweet potato fields at Kibwezi in Kenya. Similarly the concentration of 200 IJs/ml are consistent with the findings of Mahar *et al*. (2006) whose study to control nymphs of desert locust *Schistocerca gregaria* found that *H. indica* was most effective at a concentration of 200 IJs per ml.

The finding in this study of low *M. separatella* infestation on M27615 which was short in stature and had short maturity period is in agreement with the work of Ntanos and Koutroubas (2000) who reported that varieties of short stature suffer less stem borer damage. The high yields from M27608 despite heavy *M. separatella* could be explained by its short maturity period and compensatory tillering. These findings are similar to a report by (Ntanos and Koutroubas, 2000) that rice cultivars with short maturation periods escape stem borer attack and those with high tillering ability compensate for stem borer damage. The high infestation levels in Basmati 370 is also supported by the findings of Dhuyo and Soomro (2007) who reported that varieties that are aromatic and have long maturation periods are more susceptible to stem borers.

The results from this study of two-way combination of moderately resistant cultivar M27615 and tolerant cultivar M27608 with *H. indica* application at 3 WAT ability to reduce *M. separatella* damage is consistent with the findings of Gassman *et al*. (2008) that entomopathogenic nematode increased the fitness cost of *Bacillus thuringiensis* (*Bt*) resistance and their presence in refugia slowed pest adaptation to *Bt* crops. It has been suggested that EPNs are more effective when they are incorporated as a component of an on-farm Integrated Pest Management (IPM) system (KARI, 2006). Besides the joint regulatory and pest controlling roles of host-plant resistance and biological control in rice, there is the longer-term significance of their interaction in delaying or preventing the development of pest populations capable of overcoming the previously resistant host-plants.

9.2. Conclusions

1. The results of this study demonstrated that there were gaps in farmer knowledge of *Maliarpha separatella* at Mwea irrigation and that the most important source of information was from other farmers. The spraying of pesticides was routine rather than on a need basis and farmers tended to use pesticides more for risk aversion than for profit.
2. The pest's spatial and temporal fluctuations were influenced by irrigation water provision and planting regime, which resulted in asynchrony in rice cropping leading to the presence of the pests broods in different cohorts throughout the year. The highest concentration of the pest was in areas where there was sporadic water provision and where a second crop of rice was planted within the year.
3. *Maliarpha separatella* caused significant yield loss even at low infestation level (one egg batch). The intensity of infestation was found to be influenced by the time of infestation, with infestations at the early infestation period of 3 WAT being more severe than the 6 WAT. The Economic Injury Levels (EIL) was 6 egg batches per square meter of rice crop for the 3 WAT infestation period and 8 egg masses for 6 WAT.
4. *Heterorhabtidis indica* had significant efficacy of *M. separatella* under laboratory and field conditions.
5. Cultivar M27615 had low *M. separatella* infestation while cultivar M27608 compensated for heavy *M. separatella* infestation by tillering.
6. A combination of *H. indica* and M27615 had significant efficacy against *M. separatella* under field conditions.

9.3. Recommendations

1. Information on *M. separatella* management at Mwea irrigation should be disseminated. The method of dissemination should exploit the sharing of information among farmers that exist the scheme.
2. Double cropping of rice in the same area should be discouraged and farmers should be encouraged to synchronize rice cultural practices within the scheme. The developed rice cropping and management calendar should be adhered to.
3. A suitable non rice dry-land crop that can compete effectively in terms of monetary value should be sought and the crop used in rotations with rice.
4. Farmers should be trained on *M. separatella* scouting and pest monitoring using the developed economic thresholds. This would guide the farmers on whether and when to spray against the pest.
5. Use of a combination of resistant or tolerant rice cultivars and entomopathogenic nematodes to manage *M. separatella* should be explored further and the two rice cultivars, M27615 and M27608 be used to improve resistance in Basmati 370 through conventional breeding or use of biotechnology techniques

9. 4. References

Dhuyo, A. R and Soomro, N. 2007. The response of different rice varieties to infestation of yellow rice stem borer, *Scirpophaga incertulas* (Walk.) under field and green house conditions. *Pakistan Entomology* (29):27-32

Gassmann, A. J., Stock, S. P., Sisterson, M. S. Carrière, Y. and Tabashnik, B. E. 2008 Synergism between entomopathogenic nematodes and *Bacillus thuringiensis* crops: integrating biological control and resistance management *Journal of Applied Ecology* 45: 957–966.

