EFFECT OF FERTILIZER AND PESTICIDE ON THE BIOCONTROL OF CEREAL STEMBORER'S AND THE AWARENESS OF THE INTRODUCED PARASITOID IN ZANZIBAR

BY

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DECLARATION

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

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DEDICATION

To my family

This thesis is dedicated to member of my family: Wife Halima, Mum Farisha, Dad Ibrahim, My daughters, Aisha, Ilham, Zainab and Faika, Bothers, Mohd, Amin, Thabit and Ramadhani, my Sisters Amina, Zainab and Khadija, my cousins, Grand farther, and my friend Ali Maulid.

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ABSTRACT

The exotic stemborer, *Chilo partellus* (Swinhoe) causes the highest economic loss to maize and sorghum yield in the Islands of Zanzibar. A number of studies on its biology, ecology and management in Zanzibar have been conducted since early 1901 (Zanzibar Archive un-published report).However, so much still remains unknown about these pests. As a part of integrated pest management (IPM) strategy for controlling *Ch. Partellus* in Zanzibar, an exotic Braconidae larval parasitoid, *Cotesia flavipes* was introduced in 1999 as a classical biological control agent to supplement the indigenous *Cotesia sesamiae* population after being proved to be successful in Kenya. It was mass released in the coral rag as well as in non-coral areas where maize is grown for both commercial and subsistence. Assessment of the establishment of *Cotesia flavipes* surveys were conducted during 2004/05. The land quality for agricultural production is better in the Central District than the South and Northeastern zones. The results showed that stemborer density was significantly higher in the North at 2.4 stemborers/plant and lower in the Central District at 1.9/plant, and *Chilo partellus* was the dominant species. The percentage of bored internodes and tunnel length were higher in the North than in other zones during short and long rainy season. Maize cob and grain yield were higher in short than long rainy season, while cob weight was highest in the North during short rainy season, and it was highest in Central District during long rainy season. Similar results were found for the grain weight. *Co. flavipes* was recovered in all Districts; the highest parasitism level was recorded in the North District on *Chilo partellus.* Cob and grain weight observed were higher in plantation zone during short rainy season followed by coral rag and semi coral zones (Table 3.5). There was no significant difference of cob weight during long rainy season between coral, semi-coral and plantation zones, respectively. The survey finding showed the parasitism of larval parasitoids of cereal stemborers by *Cotesia sp* has increased from 4% in 2001 to 8.74% by 2005. The effect of nitrogen equivalent to 0, 60, 120, and 250kg/ha and insecticide treatments (Furadan) on population densities and parasitism of lepidopteran stemborers, and maize yields were studied in Zanzibar in 2004/05. Furadan application significantly decreased percent bored internodes and tunnel length during the long rains in both the low and high nitrogen treatments, but the effect was not significant during short rains. Results showed that stemborer density per plant increased with nitrogen application level. The survey results showed that *Ch. partellus* dominated by 3-fold than *Sesamia calamistis* and 42 fold with *Chilo orichalcociliellus.* Parasitism by *Co. flavipes* increased with an increase in nitrogen level. Percentage of bored internodes per plant caused by stemborer decreased with N levels during short rainy season. Maize yield increased 2 to 8 times from 120kg/ha. However, protected plots did not have yield increase compared with non-protected plots. The results obtained from interviewing farmers revealed that farmers were not aware of the release of biocontrol parasitoids of cereal stemborers. Therefore, more social education is required to improve awareness. About 40% farmers had a fair knowledge of biological control, 24% had good knowledge, and about 36% had no knowledge about this new biocontrol program.

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LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
ANOVA	Analysis of Variance
DAP	Days After Planting
FAO	Food and Agriculture Organization
GPS	Geographical Positioning System
GLM	General Linear Model
ICIPE	International Centre of Insect Physiology and Ecology
IIBC	International Institute of Biological Control
LR	Long Rains
N	Nitrogen
SR	Short Rains
SNK	Student-Newman-Kuels test

CHAPTER ONE

GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 General introduction

Maize, *Zea mays* L, and Sorghum, *Sorghum bicolor* (L) Moench are the most important cereal crops grown in Zanzibar (Unguja island) especially in the Northern and Southern Districts where the soil is of Coral rag (Borsa, 1987; Koenders, 1992) (Fig. 2.1, Plate 3.3). The two crops are grown during the long (Mid March to end June) and short (Mid August to mid November) rainy season (*Vuli*) for food and seed in order to ensure that, farmers have enough seed to plant during the long rainy season (*Masika*). In Zanzibar, maize yields are generally low, varying between 300 and 500kg/ha (van Keulen, 1990; Abdullah and Lada, 1996). One of the major constraints limiting yields is damage due to insect pests, with the stemborers being the most important (Briant, 1961; Allertz *et al.*, 1988; van Keulen, 1990; Bezemer, 1994). Four stem borer species belonging to the families of Noctuidae and Crambidae have been reported in Unguja and Pemba (Feijen *et al.*, 1988). The most important stem borer species is *Chilo partellus* (Swinhoe Crambidae) (van Keulen, 1990; Overholt *et al.,* 1994b). The others include *Sesamia calamistis* (Hampson Noctuidae), *Chilo orichalcoceliellus* (Strand Crambidae) and *Busseola fusca* (Fuller Noctuidae). However, Arendse (1990) reported that *B. fusca* was not a serious pest of cereal crops in Zanzibar. Grain yield losses due to stemborer attack range from 30-40% (van Keulen, 1990; Eveleens, 1990) with infestation levels of up to 70% (Briant, 1961). Arendse (1990) reported that 91% of the farmers in Unguja Island Zanzibar, considered stem borers as the most serious constraint to maize and sorghum production. In Pemba Island, Bezemer (1994) reported a stem borer infestation of 25-

51.9% in maize and 40-73.7% in sorghum during the long rains of 1994. Information on the stem borer abundance, and impact assessment of the indigenous parasitoid *Cotesia sesamiae*, and introduced species *Co. flavipes*, which was imported from India and released in Zanzibar in the year 1999 (Niyibigira *et al.*, 2000a) are lacking. Such information is important for the development of an Integrated Pest Management strategy for stem borer in smallholder cropping systems involving habitat management, use of resistant maize and sorghum varieties available in the locality and biological control methods.

1.2 Statement of the problem

Farming is a very demanding activity in any location and particularly for small holders. Key input such as chemicals, seeds, machinery, and manpower are often beyond their reach. The costs of these inputs tend to increase every year and have constrained farmer's income. The major problem is aggravated by increased infestation by cereal stemborers in all cultivated areas in Zanzibar, and many small-scale farmers were discouraged to continue with cereal crop production because of severe infestation to their crops. The fertility level in most part of Zanzibar decreases every year due to continuous cultivation of the same crops such as maize and cassava in the same peace of land which results to low soil fertility due to soil erosion.

1.3 Justification

In Zanzibar, control of stemborers is mainly dependent on the use of synthetic insecticides such as, endosulfan (Arendse, 1990), which was shown to be cost effective (van Keulen, 1990). However, subsidies by the government on pesticides have recently been removed, which has greatly increased the cost of maize production. It is unlikely that pesticides can be economically justified considering the low monetary value of cereals, particularly when grown on small scale (Abdullah and Lada, 1996). Furthermore, farmers do not follow the instructions of pesticides applications (Allertz *et al.,* 1988). Stemborers are also protected from pesticides due to their cryptic feeding behaviour in stem tunnels and this makes chemical control an unrealistic option (Niyibigira *et al.*, 2000 b). Therefore, it is important to assess the performance of exotic and native parasitoids and to determine the rate of establishment of the released *Co. flavipes* in relation to nitrogen fertilizer and pesticide (furadan) application. The study will help to determine the effect of different levels of nitrogen fertilizer and pesticide application on establishment of larval parasitoid *Cotesia flavipes* in Zanzibar. The exotic stemborer *Chilo partellus* is the most widely distributed and dominant stemborer in both Islands. The co-evolved larval parasitoid, *Cotesia flavipes* Cameron was released to help regulate the stemborer density and improve yield of maize to small-scale farmers in Zanzibar.

1.4 Null hypotheses

i. There are no differences in the level of establishment of *Co. flavipes* between the release areas and the rest of the Island.

ii. The level of parasitism of *Co. flavipes* on maize stemborers is the same during the short and long rainy seasons.

iii. The level of parasitism is not affected by application of nitrogen fertilizer.

iv. The level of parasitism is not affected by furadan pesticide application.

1.5 Objectives

1.5.1 Overall objective

To assess the establishment and efficacy of *Co. flavipes* released against cereal stem borers in relation to nitrogen fertilizer and pesticide application in Zanzibar.

1.5.2 Specific objectives

i. To determine the rate of parasitism of *Co. flavipes* released in different sites in Zanzibar.

ii. To assess the distribution of *Co. flavipes* and native parasitoids within the main ereal growing areas.

iii. To investigate the effect of nitrogen fertilizer and furadan pesticides application on the level of parasitism.

iv. To assess farmer knowledge on the biocontrol of cereal stemborers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Biology of Lepidopteran stemborers

The female moths mate soon after emergence from pupa stage and oviposit eggs on the leaf blades in case of *Chilo partellus, Chilo orichalcociliellus* and *Eldana saccharrina*, sheaths in case of *Busseola fusca* and *Sesamia calamistis,* or even next to the midribs of cereal crops. A female moth lay between 100 to 400 eggs or more in the batches of 20 to 50. Eggs hatch within 4-7 days and the newly emerged neonates enter the leaf whorls, bore through the whorl base, and enter the stems where they feed for a period ranging from two months chewing and exit hole just before pupate but in general there are six larval instars (Kuniata, 1994; Overholt *et al*., 2001). In cold or dry conditions, larvae may enter a resting stage (Diapause) in stems, stubble and other crops residues (Ofomata *et al.,* 1999b). Pupation last between 10-20 days, before the adults emerge. It is the stemborers larvae that cause damage to cereal crop plants (Overholt *et al*., 2001).

2.2 Biology of *Cotesia flavipes* and *Cotesia sesamiae.*

C. flavipes and *C. sesamiae* are gregarious endoparasitoids of the larvae of lepidopteran stemborers that attack maize and sorghum. Both parasitoids are ecologically similar, attacking medium and large-sized stemborer larvae (Smith *et al.,* 1993; Ngi-Song *et al.,* 1995). Both parasitoids have similar biology and life cycle. The two parasitoids can complete development in the exotic stemborer *Chilo partellus* (Swinhoe) (Crambidae) and two indigenous stemborers *Chilo orichalcociliellus* (Strand) (Crambidae) and *Sesamiae calamistis* Hampson (Noctuidae) (Ngi-Song *et al.,* 1995). *C. flavipes* is proovigenic and has about 150 eggs available for oviposition with each female laying a brood of 20–25% of the available egg load in the host larvae (Potting *et al.,* 1997a). *C. flavipes* has been found to experience a high level of sib mating directly after emergence from the stemborer tunnel (Arakaki and Gahana, 1986). The emergence of *C. flavipes* is usually concentrated in the morning and light stimulus plays an important role in promoting the adult emergence. Males generally emerge first and mate with their sisters soon after emergence from cocoons (Niyibigira, unpublished data). Males mate with many females and one male *C. flavipes* is capable of inseminating at least 12 sisters (Arakaki and Gahana, 1986).

2.3 Importance of *Cotesia flavipes*

Cotesia flavipes (Cameron) is a principal member of a species complex that is used in biological control of the cereal stem borer, *Chilo partellus*, and related stem borers that affect cereal crops in many parts of the world (Mohyuddin, 1972; Skoroszewski and Van Hamburg, 1987; Polaszek and Walker, 1991; Overholt *et al.*, 1994b; Kfir *et al.*, 2002). The biologically distinct species in this complex were originally difficult to separate using morphological characters (Sigwalt and Pointel, 1980), but a lot of progress has been made in species delimitation and identification using mating behaviour (Kimani and Overholt, 1995), morphometrics (Kimani-Njogu *et al.*, 1997b) and molecular techniques (Smith *et al.,* 1993b).