Heinrichs E.A. and Barrion, A.T, 2004. Rice-Feeding Insects and selected natural enemies in West Africa . Biology, ecology, identification Eds G.P. Hetel 247pp.

Heong, K.L.M and Escalada, M. 1999. Quantifying rice farmers' pest management decisions: Beliefs and subjective norms in stem borer control, *Crop Protection* 18: 315-322

KARI, 2006. Field evaluation of entomopathogenic nematodes for efficacy against cotton pests. Kenya Agricultural Research Institute 2006 Annual Report: 85-86.

Mahar, A. N., Jan, N. D., Gowen, S. R., Hague, N. G. M., Al-Siyabi, A. A. , Mahar, A. Q. 2006. A comparative study on the effectiveness of laboratory bioassays of entomopathogenic nematodes against desert locust nymphs Schistocerca gregaria (Acrididae:Orthoptera). *Pakistan Journal of Nematology,* 24: 151-161

Mwangi, O. 2011. Rice production at Mwea irrigation scheme in Kenya. District Agricultural Officer, Kirinyaga South District internal report 8p

Nderitu, J. Sila, M. Nyamasyo, G. and Kasina, M. 2009. Effectiveness of Entomopathogenic Nematodes against Sweet Potato Weevil (*Cylas puncticollis* Boheman (Coleoptera: Apionidae)] Under Semi-Field Conditions in Kenya. *Journal of Entomology*, 6: 145-154.

Ntanos, D.A. and Koutroubas, S.D. 2000. Evaluation of rice for resistance to pink stem borer. *Field Crops Research* 66: 63-71.

Ritchie , B.J and Hunt, B. 2009. Yellow stem borer (YSB) , *Scirpophaga incertulas*, Dark headed stem borer (DHSB), *Chilo polychrysus*& pink stem borer(PSB) *Sesamia inferens* CABI/IKSL/HAFRICE/AUG09/1 CABI,UK Europe centre p5

Shapiro-Ilan, D.I., and Gaugler, R. 2010. Nematodes: Rhabditida: Steinernematidae & Heterorhabditidae. In: *Biological Control: A Guide to Natural Enemies in North America*. Edited by A. Shelton, Cornell University. http://www.biocontrol.entomology.cornell.edu/pathogens/nematodes.html. Accessed 26 July 2012

Umeh, E .D. N., Joshi, R. C and Ukwungwu, M. N. 2000. Biology, status and management of rice insect pests in Nigeria. *Crop Protection* 11(5): 408-413.

APPENDIX

Questionnaire used for assessment of farmer knowledge and management of *Maliarpha separatella* at Mwea irrigation scheme.

No___	Start time___ End time___

Background information

1. District________Division________Location________Sub-Location________ Village________
2. Longitude________Latitude________ Altitude____________
3. Name of respondent________________________ Age in years________.
4. List number of all house hold members resident and involved in rice farming.
5. House hold members by
6. Name
7. Male/Female
8. Age in years
9. Relationship to the House hold head
10. Involved in rice farming 2=not involved in rice farming
11. Number of years in school
12. Years experience in rice farming
13. Major occupation of the head of household in addition to rice farming 1=No other occupation 2=Salaried employment 3= Farming horticultural crops 4= Farming field crops 5=Boda Boda taxi 6= Ox driven rotavation 7=Casual labourer 8=Rice trader.

Rice production

14. Who makes decisions and implements them during rice cultivation in the following areas?

15. Where to plant, Variety to grow, Where to source seeds, Whether to spray insecticide, When to spray insecticides, When to weed, Whether to apply fertilizer, Where to source fertilizer, When to apply fertilizer, Whether to source for credit, When to source for credit, Where to source for credit, How to pay back, When to pay back, When to harvest, Whether to sell, When to sell.