2.4 Host range and host finding behaviour of *Cotesia flavipes*

In its aboriginal home, *Co. flavipes* has been reported to parasitize several Graminecea stemborers feeding on members of poacea family. In the neotropics, *Co. flavipes* attacks several stemborers in the genus *Diatraea*. Thus, it appears that *Co. flavipes* has a fairly wide host range. Because two or more stemborer species often occur sympatrically in Africa, it was important to determine the host range of *Co. flavipes* prior to its release in early 1980's. Host range studies were also conducted in Kenya on *Cotesia sesamiae*, an indigenous parasitoid that is closely related to *Co. flavipes* and fills an ecologically similar niche (Polaszek and Walker, 1991). Laboratory studies revealed that *Ch. partellus*, *Ch. orichalcociliellus*, and *S. calamistis* were acceptable and suitable hosts for parasitization by both *Co. flavipes* and *Co. sesamiae* in Kenya (Ngi-Song *et al*., 1995). *Busseola fusca* and *Eldana saccharina* were acceptable for oviposition, but no parasitoid progeny developed to maturity in either host for *Co. flavipes* and strain of *Co. sesamiae* from coastal Kenya (Mohyudin and Greathead, 1970). However, study of the colony of *Co. sesamiae* collected from Western Kenya indicated that approximately 83% of the *B. fusca* larvae exposed to this population were successfully parasitized (Ngi-Song *et al*., 1998). Thus, there is evidence of two biologically distinct populations of *Co. sesamiae* in Kenya.

The host finding behaviour of *Co. flavipes* and *Co. sesamiae* was investigated by examining the responses of the parasitoids to volatile odours from stemborers, host plants and by-products of stemborer feeding. Both parasitoids responded more strongly to unwashed *Ch. partellus* larvae removed from maize stems than to larvae washed with distilled water after removal (Ngi-Song *et al.*, 1995). In a dual choice test, *Co. flavipes* responded more strongly to frass of stemborers than to stem borers themselves (Potting *et al.*, 1995). Several grasses not infested by stem borers proved to be unattractive to *Co. flavipes* and *Co. sesamiae*, but infested plants provoked a stronger response (Ngi-Song *et al.*, 1996). Plants infested with all the stemborer species tested (*Ch. partellus*, *Ch. orichalcociliellus*, *S. calamistis* and *B. fusca*) were attractive, and attraction was related to the number and size of the feeding stemborers (Ngi-Song *et al.*, 1996). Infested host plants released a synomone that was attractive to parasitoids (Potting *et al.*, 1995), and frass from all stemborer/host grass combinations examined proved to be highly attractive. However, slight difference in attraction to maize and sorghum was found between two parasitoids. *Co. flavipes* responded more strongly to maize, while *Co. sesamiae* exhibited a preference for sorghum (Ngi-Song *et al.*, 1996). In general, both parasitoids were attracted to volatile odors emanating from stemborers in grasses, regardless of whether the stemborer was a suitable host. These results suggest that if *Co. flavipes* were to be released in areas where suitable and unsuitable host occurred sympatrically, the parasitoid population would suffer mortality in the unsuitable hosts.

The impact of any parasitoid species on a target pest is best measured when they have established at a given population density (which usually takes several years to achieve). Thus, it is important to monitor the establishment and dispersion of *Co. flavipes* for two or more years after their release (Chinwada *et al.*, 2001).

2.5 History of *Cotesia flavipes*

There are three morphologically similar species of *Cotesia* that attack tropical stemborers. *Cotesia chilonis* is a native of Japan; *Cotesia flavipes* originates from Indo-Australian District and *Cotesia sesamiae* in native to Africa. Polaszek and Walker (1991) grouped the three species as the '*Cotesia flavipes* complex' after the well-known species used in biological control. Basic studies on the behavioural and physiological aspects of parasitism by *Cotesia flavipes* have been reported (Mountia and Courtois, 1952; Gifford and Mann, 1967; Kajita and Drake, 1969; Mohyuddin, 1972; Wiedenmann *et al*., 1992; Ngi-song *et al.*, 1995 and Potting *et al*., 1997 b). Various studies have revealed that the gregarious endoparasitoid *Co. flavipes* has a short life span and an initial egg load of around 150 eggs. A female *Co. flavipes* deposits around 40 eggs in a host and the highest reproductive success is on the latter larval instars (4-6th). The egg to adult development time is around 20 days and the sex ratio is usually female biased (60-70%). Arakaki and Ganaha (1986) studied the mating behaviour of *Co. flavipes* and found a high level of sibling mating directly after emergence from the stem borers' tunnel.

2.6 Use of *Cotesia flavipes* in biological control

Classical biological control involves the introduction and establishment of exotic natural enemies against pest species (Greathead, 1986). Sometimes, exotic parasitoids are introduced against native pests. *Cotesia flavipes* has been introduced into more than 40 countries in the tropics for biological control of pyralid stemborers in the genera *Chilo* and *Diatraea* (Polaszek and Walker, 1991). The movement of *Cotesia* materials around the world is complex and often difficult to uncover. The main sources of the worldwide introductions are field populations collected and redistributed by IIBC (International Institute of Biological Control) station in Pakistan. The *Co. flavipes* population in Pakistan may have originated from imported Japanese material (Alam *et al.*, 1972) although this is questionable *as Co. flavipes* does not seem to occur in Japan (Polaszek, 1998). Another important center for distribution of *Co. flavipes* in the new world is IIBC station in Trinidad, which used material from Pakistan and India to establish a colony of *Co. flavipes* on the neotropic host *D. saccharalis*. This formed the basis for introductions in North, Central and South America against *Diatraea spp*. in maize and sugarcane.

The exotic larval parasitoid *Co. flavipes* is now spread worldwide and due to introductions against *Ch. partellus* (Alam *et al*., 1972; Overholt *et al*., 1994). *Co. flavipes* now occurs in the Caribbean, major parts of North and South America (Polszek, 1998). Recently, *Co. flavipes* has been introduced in East, Central and Southern African countries.

2.7 Success of *Cotesia* spp as parasitoids

Several factors could be responsible for the successful establishment of *Cotesia spp* in different localities. The *Co. flavipes and Co. sesamiae* attack several species of Crambid, Pyralid and Noctuid stem borers (Mohyuddin, 1971; Nagarkatti and Nair, 1973; Beg and Inayatullah, 1980; Goraya *et al.*, 1982; Shami and Mohyuddin, 1987; and Omwega *et al.*, 1995). The relative wide taxonomic range of suitable hosts, coupled with narrow habitat specificity may favor the establishment. Since stem borers often occur as species complexes, parasitoids that can exploit more than one of the hosts may be better able to colonize a new area than monophagous parasitoids, due to a more constant availability of the hosts. Another factor may be their high reproductive potential (Songa *et al.*, 2001). Both parasitoids have short generation time (16-18 days) in comparison with their hosts (30-50 days) and fairly high fecundity (c. 30-40 female-based progeny per oviposition) (Kfir, 2002). A high host-searching ability may also be involved. Wiednmann and Smith (1993) demonstrated that, even at low densities, *Co. flavipes* was able to successfully locate stem-borer host. The high host searching ability may in part, be due to its behaviour of entering tunnels in plant stems to attack stem borer larvae.

In Mauritius, where *Co. flavipes* may have been accidentally introduced, parasitism of 4-50% of the larvae of *Co. sacchariphagus* has been reported (Rajabelee and Governdasamy, 1988). In Madagascar, where *Co. flavipes* was introduced in 1960, parasitism of 60% of *Co. sacchariphagus* larvae has been reported (Betbeder-Matibet and Malinge, 1968). *Co. flavipes* has also been introduced into several countries in the neotropics for biological control of *Diatraea saccharalis* (F) in sugarcane, and substantial control has been reported in many areas (Alam *et al.*, 1971; Fuchs *et al.*, 1979; Macedo *et al.*, 1984). The success of *Co. sesamiae* is limited to its establishment on Mauritius, Reunion and Madagascar against *S. calamistis* larvae. The exotic larval parasitoids Co. flavipes was introduced in Kenya in the early 1990s, and since has established (Omwega *et al.*, 1995; Overholt, 1998). Although a wide range of larval parasitoids attack stemborer larvae, percentage parasitism is seldom higher than 10% (Oloo, 1989; Skovgard and Pats, 1996; Songa *et al.*, 2002a)

2.8 Importance of nitrogenous fertilizer to maize cereal stemborer and parasitoids

Soil nutrients have been found to affect the susceptibility of plants to pests and diseases. Haseman (1940) suggested soil improvement as a new approach that could complement various measures of controlling pest and diseases. Since then, highly variable results have been obtained with different insects and host plants in relation to soil nutritional level. However, information on the relationship between soil (i.e., plant nutrients) and African cereal stem borers is scarce. Laboratory studies carried out by Sétamou *et al.* (1993) showed that nitrogen application increased survival and growth rates as well as fecundity of *S. calamistis*. In addition, surveys in the farmer's fields showed a positive relationship between soil nitrogen levels and stemborer densities (Sétamou *et al.,* 1995). It was concluded that greater use of Nitrogen fertilizer in order to increase maize yields could also increase borer populations and aggregate the pest problem especially during the second planting season. Sétamou *et al.* (1993) reported that adult *S. calamistis* fecundity, egg viability, and the percentage of larvae reaching the adult stage were positively correlated with N doses applied to plants. Similarly, longevity and fecundity increased with increase in the level of N applied. In addition, N mainly affected the survival of young larval stages before they penetrated into the stem for all borer species, and that the N × insect level interactions were not significant (Sétamou and Schulthess, 1995). The agronomic data were also significantly affected by both N fertilization and borer activity. For instance, increasing the rate of N increased plant height, basal stem diameter and yield, where as borer activity had a negative effect on them (Sétamou *et al.,* 1995). Nitrogen fertilizer is an important agronomic practice for maize production in West

African moist Savannas (Oikeh *et al.*, 1998). Maize cultivars differ in grain yield response due to application of N fertilizer (Kling *et al.*, 1997; Oikeh *et al.*, 1997).

2.9 Effect of pesticides on stemborers and parasitoids

Implicit in IPM is the maximum utilization of natural enemies, supplemented with selective use of insecticides when necessary (Metcalf, 1982). In the development of IPM programme, the side effects of insecticides on beneficial arthropods, i.e. parasitoids and predators should be evaluated (Franz, 1974). Interest in studying the effects of insecticides on predators has increased, whereas very few studies have dealt with their effects on parasitoids, especially on *Co. flavipes* on cereal stemborers. (Linski, 1977; Horn, 1983; Mishra and Sapathy, 1985; Kalule *et al.,* 1998). In assessing the effects of insecticides on parasitoids, it is necessary to evaluate not only the direct mortality caused by contact or residual toxic, but more importantly any absence of such effects and also sub-lethal effects on emergence, survival, fecundity and predation/parasitism (Sétamou *et al.,* 1995). Adult parasitoids are especially likely to be killed by insecticides while in the process of emerging from their host (Barlett, 1964; Kot and Plewka, 1970). It is for this reason that the effect of Furadan, a commonly used insecticide against maize stemborers in Zanzibar on the introduced parasitoid, *Co. flavipes* was evaluated in the study.

2.10 Contributory factors to low agricultural productivity in Zanzibar

There are a variety of different, but inter-related, factors that have contributed to the low level of productivity within the agricultural sector of Zanzibar. These include: Low soil nutrient level, Weather conditions, pest and diseases, poor agronomic practices etc.

2.10.1 Low soil nutrient levels

As a result of continuous cultivation and non replacement of nutrients lost through leaching or removed in the harvested products, and related low soil organic matter level, almost all soils currently used for crop production are low in plant nutrients. Nitrogen is the most limiting, and ranges between 0.03 and 0.09%. Phosphorous is also low in all types of soil. Potassium is locally deficient especially in heavy textured soils. There is zinc deficiency in both irrigated and rain fed rice areas (Anon, 2003).

2.10.2 Low soil organic matter

The causes are similar in all farming systems, notably:

(1) The practice of growing cassava on the same plot for long time without rotation (mono-cropping);

(2) The removal of crop residues as fuel or fodder;

(3) The burning of crop residues and other organic matter, especially during land preparation (instead of incorporating them or leaving them as mulch);

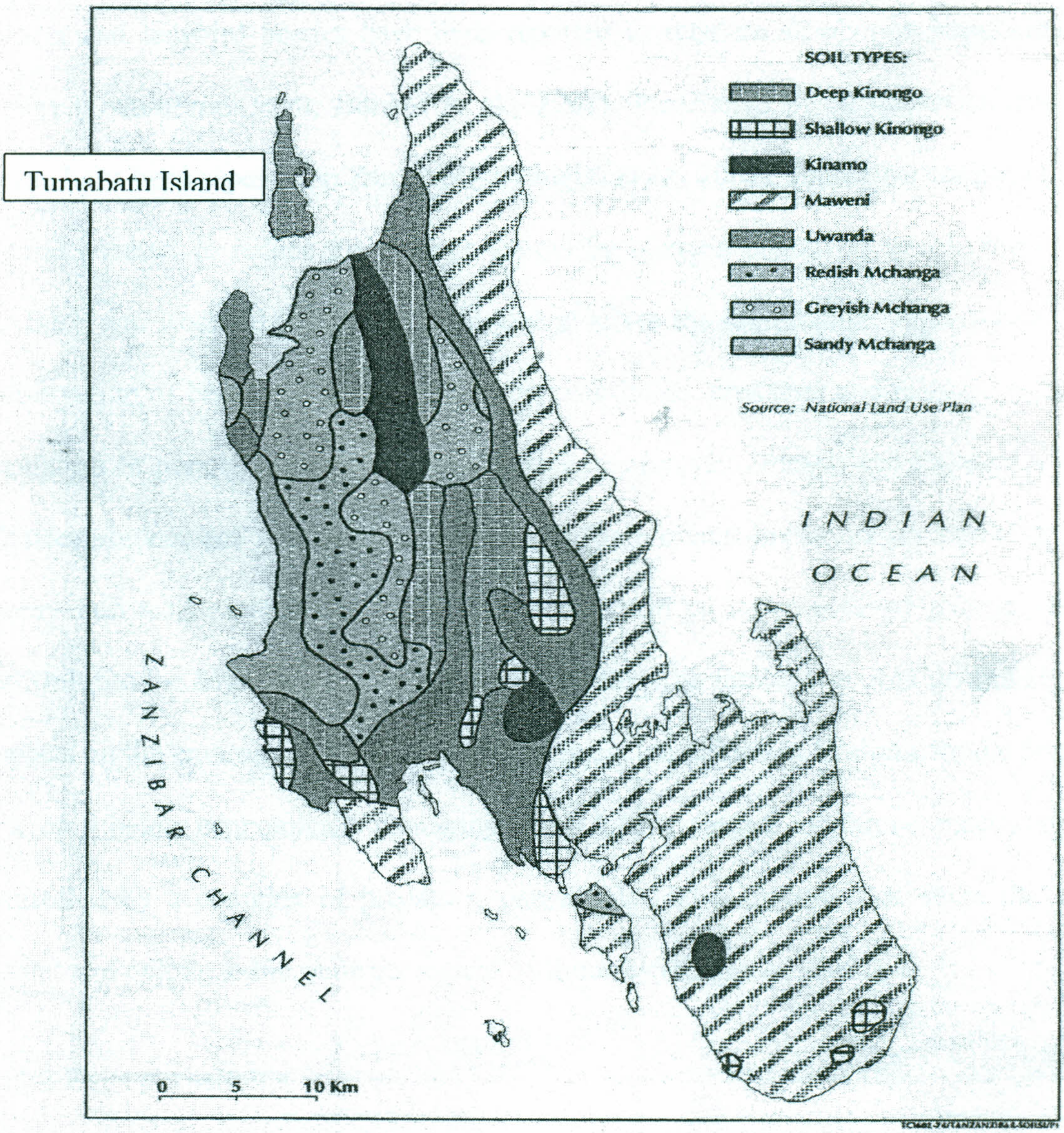
(4) Little application of farmyard manure, which often goes uncollected and unutilized. The end result is quantities of organic matter and a loss of an important source of plant nutrients (Anon, 2003);

(5) Reduced fallows have leading to reduce yields. This is especially a problem in coral rag where shifting cultivation is practiced (Plate 3.3) and the fallow period has been shortened considerably due an increase in population pressure, and the high demand for land for other development activities (particularly tourism). Both in coral rag and other parts of Zanzibar, there is little land remaining to allow for fallow (Anon, 2003).

Fig. 2.1 The distribution of different soil type in Zanzibar (Unguja Island).

ZANZIBAR: Land Husbandry Improvement Programme – Strategy and Action Plan

Map 4. Unguja: Soil Types



Key explanation: Deep Kinongo (loamy soil), Shallow Kinongo (Sandy loamy), Kinamo (Clay soil), Maweni (Coral soil), Uwanda (Semi coral soil), Redish Mchanga (spodosol), Greyish Mchanga (Ultisol), Sandy Mchanga (Aridsol).

2.11 Control of maize stemborers

2.11.1 Biological control of stemborers

Natural enemies play an important role in regulating the populations of lepidopterous stemborers in Africa (Polaszek, 1992). Predators of sytemborers such as earwigs, ants, spiders and ladybird beetles have been reported to regulate stemborers populations in Kenya (Dwumfour, 1990; Bonhof et al., 2001). Parasitoids of stemborers pupae and larvae have been reported in Zanzibar (Niyibigira *et al.,* 2001). Biological control utilizes natural enemies to reduce the damage caused by noxious organisms to tolerable levels (DeBach and Rosen, 1991). Biocontrol also involves the importation, augmentation and conservation of beneficial organism such as parasitoids, predators and pathogens for the regulation of population densities of other organisms (van Driesch and Bellows, 1996). Classical biocontrol involves the importation and establishment of an exotic natural enemy into a new environment for the management of its co-evolved pest (Knutson, 1998). It has the advantage of being safe, with little or no farmer contribution and adverse impacts on the environment. The goal of biological control is not to eliminate the pest but to keep it below economically damaging levels. Under natural conditions, most pests are controlled by a complex of predators, parasitoids and pathogens that share the same habitat and belong to the same ecological community (Kfir *et al*., 2002).

2.11.2 Eggs parasitoids

Egg parasitoids are an important source of stemborer mortality because the pest is killed at the egg stage such as *Telenomus sp* on eggs of cereal stemborers before it damages the crop (Temerak, 1981). In Western Africa, egg parasitoids have been reported to play an important role in regulating lepidopteran stemborers (Ndemah *et al.*, 2003; Schulthess *et* *al*., 2001; Sétamou & Schulthess, 1995). Information on egg parasitoids in East Africa is scarce and very rare in the islands of Zanzibar. Few species of egg parasitoids has been reported in Unguja Island, namely *Telenomus nemesis, Telenomus sudanensis, Telenomus thestor, Telenomus busseolae* and *Telenomus sesamiae.* Others are; *Trichogrammatoidea sp, Trichogramma lutea* and *Trichogramma mwanzai* (Abdalla unpublished). In Benin, parasitism by *Telenomus* spp. was one of the key mortality factors that reducing the population of stemborers (Schulthess *et al.,* 2001), that parasitism of *S.calamistis* egg by *Telenomus busseolae and Telenomus isis* was up to 95% (Schulthess *et al*., 1997). Similarly, in Cote d'Ivoire, Moyal (1998) reported 72% parasitism of *B. fusca* eggs by *T. busseolae* and in Cameroon; it was up to 80%. The egg parasitism in Kiboko and Katumani Central Kenya ranged from 0.34-12.54% in 2005. *Telenomus busseolae* had a major contribution to the parasitism level of *Busseola fusca* in Kenya, and had a higher discovery efficiency than the other *Telenomu species s* and *Trichogramma* species (Okoth *et al.,* 2006). In Zanzibar, there is no report on the use of egg parasitoids on controlling maize stemborers.

2.11.3 Larval and pupal parasitoids

In Zanzibar *Co. sesamiae* is the most abundant and widespread larval parasitoid and attacks all the stemborer species (Niyibigira *et al.,* 2001a). The exotic larval parasitoids *Co. flavipes* play an important role in reducing the population levels of *Ch. partellus,* the indigenous parasitoids in Africa *Co. sesamiae* are unable to reduce stemborer populations below economic damage levels (Kfir, 1992). The parasitoids could not prevent the dispersal and subsequent wide distribution of *Ch. partellus* after its introduction into Africa (Kfir, 1992). The most abundant larval parasitoids of *Ch. partellus* are *Co. flavipes* and *Co.sesamiae* (Omwega *et al.,* 1995). According by Niyibigira *et al.* (2001b), seven Hymenopterans pupal parasitoids have been recorded in Zanzibar and these include: *Dentichasmias busseolae* Heinrich (Ichneumoidae), *Brachymeria sp.* Westwood (Chalcididae), *Brachymeria olethria* Waterston (Chalcididae), *Pediobious furvus* (Gahan) (Eulophidae), *Psilochalcis soudanensis* Steffan (Chalcididae), *Syzectus ruberrimus* Benoit (Inchneumonidae) and an unidentified Chalicididae. *Pediobious furvus* was the dominant pupal parasitoid in Unguja but the numbers were very low and hence parasitism levels were negligible (Niyibigira *et al.,* 2001b).

2.11.4 Chemical control

Chemical control is the most powerful tool and mostly used for controlling stemborers and usually recommended by plant protection division of Zanzibar. Economic thresholds are also important considerations on use of chemical control in Zanzibar, both for cost effective application and for minimum impact on environment. Stemborers of maize and sorghum can be effectively controlled by leaf whorl placement of granules or dust applications of Carbofuradan, Endosulfan, Lindane, Carbaryl and Malathion (Van Keulen, 1990). The control of stemborers using chemicals is more difficult as they feed in sheltered areas (Leslie, 1993), and most of their life cycle is spent within plant tissues that cannot be reached by contact insecticides (Jotwani, 1983). However, chemicals reduce stemborers populations if applied at the correct time, before the larvae bore into the stems (Warui and Kuria,1983). Control using systemic insecticides provides only protection against early attacks but not against borers feeding in the cob (Sètamou *et al.*, 1995; Ndemah and Schulthess. 2002). Furthermore, broad-spectrum insecticides such as carbofuradan, with high trans-dermal toxicity, are environmentally damaging and a serious health hazard in the hands of untrained farmers. Commercially produced alternative pesticides such as neem trees (*Azadirachta indica* A.Juss) products or bacteria *Bacillus thuringiensis*, have a potential but are not readily available or are too costly (Brownbridge, 1991, ICIPE, 1991). There is also conflicting evidence on pesticides-yield relationship. It has been reported that, despite heavy attack by *Chilo partellus* in Uganda and India respectively, the infested crops compared favourably with the insecticide-protected plots in terms of grain yield hence no significant difference was observed (Ingram, 1958; Trehan and Butain, 1949).

CHAPTER THREE

EFFECT OF THE POPULATION DENSITY OF CEREAL STEMBORERS AND ITS LARVAL PARASITOID, *Cotesia flavipes* (HYMENOPTERA: BRACONIDAE) IN MAIZE YIELDS

3.1 Introduction

In Zanzibar, maize is widely grown and farming practices are different between main agro-ecological zones (Plantation, Coral rag and Semi-coral zones). Plantation zones are mostly located in Western and Central Districts of the island receiving high rainfall annually where the soil is deep and fertile allowing good performance of the crop (Fig. 5.1). Semi-coral area is the medium potential agricultural land that receives moderate rainfall, has few limitation of mixture of good soil and coral stone patches, mostly scattered in the island and can be found from West, North and Central Districts (Fig. 2.1) The coral rag zone is mostly located in Southeastern and Northeastern zone. Maize, sorghum, green grams, pumpkins, pigeon peas and cowpeas are common crops in this zone. Maize and sorghum are the major food crops intercropped with the cowpeas. This area receives very low amount of rain, which is unreliable, and the soil is less fertile but farmers practice shifting cultivation in order to have s solution of fertility problem.