16. i.Decision__________17.ii. Decision maker____________ 17.iii. Decision Implementer__________________

17. Do you have any rice crop in the field currently 1=Yes 2=No

18. i).Parcel no. 17.ii). Área (acres)

19. Land tenure 1=With Title deed 2==Inherited 3=Leased 4= Jua kali

20. Name of variety currently in the field

21. Variety attributes

22. Planting material used at planting 1=seed 2= seedlings 3=Both

23. Source of the planting material neighbours 3=NIB 4=Agro dealers 5=MRGMS

24. Current stage of development

25. Are there any rice varieties that you used to grow and you no longer grow them 1=Yes 2=No

26. If yes what is the main reason (one per variety) for the abandonment

27. Is there a time that you leave the rice parcel fallow 1=Yes 2=No

28. If no go to question 32

29. If yes why do you leave it fallow 1=To regain fertility 2=For pest control 3= For disease control 4= Aeration 5=To avoid bogging 6=To increase production 7=lack of irrigation water 8=To dry

30. How long is the fallow period 1=1 season 2= 2 seasons 3= Other (specify)

31. After the fallow period, do you continue with rice?1=Yes 2=No

32. If no which other crops do you grow on this plot
33. Do you hire labour for rice farming 1=Yes 2=No
34. If Yes at what stage 1=Nursery establishment 2=Transplanting 3= weeding 4=Spraying 5=Harvesting 6=Land preparation 7=Ratooning 8=Threshing 9=Leveling 10=Loading and unloading
35. At what stage do you require the highest number of hired farm labourers1=Nursery establishment 2=Transplanting 3= weeding 4=Spraying 5=Harvesting 6=Land preparation 7=Ratooning 8=Threshing 9=Leveling 10=Loading and unloading
36. Do you spray the rice crop with insecticides 1=Yes 2=No
37. b) If Yes, against which pests
38. If yes list the pesticides (the ones used in the last season only)
39. Do you use fertilizers 1=Yes 2=No
40. If yes list them (For last season only)

Investment and financing

41. What is the source of capital for rice farming activities 1=Remittances from relatives 2=Own Savings from other sources 3=Rice sales from last season 5=loans 6=Casual wages
42. Have you ever obtained credit for rice farming 1=Yes 2=No (If no go to 46)
43. If Yes what are the main sources of credit 1=Banks 2=Cooperatives 3=Self help groups 4=Micro finance institution 5=Mwea Rice Growers Multipurpose Society 6=Friends
44. Type of loan 1=Cash 2=Farm inputs (specify) 3=other (specify
45. If farm inputs what are they 1=Tractor hire 2=Seed 3=Fertilizers 4=Pesticides 5=other (specify)

46. If no what is the main reason for not seeking credit 1=Insufficient information 2=High interest rates 3=lack of collaterals 4=Application process complicated 5=No need for credit 6=lack of credit institutions 7=Fear of foreclosure 8=Rice farming is on a small scale

47. What type of investments do you make with the money from rice sales 1= Lease more land to grow more rice 2=Buy livestock3=Build rental houses 4= lease more land to Grow horticultural crops 5= Buy plot 6=Build residential house 7= Mill and sell rice 8=Buy motor cycle (Boda boda) taxi

48. If you do not investment what else do you do with money from rice sales?1=Pay school fees 2=Buy consumer goods(Radio, Bicycle) 3=General household use 4=Buy clothes

Sources of information for rice farming

49. List the main sources of information on rice farming 1=Radio 2=Personal contacts with other rice farmers 3=Extension officers from Ministry of agriculture 4=NIB 5=KARI 6=Magazines 7=Agro inputs suppliers 8=MRGMS 9=Field day 10=Newspapers

50. Which of these sources is the most important?

51. What type of information is available from the source you have given in 52 1=Agronomic 2=Pest control 3=Crop and livestock production 4=Rice farming in general 6=Farm planning and investments 7=Growing of horticultural crops