It is estimated that about 60% or more of the farmers In Zanzibar are females. In Tumbatu Island, 100% of farmers are females, with men mostly engaged in fishing and small business. In general, most farmers in Zanzibar grow maize and other crops for subsistence. Abdullah and Lada (1996) reported that stemborer density is dependent on the location and growing season. The current study was undertaken to investigate the relationship between stemborer densities and larval parasitoids, *Co. flavipes* and their impact on maize yield in different agricultural ecological zones. It's involved the investigating of the distribution of stemborer species, and their abundance in different Districts, assessing the impact of stemborer on maize growth and yield damage and evaluating the establishment of exotic larval parasitoid, *Cotesia flavipes* and its parasitism level and abundance in Zanzibar.

3.2 Materials and methods

Surveys were conducted in the major maize and sorghum growing areas of Unguja Island, Zanzibar. Twenty sites were randomly selected from the coral and the non-coral areas where they were of maize and sorghum plantations (Appendix 2). Farmer's fields of approximately 0.5-1.0 were selected and they were at least 5km apart from one another. Surveys were carried out during the long (March -June) and short (September - November), rainy seasons. Within each season, the fields were sampled twice, during the tasselling stage about eight weeks after planting and the harvesting period of hard dough. The stage of the plant was determined by using the protocol developed by Gounou *et al.* (1994) and Cardwell *et al.* (1997). Each field was divided into four quadrants, and 10 maize plants per quadrant were selected randomly along x/y coordinates.

The number of larvae and pupae per borer species, plant height, stem diameter at the base node, of stem tunnelling length (below and above), and exit holes were recorded. At harvest time, for each plant, percentage of ear weight without husk was recorded. Larvae collected were reared in the laboratory by placing them individually in flask glass and the were plugged with a piece of white cotton fastened tightly with a rubber band (Plate 3.1). All larvae were fed by natural diet from respective. All emerging moths were identified to species level and then discarded. Emerged parasitoids were counted (Plate 3.2), recorded preserved in 98% Ethanol and sent to ICIPE for identification. Voucher specimens were deposited at ICIPE, Nairobi and Kizimbani Research Station Zanzibar.

3.3 Statistical analysis

For each site, the average mean of stemborers and parasitoid were calculated over the sampling occasion per season, which represented the pre-tasselling and reproductive growth stages (hard dough). Mean borer density of each species, tunnel length, exit holes, bored internodes, plant height and diameter of each plant at different Districts were compared using Analysis of Variance (ANOVA PROC GLM, SAS 2004), and significant differences in means were separated by Student-Newman-Kuels test (SNK). ANOVA was also used to compare mean progeny and sex ration for each District surveyed. Percentage of parasitism by each parasitoid species was compared using chi-square test. Stemborer data was square root transformed and original data was presented in the tables. Correlation analyses were done to detect relationship between tunneling length and cob weight.

3.4 Results

3.4.1 Stemborers densities in four Districts surveyed.

The total densities of stemborers are significantly different in all the Districts and were high in the South District during the short rainy season, (> 1 per plant). There were no significant differences between the Districts in the stemborers density during the long rainy season (Table 3.1) and between species during the short rainy season. The density of *Chilo orichalcociliellus* in West District was significantly higher than the other Districts during the long rainy season. In South District compared to Central during the short rainy season, there was significantly higher level of total borer infestation of maize and no difference was observed in long rainy season (Table 3.1). *Ch. partellus* was pre-dominant in all Districts surveyed but this was not observed in the long rains, while *Ch. orichalcociliellus* was the least encountered (Fig. 3.1).

3.4.2 Plant height and diameter

During the short rainy season, plant heights were significantly higher in South District although the soil is of coral rag with low fertility (Table 3.2). During the long rainy season, the plant heights were lowest in the West District. There were significant differences of plant height between the short rainy and long rainy season, the difference were observed in South and West Districts where plants were tallest during the short rainy season (Table 3.2). The stem diameters of plants were the lowest in Central District during short rainy and West District during long rainy season respectively (Table 3.2).

3.4.3 Maize yield and its relationship with stemborers and the damage variables

During short rainy season, cob and grain weight were significantly different between the Districts, with the highest weights being found in the Northern District followed by Central District. The lower yields were observed in West District, which was only 49% of that in the North (Table 3.4).Plant height and stem diameter, did not show any correlation with maize grain yield (Fig. 3.2).

3.4.4 Cob and grain weight for Districts survey

Differences between cob weights were observed during the short and long rain seasons respectively. The cob weight was higher in the North Districts during the short rainy season followed by the Central District. In the South and West Districts, the weights were the same. For all Districts, higher cob weight were obtained during short rainy season, which is similar to results for grain weight where higher grain weight were observed during short rainy season (Table 3.4). The grain weights between the Districts were high in the North followed by Central and no differences observed between the South and West during short rainy season. During the long rainy season, higher grain weights were observed in the Central and South Districts than in the North and West Districts (Table 3.4)

3.4.5 Cob and grain weight for Agro-ecological zone

Cob and grain weight observed were higher in plantation zone during short rainy season followed by coral rag and semi coral zones (Table 3.5). There was no significant difference in cob weight during long rainy season between coral, semi-coral and plantation zones, respectively. However, significant differences were observed in grain weight during long rainy season (Table 3.5). In general, higher cob and grain weight were higher in plantation zone during short rain than the long rain season (Table 3.5).

3.4.6 Stemborer parasitism in different Districts

The mean total parasitisms by larval parasitoids in 2004/2005 in Zanzibar (Unguja Island) were 8.74%. Highest parasitism (19.8%) by *Co. flavipes* was recorded on *S. calamistis*, in the North (Table 3.6). Parasitism of *Ch. partellus* by *Co. flavipes* was between 3.96 to 7% in all Districts surveyed. However, the larval parasitoids of *Cotesia flavipes* and *Cotesia sesamiae* were not recovered from *Ch. orichalcociliellus*. Similarly larval parasitoids of *Co. sesamiae* was not recovered from *Ch. partellus (*Table 3.6).

3.4.7 Sex ratio and the number of progeny of *Cotesia* spp between the Districts surveyed

There were no significant differences in the mean number of progeny and sex ratio of *Co. flavipes* during both short and long rainy seasons (Table 3.7). For *Co. sesamiae*, significant differences in sex ratio were observed between seasons only in South District for both parasitoid species, but population from the North and West were significantly more female during the long rains. For *Co. sesamiae*, the number of progeny in the West District was significantly higher than other Districts during the short rainy season. In the long rains, *Co. flavipes* produce significantly more progeny than in the short rains in all Districts except West. Similarly the progeny of *Co. sesamiae* was significantly higher in the long rains than in the short rains in the South and Central Districts (Table 3.7)

Plate 3.1 Flasks with stemborers reared on natural diet.

Plate 3.2 Petri dish with emerged larval parasitoids (*Cotesia* spp).

Plate 3.3 Maize growing on Coral rag in Zanzibar

Plate 3.4 Damages caused by stemborers feeding on maize stem

Table 3. 1 Stemborer density /plant (mean ± SE) in different Districts and rainy seasons in Zanzibar during 2004/2005.

Districts	Short rains				Long rains			
	Ch. partellus	*S. calamistis*	*Ch. orichalcociliellus*	*Total borer*	*Ch. partellus*	*S. calamistis*	*Ch. orichalcociliellus*	*Total borer*
Central	1.03±0.11a	0.39±0.05a	0.14±0.02a	1.56±0.12b	0.60±0.05a	0.18±0.03a	0.04±0.01b	0.82±0.07a
North	1.12±0.12a	0.57±0.09a	0.12±0.03a	1.80±0.15ab	1.05±0.08a	0.05±0.01a	0.01±0.01b	1.12±0.09a
South	1.37±0.17a	0.65±0.11a	0.15±0.04a	2.18±0.19a	0.77±0.12a	0.10±0.03a	0.06±0.02b	0.93±0.14a
West	1.25±0.11a	0.55±0.08a	0.18±0.03a	1.98±0.15ab	0.58±0.09a	0.55±0.20a	0.56±0.25a	1.61±0.07a
F-value	2.65	0.28	0.78	3.59	3.36	2.13	8.54	1.24
P-value	0.05	0.84	0.51	0.01	0.02	0.10	0.0004	0.29

Means (± S.E) followed by the same lower case letter in the same column are not significantly different (Student-Newman-Keuls, P<0.05).

Table 3.2 Plant height and diameter (cm/plant) (mean ± SE) at maize pre-tasselling stage in different Districts and rainy seasons (SR=Short rain and LR=Long rain) in Zanzibar of 2004/2005.

	Plant height (cm)		**Plant diameter (cm)**	
Districts	**SR**	**LR**	**SR**	**LR**
Central	115.98±3.11bA	110.40±2.20aA	2.32±0.04bA	2.21±0.05aA
North	107.51±3.82bA	113.94±2.00aA	2.53±0.18abA	2.29±0.04aA
South	126.11±3.85aA	111.67±2.43aB	2.73±0.10aA	2.31±0.06aB
West	114.12±2.53bA	95.12±2.35bB	2.74±0.05aA	1.78±0.05bB
F	3.76	10.13	5.12	17.56
P	0.0108	<.0001	0.0017	<.0001

Means (± S.E) followed by the same lower case letter in the same column are not significantly Different; Means followed by the same upper case letter(s) in the same row are not Significantly different (Student-Newman-Keuls, P<0.05)

Table 3.3 Maize bored internodes, exit holes and tunnel length, percentage of bored internodes and tunnel length per plant at maize pre-tasselling stage in different Districts and rainy seasons (SR=short rain and LR=long rain) in Zanzibar.

	Exit holes		Bored internodes		Bored internodes (%)		Tunnel length (cm)		(%) Stem Tunnelled	
Districts	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR
Central	1.3±0.1bA	0.8±0.1bB	0.9±0.1cA	0.6±0.1bB	11.7±1.1cA	9.5±1.0bA	24.5±0.5cA	3.46±0.4bA	4.2±0.8cA	4.0±0.5bA
North	1.7±0.1bA	2.4±0.2aA	1.2±0.1cA	1.5±0.1aA	15.4±1.6cA	25.0±3.7aA	56.6±0.6bcA	8.01±0.6aA	6.6±0.7bA	7.7±0.6aA
South	3.8±0.3aA	0.9±0.1bB	2.7±0.1aA	0.6±0.1bB	27.4±1.8aA	8.1±1.0bB	108.0±1.3aA	3.08±0.4bB	11.6±1.1aA	2.9±0.4bB
West	3.2±0.2aA	0.6±0.1bB	1.9±0.1bA	0.4±0.1bB	20.7±1.3A	8.7±1.5bB	76.9±0.6bA	98±0.4bB	7.5±0.7bA	2.4±0.5bB
F-value	30.78	23.47	35.04	37.80	20.79	10.62	25.03	32.33	16.87	22.22
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	<. 0001	<. 0001	0.0001	0.0001

Means (± SE) followed by the same lower case letter(s) in the same column are not significantly different; Means followed by the same upper case letter(s) in the same row are not significantly different (Student-Newman-Keuls, P<0.05).

Table 3.4 Maize cob and grain weight (g/plant) at harvest time in different Districts and rainy seasons (SR=short rain and LR=long rain) in Zanzibar of 2004/2005.

	Cob weight (g/plant)		**Grain weight (g/plant)**	
Districts	**SR**	**LR**	**SR**	**LR**
Central	346.6±13.4bA	156.7±6.6aB	259.7±11.8bA	114.9±6.1aB
North	493.1±31.0aA	114.8±4.4bB	386.1±27.9aA	80.2±3.4bB
South	290.0±15.9cA	151.7±6.4aB	207.7±11.0cA	111.7±5.5aB
West	242.7±15.5cA	108.6±5.6bB	173.7±11.6cA	75.0±4.8bB
F	29.00	18.39	30.10	17.28
P	0.0001	<. 0001	0.0001	0.0001

Means (± S.E) followed by the same lower case letter(s) in the same column are not Significantly different; Means followed by the same upper case letter(s) in the same row are not significantly different (Student-Newman-Keuls, P<0.05).

Table 3.5 Maize cob and grain weight (g/plant) in different agro-ecological zones (AEZ) and rainy seasons (SR=short rain and LR=long rain) in Zanzibar of 2004/2005.

AEZ	Cob weight (g/plant)		Grain weight (g/plant)	
	Short rain	**Long rain**	**Short rain**	**Long rain**
Plantation	395.0±14.1aA	124.6±8.1aB	291.3±12.1aA	86.84±5.98abB
Coral rag	304.9±12.3bA	126.7±4.0aB	231.6±10.5bA	88.89±3.43abB
Semi coral	170.2±17.1cA	139.0±4.8aB	143.3±11.613cA	101.91±4.19aB
F	48.48	2.34	37.65	3.52
P	<. 0001	0.0969	<. 0001	0.0302

Means (± S.E) followed by the same lower case letter(s) in the same column are not significantly different; Means followed by the same upper case letter(s) in the same row are not significantly different (Student-Newman-Keuls, P<0.05) .

Table 3.6 Parasitism of stemborer by different parasitoid species (%) in different Districts.

Parasitoid-host	Central	North	South	West	$\chi 2$	P
Co. flavipes-Ch. partellus	6.25	4.02	6.84	3.96	1.59	0.66
Co. flavipes – S. calamistis	0	19.78	3.64	0	46.45	0.0001
Co. flavipes –Ch. orichalcociliellus	0	0	0	0	-	-
Co. flavipes -cocoon	1.60	2.80	2.17	5	3.56	0.34
Co. sesamiae – Ch. partellus	0	0	0	0	-	-
Co. sesamiae – S. calamistis	0.85	2.20	1.82	1.02	2.78	0.43
Co. sesamiae – Ch. orichalcociliellus	0	0	0	0	-	-
Cotesia sesamiae -cocoon	1.60	0.70	0.54	0.30	2.79	0.42
Total	7.22	12.94	8.70	6.10	10.60	0.014

$\chi 2$ = P = 0.05

$$\text{The mean parasitism} = \frac{\text{Total percentage of parasitized stemborers}}{\text{Number of Districts}} \quad \frac{34.96}{4} \quad = \mathbf{8.74\%} \text{ for both seasons in 2004/05}$$

Table 3.7 Progeny and sex ratio of parasitoids *Cotesia spp* emerged from parasitized host in different Districts and rainy seasons (SR=short rain and LR=long rain) in Zanzibar.

Districts	Progeny mean number of parasitoids				Sex ratio % females parasitoids			
	Cotesia flavipes		*Cotesia sesamiae*		*Cotesia flavipes*		*Cotesia sesamiae*	
	SR	**LR**	**SR**	**LR**	**SR**	**LR**	**SR**	**LR**
Central	28.7±1.6aB	39.3±4.4aA	24.2±1.7abB	54.1±8.6aA	0.59±0.02aB	0.78±0.04aA	0.68±0.04aA	0.81±0.04abA
North	26.7±2.4aB	51.4±4.4aA	29.0±5.9abA	52.2±6.7aA	0.67±0.03aA	0.72±0.03bA	0.63±0.08aA	0.72±0.05bA
South	27.3±1.6aB	48.6±4.5aA	17.9±3.1bB	37.9±7.4aA	0.56±0.04aB	0.76±0.02abA	0.59±0.04aB	0.83±0.03aA
West	34.5±3.1aA	43.7±6.6aA	33.9±4.2aA	44.2±15.7aA	0.63±0.03aA	0.74±0.04bA	0.66±0.05aA	0.75±0.05bA
F-value	2.26	1.19	2.86	0.68	1.98	0.78	0.42	1.11
P-value	0.08	0.32	0.04	0.57	0.12	0.04	0.74	0.03

Means (± S.E) followed by the same lower case letter(s) in the same column are not significantly different; Means followed by the same upper case letter(s) in the same row are not significantly different (Student-Newman-Keuls multiple comparison test, $P<0.05$).

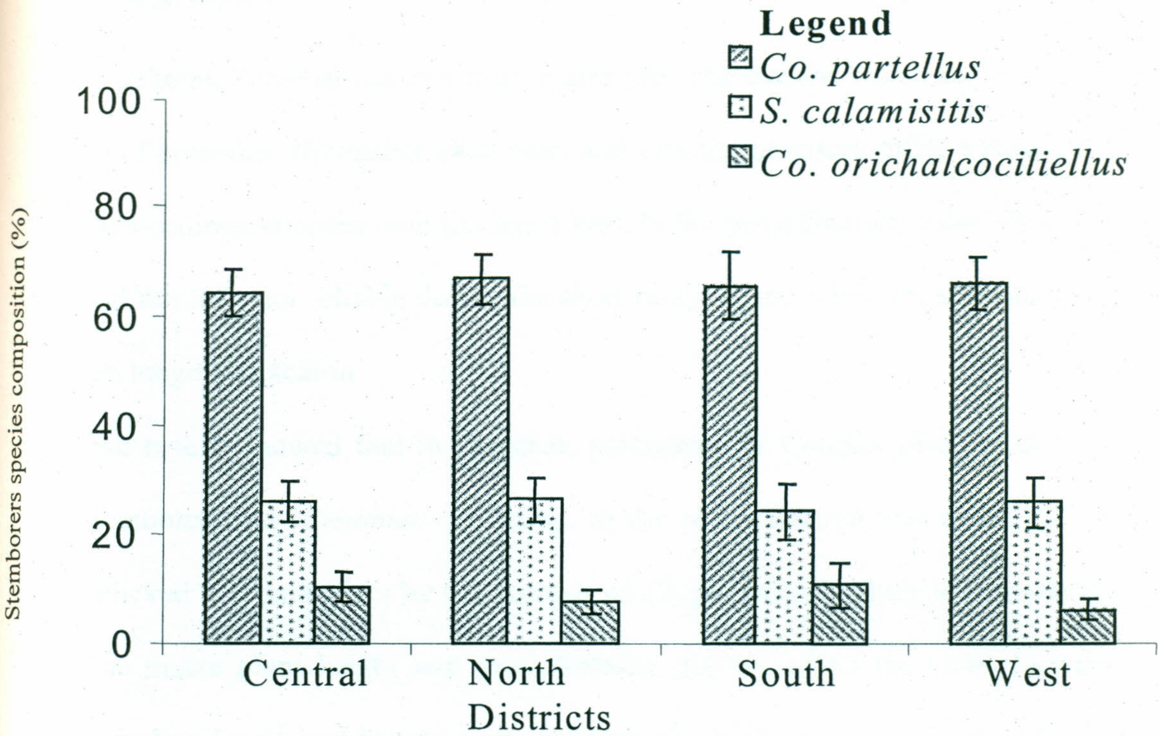


Fig. 3.1 The stemborer species composition at different Districts in Zanzibar.

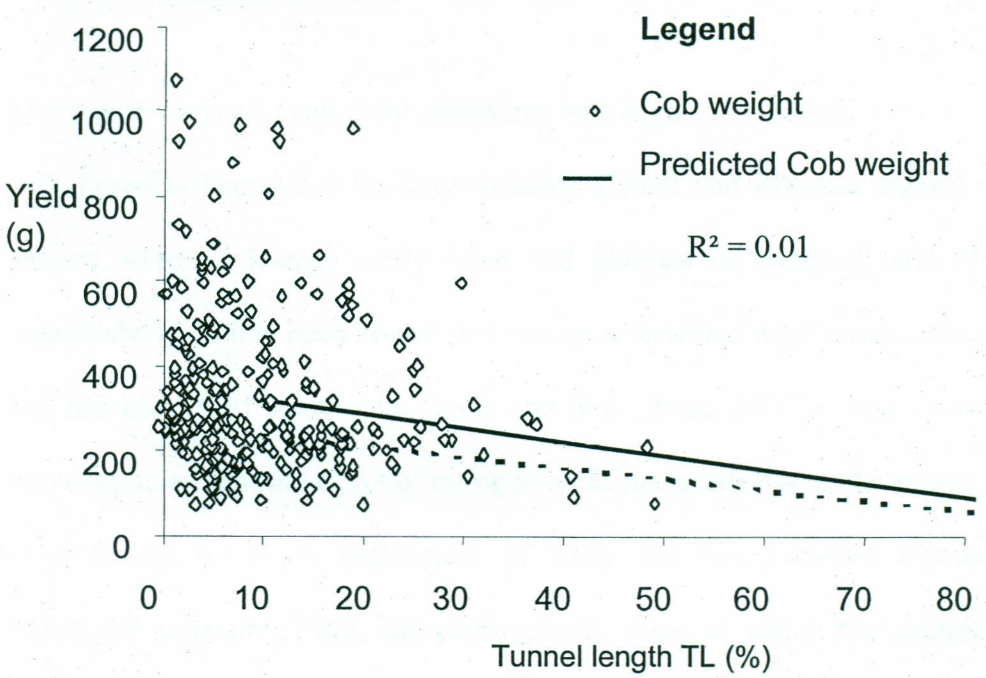


Fig. 3.2 The relationship between percentage of tunnel length (TL) and maize yield.

3.5 Discussion

In general, Zanzibar has two main maize growing seasons which are from March to June and September November each year, and farming practices differ between Districts and agro-ecological zones (van Keulen, 1990). In Southern District, about 98% of soil is coral and rainfalls not reliable during the short rainy season while reliable rainfalls are during the long rainy season.

The results showed that in Zanzibar, parasitism by *Cotesia. flavipes* of the indigenous stemborer host *Sesamiae calamistis*, in the North District was about 19.78% and it is believed that parasitism by *Co. flavipes* of *Ch. partellus* is likely to increase in the future. The maize plant height and stem diameter did not affect the yield. However, percent tunneling length and bored internodes were also highest in coral zones. The plant damage was lowest in plantation areas in both rain seasons surveyed.

The maize damage caused by stemborer was high in Zanzibar, and maize yield varied with Districts because of fertility variation (Uledi and Masoud unpublished). The soil natures were of loamy, sandy loam and patches of spodosol and clay soil (Uledi unpublished). It has been found that nitrogen fertilizer application affects maize yield, and life history of stemborers (Jiang and Schulthess, 2005). Chabi-Olaye *et al.* (2005) also concluded that the effect of nitrogen on *B. fusca* infestation decreased with age of the plant but at 63 DAP, differences in borer numbers between treatments were not significant anymore. Thus, the plant growth stage at which the samples are taken is crucial and should be taken at least twice for a reliable assessment of insect density. First sampling should be taken at vegetative period and the second shortly after tasselling.

Sétamou *et al.* (1995) reported that yield losses due to *S. calamistis* and *Eldana saccharina* Walker (Lepidoptera: Pyralidae) decreased from 20 to 11% with an increase in N fertilizer dosage from 0 to 120 kg N/ha. Chabi-Olaye *et al.* (2005) showed that yield losses due to *B. fusca* in maize planted in continuous cropping were around 20% versus 6% and 9% in maize planted after a leguminous cover and grain crop, respectively. Similarly, in a continuous maize cropping system, yield losses due to *B. fusca* in fertilized maize was only 2-6% versus 17-25% in unfertilized plots (Borgemeister *et al.,* 2005).