52. If information was on pest control. List the target pests 1= African white rice stem borer 2= Rats 3=Birds 5=Earth worms

53. Is the information sufficient 1=Yes 2=No

54. If no what additional information do you require 1=Rice farming in general 2=Synchronized planting 3=Pests and disease control 4=Rice agronomy

55. Have you ever participated in any agricultural training in the last 1 year?

56. 1=Yes 2=No

57. If yes, was the training on 1= African white rice stem borer 2=Efficient land use 4=General rice growing 5=Maize growing 6=Upland rice growing 7=Agricultural practices and pest control

58. Was the training adequate? 1=Yes 2=NO

59. If not what additional training do you require1=Pests and diseases of rice 2=Rice husbandry

Farmer knowledge on pests and diseases

60. What are the major constraints to rice production (tick one) 1=Marketing 2= Weeds 3= Irrigation water 4=Pests 6= Diseases 7=Operating capital 8=Salinity 9=Paddy rice theft

61. Which are the most important pests 1=Arthropod pests 2=slugs 3= Other(specify)

62. Are you able to differentiate the different arthropod pests (show photographs or specimens of different arthropod pests) 1=Yes 2=No

63. If Yes. Rank the listed pests in order of cost of managing them

64. How did you get the knowledge to be able to differentiate them 1=National Irrigation Board 2=Ministry of Agriculture =Kenya Agricultural Research Insitute 4=Mwea Rice Growers Multipurpose Society 5=Other farmers

65. Are you able to distinguish the damage symptoms caused by African white rice stem borer 1=Yes 2=No (Show samples of white heads, tunneled stems and windowed leaves)

66. If Yes. What is the local name of these symptoms 1=White heads 2=Dead hearts 3=Stunted growth 4=No tillering 5=Caterpillar attack6=Holed leaves

67. Are you able to distinguish the African white rice stem borer (WRSB) (Show specimens of larvae and adults of stem borers) 1=Yes 2=No

68. What is its local name 1=Caterpillar 2=Other

69. When was it first reported in Mwea 1=Long time ago 2=Since NIB times 3=Recently 4=Do not know

70. How did you come to learn of it? 1=from other farmers 2=NIB 3=From Field observations

71. Are there any myths associated with it? 1=Yes 2=No

72. If yes what are the myths.

73. Can you distinguish the various developmental stages of African white rice stem borer 1=Yes 2=No (Show specimens of larvae, pupae and adults mixed with other arthropod pests and let them pick the different stages)

74. How does it develop all the year round? 1=Egg-larvae-pupa-Moth 2=Moth-larva 3=larva-pupa 4=Do not know.

75. Are there particular stages of the rice crop when the African white rice stem borer is most important 1=Nursery 2=Tiller 3=Heading 4=Panicle formation 5=Maturity 6= Harvest 7= throughout the rice crop cycle.

Farmer management practices of stem borer

76. Do you control African white rice stem borer 1=Yes 2=No

77. If Yes what do you use 1=pesticides 2=other (specify)

78. If by pesticides when do you spray 1=As often as there are symptoms 2=Three weeks after transplanting 3=Do not spray

79. How many times?.1=1 2=2 3=3 4=5 5=No spray

80. If by pesticides how much does it cost in shillings per season to control the African white rice stem borer 1=100-400 2=401-700 3=701-1000 4= 1001-1300 5=1301-1600 6=1601-1900 7=1901-2200 8=.>2201 9=Do not know
81. Are you aware of any indigenous methods of controlling the African white rice stem borer 1=Yes, 2= No
82. If yes what are they?
83. Are you aware of any organisms that eat African white rice stem borers 1=Yes 2=No
84. If yes. What are their names? 1=Birds 2=Others
85. Are these organisms plenty 1=Yes 2=No
86. Do you think they can be increased? 1=Yes 2=No
87. If Yes how?

Conclusion

At the end of the interview thank the respondent and explain that this is for university degree in the University of Nairobi but the information may be used by Ministry of Agriculture, Kenya Agricultural Research Institute or the University of Nairobi to improve rice production at Mwea and other irrigation schemes in the country.