The negative relationship between percent tunneling length and grain yield reported in present studies have been reported for several other studies (Sétamou *et al.*, 1995; Sétamou and Schulthess, 1995; Gounou *et al.*, 1994; Ndemah *et al.*, 2001a). Sétamou *et al.* (1993) showed that, increasing soil nitrogen enhances the plant's tolerance to borer attacks but also increases stemborer populations in the field during the second planting season. The results also showed that, many small-scale farmers applied high dose of nitrogen during long rainy season, which aggravate the problem of high borer density and damage during short rainy season. However, this situation did not affect the maize yield during short growing season, which is higher than long rainy season in all Districts surveyed. In general, tunnel length was a more reliable measure of yield loss than insect numbers; because by the time the plants are sampled, many borers might have already reached adulthood and left the plant, or killed by predators or parasitoids. *Chilo partellus* was the most dominant stemborer species in all Districts surveyed for both rainy seasons in (Unguja Island) Zanzibar.

There was no difference in stemborer densities in all Districts surveyed. However, in the North, parasitism and maize yield were the highest. In South and West Districts, maize plant damage was higher with lower yield. The results also revealed that agro-ecological zones produced different maize yield. It has been shown that high yield was obtained during short rain season in plantation area. Field results suggest that significance difference exist between the Districts surveyed for parasitism of *S.calamistis by Co.flavipes*. In the present study, field parasitism of stemborer larvae was mainly due to exotic parasitoids *Cotesia flavipes*. Likewise, in the North District, parasitism of *S .calamistis* by *Co.flavipes* was higher by 19.78% than *Chilo partellus by* Co. *flavipes*. There was no parasitism observed on *Ch. partellus* by *Co.sesamiae;* similarly, *Co. flavipes* nor *Co sesamiae* was observed to parasitize *Ch. Orichalcociliellus*. The survey results suggest that *Co.flavipes* is a more efficient parasitoid and therefore is likely to increase suppression of stemborers population in Zanzibar. It could be speculated that the exotic specie might eventually dominate the ecological niche occupied by the native larval parasitoids *Co. sesamiae*. Niyibigira *et al*., (2001a) reported that *Co. sesamiae* Cameron was the most common parasitoid recorded and was recovered in all sites surveyed, accounting for 85.2% of parasitized larvae in (Unguja and Pemba Islands) Zanzibar. However, its efficiency was reduced by two hyperparasitoids *Aphagnomus fijiensis* (Ferriere) (Hymenoptera: Ceraphronidae) and *Elasmus* sp. (Hymenoptera: Elasmidae) (Niyibigira *et al*., 2001b).

CHAPTER FOUR

EFFECT OF NITROGEN FERTILIZER LEVELS AND PESTICIDES (Furadan) ON INFESTATIONS OF LEPIDOPTEROUS STEMBORERS, MAIZE YIELD AND LARVAL PARASITOIDS IN ZANZIBAR

4.1 Introduction

In Zanzibar, maize yields are generally low varying between 300 and 500kg/ha (van Keulen, 1990). Lepidopteran stemborers are the most serious constraints to maize production. *Chilo partellus* (Swinhoe) (Crambidae) is the most abundant stemborer accounting for 75.3% of all species composition, followed by *Sesamia calamistis* Hampson (Noctuidae) and *Chilo orichalcociliellus* Strand (Crambidae) (Niyibigira *et al.*, 2001b).

Surveys of farmer's in West Africa showed a positive relationship between soil nitrogen and stemborer densities (Sétamou and Schulthess, 1995). Laboratory studies carried out by Sétamou *et al.* (1993) showed that nitrogen application increased survival and growth rates as well as fecundity of *S. calamistis*. It is speculated that the greater use of N fertilizer in order to increase maize yields could also increase borer populations and aggravate the pest problem especially during the second planting season. Chabi-Olaye *et al.* (2005) reported that an increased nutrition status of the plants leads to an increase in borer attacks during early stages of plant growth, but that it might also lead to improved plant vigour, resulting finally in a net benefit in the form of increased grain yield. In Zanzibar, the soils in the reef are poor in nitrogen (SMZ, 1987). In coral areas nitrogen fertilizer is an important component for cereal and other crops grown in this marginal land (SMZ, 1987; Kling *et al.,* 1997). In addition to that nitrogen fertilization is an important agronomic practice for maize production in the West Africa moist savanna, (Kling *et al*., 1997; Oikeh *et al*., 1997).

In Zanzibar, introduction of classical biological control has become more important since the government cancelled pesticide subsidies to small-scale farmers and because parasitism levels by the indigenous parasitoid *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae) does not exceed 4% (Niyibigira *et al*., 2001b). In 1999, the braconid larval parasitoid *Cotesia flavipes* was introduced into Zanzibar by International Centre of Insect Physiology and Ecology (ICIPE) for control of *Ch. partellus*. The parasitoid was introduced in Zanzibar because it had reduced pest densities in coastal Kenya by 70 % (Zhou *et al.,* 2001; Jiang and Schulthess 2005). Furthermore, studies by Jiang and Schulthess (2005) indicated that N fertilizer increased the performance of this parasitoid. The present study was initiated to assess the effect of different nitrogen levels and pesticide application on stemborer infestation, particularly *Ch. partellus*, and yield of maize as well as on the performance of *Cotesia* spp. The current study was undertaken to investigate the effect of nitrogen fertilizer and pesticides application on the level of parasitism and in relation to yield.

4.2 Study site

Zanzibar has a lowland tropical sub-humid climate, dominated by a bimodal pattern of rainfall, influenced by the prevailing monsoon trade winds, which blow from Southeast in June- September and Northeast in November-February. Rainfall throughout Zanzibar varies between 1000-2500 mm/yr (Anon, 2003). A long rainy season occurs between March-June while the short between October-December. The long rainy season (900-1000mm) tends to be more reliable than the more variable short rainy season (400-500mm). The trial was conducted during the long and short rainy seasons at Bambi Research Station, Central District of Unguja Island.

4.3 Materials and Methods

The experiments were conducted in a field size measuring 40x 36m^2. It was divided into 24 plots of 6m × 6m each, and distance between plots of 2 m. Maize (Cv. STAHAMILI – Z), was planted at spacing of 30cm within row and 60cm between rows. The short rain lasted from mid of August 2004 to mid December 2004 and the long rain experiment from 21st March to end of July 2005. Three plants were grown per hole and thinned to two at 14 days after planting (DAP). Soil samples were taken and analysed before planting, to determine uniformity of the experimental block. The soil is classified as mollic leptosol (FAO Classification) (Anon, 2003), less red (IOR 4/6). The area is under continuous cultivation, and exhibits rather mild plough pan at 40-50cm. The pH values showed an alkaline reaction, which is typical of calcareous coral soil of Zanzibar. Phosphorus (P_20_5) was low due to fixation of this element with excess calcium cations in the whole profile. Four nitrogen treatments were carried out N0, N1, N2 and N3, i.e., 0, 60, 120 and 250kg/ha which was equivalent to 0, 1.13, 2.25 and 5g N/plant, and two pesticide treatments at the lowest (N0P) and highest nitrogen levels (N3P), were applied. The treatments were arranged in a complete randomized block design with four replications for each treatment. Nitrogen fertilizer in form of granules was applied once at

18 DAP. All plots received triple super phosphate and potassium fertilizer at the rate of 5gm/plant. Furadan was applied at 35 DAP at the rate of 1.5 a.i kg/ha by placing 5 gm of the granules in the soil.

Data collection was done at the pre-tasselling and harvest stages. Fifteen plants per plot were randomly sampled. Number of stemborer larvae and pupae per borer species, plant height, basal stem diameter, stem tunnel length, exit holes, internodes bored were recorded. Percentage of tunnel length and bored internodes was assessed. At harvest time, ears were dehusked, weighed and then threshed for determination of grain weight. (Plate 4.4). Each stemborer larva was kept individually in glass vials (8.5x 2.7cm) and reared for parasitoid emergence (Plate 4.1; Plate 4.2). The number of male and female parasitoids were counted, preserved in 98% ethanol (Plate 4.3) and sent to ICIPE for species identification.

4.4 Statistical Analysis

The effect of nitrogen levels on the abundance of stemborers for each species, percentage of tunnel length and borer internodes per plant during both seasons were compared using analysis of variance (ANOVA) (PROC GLM) (SAS Institute 2004), and mean differences separated using Student-Newman-Keuls test. The effect of pesticide on protected and non-protected plots was compared by *t*-test. Percentage of parasitism by each parasitoid species on different host species was compared using chi-square test. Stemborer data was log (x+1) and percentages square root transformed but untransformed data were presented in the tables.

4.5 Results

4.5.1 Effect of N level on stemborer densities

During both seasons, *Chilo partellus* by far outnumbered *Sesamia calamistis* and *Ch. orichalcociliellus* (Table 4.1). During the short rain season, *Ch. partellus* and total numbers of borers were higher in N2 and N3 than in N0 and N1. During the long rainy season, *Ch. partellus* number tended to increase with nitrogen levels. There was no difference between treatments in density for the other two stemborer species. During the short rains, furadan applications resulted in significantly decreased stemborer densities in both N0P and N3P treatments (Table 4.2). The reduction of stemborer was greater in N3 than N0. Pesticide also reduced total stemborer numbers during long rainy season. Total borer density was significantly higher in the unprotected N0 and N3 nitrogen fertilizer treatment plots than the other treatment plots for both short and long rainy season respectively (Table 4.2). However, there was no effect of pesticide on densities of indigenous stemborer *Sesamia calamistis* at the different nitrogen levels during the long rains.

4.5.2 Effect of N levels on parasitism, progeny and sex ratio of *Cotesia spp.*

Six parasitoid species were recovered, which included hyperparasitoid, *Aphanogmus fijiensis* (Ferrière) (Hymenoptera: Ceraphronidae), pupal parasitoids, *Xanthopimpla stemmator* Thunberg (Hymenoptera: Ichneumonidae), *Pediobius furvus* (Gahan) (Hymenoptera: Eulophidae), *Dentichasmias busseolae* Heinrich (Hymenoptera: Ichneumonidae), *Syzeuctus ruberrimus* Benoit (Hymenoptera: Ichneumonidae), *Stenobracon* (*Euvipio* sp). However, the numbers were very low, and parasitism was negligible. Exotic and indigenous larval parasitoids, *Co. flavipes* and *Co. sesamiae*, respectively, were the major parasitoid species, and both were recovered from three stemborer species namely *Sesamia calamistis, Chilo partellus and Chilo orichalcociliellus* (Table 4.3). Parasitism of *Co. flavipes* was higher at high nitrogen levels during short rainy seasons, and it was higher than that of *Co.sesamiae*. During the short rains, only *Co. flavipes* was recovered from *Ch. partellus*. Parasitism of *Ch. partellus* by both parasitoids did not vary significantly with N treatments during both seasons. For *S. calamistis*, significant differences in parasitism levels between N levels was observed during the long rainy season. In the protected plots, parasitism was very low or zero. Higher progeny of *Co. flavipes* was found at higher N level during long rain season. No differences were found in sex ratio and progeny of *Co. sesamiae* between N treatments during both seasons (Table 4.4).

4.5.3 Effect of nitrogen on plant damage variables

During the short rains, percent bored internodes and tunnel length per plant was greater in plots with low N levels than the with high dosages; they were also greater during the short rain than in the long rainy season (Table 4.5). No difference was observed during the long rainy season.

Furadan application significantly decreased percent bored internodes and tunnel length during the long rains in both the low and high nitrogen treatments (Table 4.6), but the effect was not significant during short rains.

4.5.4 Effect of nitrogen on maize yields

During both seasons, cob and grain weight increased with nitrogen level (Table 4.7). Cob yield increased 2.7 to 7.5 times from N0 to N3, during the short rains, and it was 2.3 to 3.8 times compared to the zero N application during the long rain season. Yield gain of maize grain had a similar trend. During seasons and both the N0 and N3 treatments, cob and grain weights were not affected by the Furadan treatment (Table 4.8).

Plate 4.1 A parasitized stemborer *Chilo partellus* larvae.

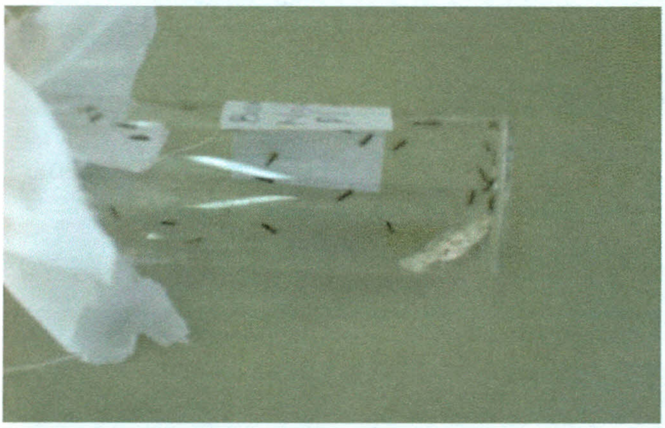


Plate 4.2 *Cotesia* spp emerged from cocoon reared at Kizimbani laboratory

Plate 4.3 Preserved bottles with *Co. flavipes* and *Co. sesamiae* ready for identification.

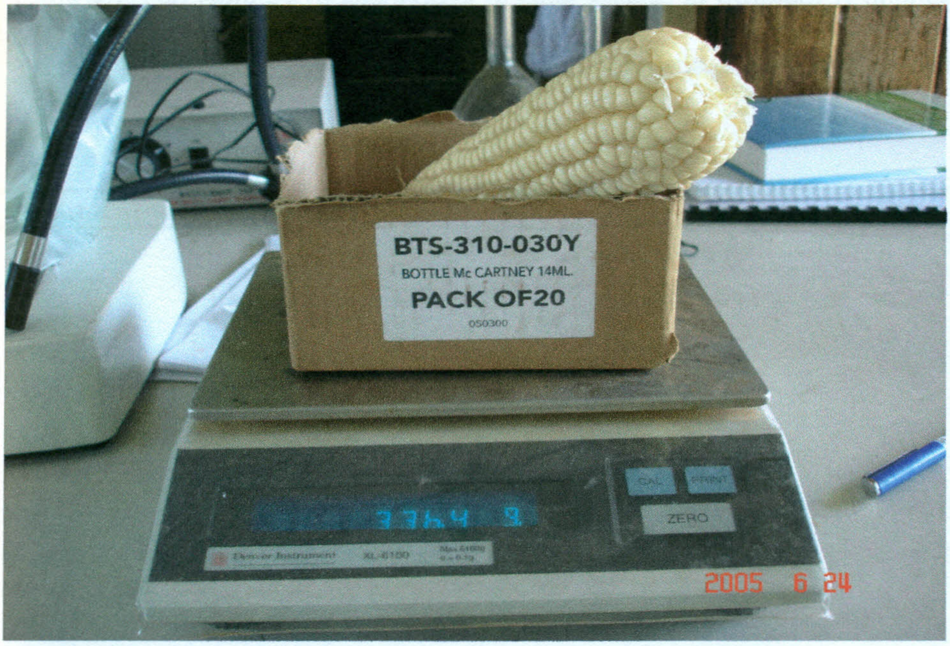


Plate 4.4: Weighing of cob weight.

Plate 4.5: Effect of Nitrogen level on maize growth and yield.

Table 4.1 The Number of stemborers of each species at different N application rates during short rain and long rain at Bambi Agricultural research station in Zanzibar of 2004/05.

Treatment	Short rains			
	Ch. partellus	*S. calamistis*	*Ch. orichalcociliellus*	**Total borer**
N0	1.0±0.2b	0.37±0.1a	0.08±0.04a	1.5±0.2c
N1	1.7±0.2ab	0.58±0.1a	0.13±0.05a	2.4±0.3b
N2	3.0±0.4a	0.59±0.1a	0.11±0.05a	3.7±0.4a
N3	2.1±0.3ab	0.71±0.2a	0.07±0.03a	3.0±0.32b
F-value	5.84	0.88	0.47	16.58
P-value	0.0006	0.452	0.700	<. 0001
	Long rains			
N0	0.7±0.1b	0.1±0.03a	0.01±0.01a	1.0±0.2a
N1	1.0.±0.1ab	0.2±0.08a	0.01±0.01a	1.0±0.1a
N2	1.3±0.2a	0.2±0.05a	0.02±0.02a	1.4±0.2a
N3	1.1±0.1a	0.1±0.04a	0.04±0.04a	2±0.1a
F-value	3.86	1.31	1.22	0.74
P-value	0.009	0.271	0.302	0.527

Means (± S.E) in the same column followed by the same letter(s) are not significantly different (Student-Newman-Keuls, P<0.05).

Table 4.2 Effect of pesticide (Furadan) on stemborer density during short and long rain seasons in Zanzibar of 2004/05. (N0P = Protected with furadan with zero N; N0 = neither furadan nor fertilizer; N3P = 5g[N] and with Furadan; N3 = 5g[N]/plant and without Furadan)

Treatment	Short rains			
	Ch. partellus	***S. calamistis***	***C. orichalcociliellus***	***Total borer***
N0P	0.2±0.1b	0.03±0.02b	0.00±0.0a	0.2±0.1b
N0	1.0±0.2a	0.37±0.10a	0.08±0.0a	1.5±0.2a
t-value	-5.68	-3.60	-1.73-	-8.86
P-value	0.0001	0.0004	0.086	0.0001
N3P	0.2±0.05b	0.1±0.0b	0.0±0.0b	0.2±0.1b
N3	2.1±0.29a	1.0±0.2a	0.1±0.0a	3.0±0.3a
t-value	-7.10	-4.28	-2.44	9.73
P-value	0.0001	0.0001	0.016	0.0001
	Long rains			
N0P	0.5±0.1a	0.0±0.0a	0.00±0.0a	0.5±0.1b
N0	0.7±0.1a	0.1±0.0a	0.01±0.0a	1.0±0.2a
t-value	-1.75	-0.92	-1.42	-3.91
P-value	0.082	-0.359	0.157	0.0001
N3P	0.2±0.1b	0.03±0.02a	0.01±0.01a	0.23±0.06b
N3	1.1±0.1a	0.09±0.04a	0.04±0.04a	1.18±0.14a
t-value	-6.87	-1.30	-1.34	-7.02
P-value	0.0001	0.196	0.183	0.0001

Means (± S.E) in the same column followed by the same letter(s) are not significantly different (Student-Newman-Keuls, P<0.05).

Table 4.3 Effect of different nitrogen level on parasitism of *Co. flavipes* and *Co. sesamiae* on maize stemborers.

		Short rain						**Long rain**					
Parasitoid	Host	N0	N1	N2	N3	χ^2	P	N0	N1	N2	N3	χ^2	P
Co. flavipes	*Ch. partellus*	3.33	9.61	5.38	7.17	3.69	0.30	5.82	6.76	6.60	5.66	0.19	0.98
	S. calamistis	0	2.80	2.8	0	5.63	0.13	0	3.22	4.54	21.42	36.69	0.0001
	Ch. orichalcociliellus	0	0	0	37.50	115.57	0.0001	50.0	100.0	63.36	36.36	296.68	0.0001
Co. sesamiae	*Ch. partellus*	0	1.44	0.83	0.30	2.79	0.43	0.90	0	0.90	1.25	2.78	0.43
	S. calamistis	0	1.40	2.8	4.7	6.15	0.10	10.0	0	18.18	0	43.87	0.0001
	Ch. orichalcociliellus	0	0	0	0	-	-	50.0	100.0	9.00	0	416.90	0.0001
Co. flavipes		2.3	7.5	3.6	6.1	9.29	0.026	6.0	7.8	10.6	9.5	2.42	0.489
Co. sesamiae		0	1.4	0.9	1.5	4.47	0.215	2.6	1.2	2.3	1.11	1.55	0.672

χ^2 P = 0.05

Table 4.4 Effect of N level on progeny and sex ratio (No of female/total progeny) of *Cotesia spp.* of each parasitized host at short and long rainy seasons.

Treatment	**Progeny**			
	Cotesia flavipes		***Cotesia sesamiae***	
	Short rain	**Long rain**	**Short rain**	**Long rain**
N0	24.0±4.1a	32.3±6.5b	-	28.3±2.7a
N1	28.4±2.8a	35.5±3.9b	28.8±5.3a	92.0±44a
N2	31.1±4.3a	53.9±6.9a	31.5±14.8a	44.8±20a
N3	43.9±6.3a	32.0±3.8a	26.8±1.8a	24.0±2.0a
F-value	2.62	3.59	0.08	1.36
P-value	0.06	0.02	0.93	0.32
	Sex ratio			
	Cotesia flavipes		***Cotesia sesamiae***	
	Short rain	Long rain	Short rain	Long rain
N0	0.46±0.13a	0.87±0.02a	-	0.79±0.05a
N1	0.52±0.06a	0.73±0.05a	0.69±0.11a	0.80±0.05a
N2	0.48±0.08a	0.80±0.02a	0.61±0.21a	0.83±0.03a
N3	0.84±0.22a	0.82±0.03a	0.68±0.10a	0.62±0.34a
F-value	1.36	2.24	0.08	0.66
P-value	0.26	0.09	0.93	0.60

Means (± S.E) followed by the same lower case letter(s) in the same column are not significantly different; (Student-Newman-Keuls, $P<0.05$).

Table 4.5 Percentage of bored internodes and tunnel length per plant at N application rates during the short (SR) and long rains (LR) in Zanzibar of 2004/05.

	Bored internodes (%)		**Tunnel length (%)**	
Treatment	**Short rain**	**Long rain**	**Short rain**	**Long rain**
N0	29.7±2.0aA	9.4±1.9aB	17.6±1.6aA	3.5±0.9aB
N1	33.6±2.1aA	8.2±1.6aB	16.8±1.8aA	3.2±0.6aB
N2	27.6±2.3aA	11.9±1.6aB	14.7±1.8aA	4.8±0.7aB
N3	19.0±1.9bA	11.7±1.8aB	9.1±1.3bA	4.4±0.8aB
F-value	10.25	1.64	8.32	1.62
P-value	0.0001	0.181	0.0001	0.186

Means (± S.E) followed by the same lower case letter(s) in the same column are not significantly different; Means followed by the same upper case letter(s) in the same row are not significantly different (Student-Newman-Keuls, P<0.05).

Table 4.6 Percentage of bored internodes and tunnel length per plant at N application rates on treated and un-treated plots during short and long rainy seasons in Zanzibar 2004/05 (N0P= Protected with furadan but zero N, N0= neither furadan nor fertilizer, N3P= 5g[N] and Furadan/plant; N3=5g[N]/plant).

	Bored internodes %		**Tunnel length %**	
Treatment	**Short rain**	**Long rain**	**Short rain**	**Long rain**
N0P	31.6±2.4A	2.4±0.8B	21.3±3.2A	0.8±0.3B
N0	29.7±2.0A	9.4±1.9B	17.6±1.6A	3.5±0.9B
t-value	0.60	-3.84	0.45	-3.69
P-value	0.547	0.0002	0.654	0.0003
N3P	21.7±2.1A	3.7±0.9B	13.2±1.6A	1.7±0.7B
N3	19.0±1.9A	11.7±1.8B	9.1±1.3bA	4.4±0.8B
t-value	0.93	-3.96	1.57	-3.39
P-value	0.354	0.0001	0.120	0.0009

Means (± S.E) followed by the same lower case letter(s) in the same column are not significantly different; Means followed by the same upper case letter(s) in the same row are not significantly different (Student-Newman-Keuls, $P<0.05$).

Table 4.7 Maize cob and grain weight (kg/plot [N treatment]) without pesticide at different nitrogen levels in different rainy seasons in Zanzibar 2004/2005. The plant density was 5.56/m^2.

	Short rain		Long rain	
Treatment	**Cob weight (kg)**	**Grain weight (kg)**	**Cob weight (kg)**	**Grain weight (kg)**
N0	2.0±1.0cA	1.4±0.8bA	4.3±1.0cA	2.6±0.64cA
N1	5.4±1.1bB	3.2±1.1bB	10.1±1.2bA	7.1±1.06bA
N2	13.4±1.7aA	10.8±1.2aA	12.1±2.1bA	9.3±1.89bA
N3	15.0±0.5aA	13.1±0.1aA	16.3±1.3aA	13.6±1.15aA
F-value	30.98	25.45	13.13	12.96
P-value	0.0001	<. 0001	0.0001	0.0002

Means (± S.E) followed by the same lower case letter(s) in the same column are not significantly different; Means followed by the same upper case letter(s) in the same row are not significantly different (Student-Newman-Keuls , P<0.05).

Table 4.8. Effect of pesticide (Furadan) on maize cob weight and grain weight (kg/treatment) and two rainy seasons (N0P= Protected with furadan but zero N, N0= neither furadan nor fertilizer, N3P= 5g[N] and Furadan/plant; N3=5g[N]/plant).

	Cob weight (Kg/treatment)		**Grain weight (Kg/treatment)**	
Treatment	**Short rain**	**Long rain**	**Short rain**	**Long rain**
N0P	6.57±2.93a	5.92±0.64a	4.41±2.09a	2.44±0.31a
N0	1.84±0.87a	4.28±0.87a	1.41±0.79a	2.64±0.64a
t-value	1.55	1.52	1.34	0.28
P-value	0.172	0.167	0.229	0.784
N3	14.88±0.47a	16.34±1.27a	13.05±0.48a	13.56±1.15a
N3P	15.31±1.64a	17.04±1.87a	13.33±1.52a	14.08±1.55a
t-value	-0.26	-0.31	-0.18	0.27
P-value	0.806	0.761	0.8640	0.795

Means (± S.E) followed by the same lower case letter(s) in the same column are not significantly different; (Student-Newman-Keuls, $P<0.05$).

4.6 Discussion

The results in this study showed that increase of nitrogen fertilizer increased the number of borers, while plant damages decreased resulting in higher maize yields. Setamou *et al.* (1995) reported that increasing N fertilizer does not only increase maize yields but also pest infestations. It is well known that the nitrogen content of plants can be a crucial factor for the development and reproduction of herbivores (Strong *et al.*, 1984). Saroja *et al.* (1987) reported that every increase in N level resulted in an increase in incidence of both *Scirpophaga incertulas* Walker (Lepidoptera: Pyralidae, Schoenobiinae) as well as yield of rice. Archer *et al.* (1987) found that N increased pest infestations and stem damage while P decreased it, and with combinations of N and P pest numbers were not different from those of the control. The present results showed that maximum yield was obtained at N levels of 60 and 120kg/ha. Sétamou *et al.,* (1995) found a negative linear relationship between average cob weight losses due to borer activity with increase N application. In the present study, high N dosages drastically reduced number of exit holes, tunneling length and bored internodes. Therefore this result concurs with results reported by Sétamou et al. (1993, 1995), Jiang and Schulthess (2005), which indicates that under the prevailing damage levels, the positive effect of N fertilization enhanced plant vigor, and surpassed the negative effect of increased borer's feeding.

The pesticide applications had more effect on borer at high than low stemborer densities. Nevertheless, the treatments applied had little effect on maize yields because it was only applied once, which was not sufficient, corroborating results by (Kalule *et al.*, 1998; Ndemah and Schulthess, 2002). Similarly, Egwuatu (1982) reported that furadan failed to control flea beetles, *Podagrica spp*. on okra during late stage of crop development.

This study confirmed, that *Co. flavipes* has established in Zanzibar. Nitrogen application was found to increase parasitism of *Co. flavipes* corroborating results by Jiang & Schulthess, (2005) who showed that brood size of *Co flavipes* increased with nitrogen level due to an increased quality of the larval host. Sétamou *et al.* (2005) reported that the brood size of *Co. flavipes* significantly varied with the host larval size. However, no significant differences of nitrogen treatments were found in sex ratio and progeny of *Co. flavipes* corroborating result by Jiang and Schulthess (2005).

In Zanzibar, nitrogen and fertility level differ between agro-ecological zones. In plantation zones, soil nitrogen is higher compared with semi-coral and coral rag areas. Higher fertilizer N rate is mostly lower in Northeastern and Southeastern part of the island, where the soil is sandy loamy and rocky. In Central and Western Districts, the soils are fertile with higher N rates. However there is variability of soils patches (Fig 2.1). Moreover, in the Unguja Island, the much more productive areas are the Central and Western zones. The Northern and Southern zones are not good for farming due to their coral nature and unreliable rains. (Fig 5.1). Therefore lower maize production in these areas was the results of lower N in the soil in Coral rag zone. Application of N at 5g/plant is best option for maize production and it also reduces incidence of stemborers attack. Lower rate of N application (0. 2.25 and 1.13N/plant) tend to increase borers population.

CHAPTER FIVE

ASSESSMENT OF FARMERS AWARENESS ON THE USE OF BIOLOGICAL CONTROL IN THE MANAGEMENT OF CEREAL (MAIZE) STEMBORERS

5.1 Introduction

Maize was introduced into East Africa in 17th century with varieties originating from the Caribbean which were only suited to the coastal strip of E. Africa (Seshu Reddy, 1998). Although it is not known when maize first arrived in Zanzibar, the earliest available record indicated that by the 1870s it was being grown (Burton, 1872). Sorghum, on the other hand, is a native African cereal crop reported to have originated in Sudan/Ethiopia boarder region (De Wet, 1978) and was already being grown in Zanzibar by 1860s (Rigby, 1861). In Zanzibar, maize is mainly grown as subsistence food, though farmers sell their surplus in order to buy other household commodities such as cooking oil, soup, sugar, clothes etc. Cultural practices are the major way used by farmers for controlling pests such as stemborers, which destroy and cause severe damage if control measures are not applied (SMZ, 1987). In Africa the majority of poor peasant farmers cannot afford to buy insecticides, and furthermore, these insecticides are seldom available on time, and have required proper application, equipments and appropriate knowledge (Bosque-Pérez and Schulthess, 1998, Bonhof *et al.,* 2001). Classical biocontrol is a pest management approach that involves the importation of natural enemies from one geographic area of the world, and the release of the natural enemies in another area of the world, where they formerly did not exist, for sustainable suppression of specific pest population (Ehler, 1982). The objective of this study was to assess farmer's knowledge on the biocontrol of cereal stemborers, evaluation on effect of maize stemborers between long rainy and short rainy seasons and to study factors affecting maize yield and different tactics used by farmers to control maize stemborers in Unguja island of Zanzibar.

5.2 Materials and methods

5.2.1 Selection of farmers

A semi-structured questionnaire (Appendix 1) was administered to 50 farmers from Unguja Island in order to collect information on their knowledge about biological control of cereal stemborers. The survey was conducted during the long rainy season in 2005. In the Central District, farmers were randomly selected out of 250 farmers from maize growing areas and about 50 farmers were selected which represent 20%. The distance between one farmer to another ranged between 1 to 10 kilometers. GPS was used for direction and to measure the distance. In some villages, 2 to 3 farmers were interviewed depending upon the population of maize farmers. Farmer's selection was done in collaboration with BEO's (Block Extension Officers) and District agricultural specialist who prepared the scheme of the areas to be surveyed. The survey was conducted between the tasselling and hard dough stages of maize in the field, because at this stage most farmers were present in their farms to scare away wild animals that attacked their crops.

5.3 Methodology

Extension officers and maize farmers were involved in this study. The questionnaire was used to obtain information from the farmers. In addition secondary information was obtained from District agricultural offices, books, journals, local reports and other government unpublished reports. The questionnaire was pre-tested with five farmers to determine its suitability and a few adjustments made. The questionnaires were distributed afterwards to the plant protection officers for discussion and comments before use. One highly structured questionnaire was used for different objectives. Data was collected by direct interviewing the farmers and village leaders were interviewed whenever necessary.

5.4 Results

In the survey, the average (mean) land size of all farmers interviewed was 11 acres. However, the majority of farmers owned between 1 to 3 acres distributed by the government after 1964 revolution. About 66% of farmers interviewed practiced intercropping because of land scarcity. Most of these farmers had practiced agriculture for more than 20 years. About 42% of farmers interviewed reported that, bad weather, pest and diseases, and weeds are the major factors, which contribute to low yield of maize. About 98% of farmers complained of soil fertility. The long rain is generally reliable throughout Zanzibar, while the short rain is less reliable particularly in the Eastern coral rag areas of marginal land quality (Fig. 5.1). Most samples of the surveyed farmers were of the opinion that during the short rains the stemborers oriented destruction is massive. The survey findings indicated that 42% of the surveyed farmers commented on the massive destruction caused by stemborers during the short rains, 24 % associated it with the long rains and 34% found the destruction almost similar in both the rainy seasons.(Fig. 5.2). In all villages, about 56% of farmers used inorganic pesticides, 18% used botanical pesticide (Neem, Mucuna), 18% was dependent on biological control and 8% used cultural and local pesticides, e. g. cooking ash, mucuna, neem, early planting, burning of crop residues, removal of infested plants and local variety which they believe to have resistance or tolerance against maize stemborers and bad weather (Fig. 5.3). Unreliable rains make it difficult for farmers to plan their cropping calendar. Pest and diseases reduced yields by up to 50%, and about 12% of farmers reported that pest (stemborers) was the main obstacle of maize production. The presence of wild host plants all over the island harbors stemborers during off-season. Weeds such as *Striga asiatica* and nut grass *Cyperus rotundus* can cause 100% losses if timely weeding was not done, normally 2-4 times during growing season. Weeds were a major problem for upland farmers who practiced intercropping. The delayed weeding in rice areas reduces yields by 30-40 percent. Most soil in Zanzibar has a very low water holding capacity due to the sandy nature of the topsoil and subsoil horizon. In coral rag areas, where the soil texture is silt loams, with porous underlying crevices of limestone, the problem is even worse. Therefore, soil fertility is a crucial problem and many farmers might stop planting maize without alternative inorganic or organic nitrogen fertilizer during the season. Low soil nutrient level was a result of continuous farming and non-replacement of nutrients. High percentage of farmers were dependent on farmyard manure due to high cost of inorganic fertilizer, although most farmers still want to use inorganic fertilizer because of its quick effectiveness. Besides, rats destroy seeds and dried maize during planting and harvesting period if seeds are not treated with chemicals.

5.5 Discussion

The use of pesticides is still the main method of controlling maize stemborers and other agricultural pests. Most farmers who were interviewed pointed out that pesticides could solve their problems in a short period, but used it only occasionally because of the high cost. Since the government is still reducing subsidies, the cost/benefit ratio is high. If a farmer decides to use both pesticide and fertilizer, price of fertilizer and pesticides are 25,000Tsh, and 10,500Tsh/acre, respectively (District Agricultural report unpublished 2003). Average price of maize is 5,140Tsh/50kg and the average yield of a farmer is 16.65 bags (50kg/bag) with a farm size of 11.35 acres, which means that the farmer gets 85,581Tsh (SMZ, 1987). Therefore, farmer's income cannot cover the cost of pesticide or fertilizer. Thus using insecticides was not profitable under high-pest-low-soil fertility conditions. Mgoo *et al.* (2006) in Tanzania reported that nitrogen application increased maize yield by compensating for borer damage and farmers income increased with nitrogen level.

Various control measures have been used in attempts to reduce the losses due to stemborers, including chemical control, cultural practices, the use of host plant resistance, and biological control. Stemborers have been controlled with insecticidal dust applied against young larvae entering the plants (Swaine, 1957; Walker, 1961), but this method is not often economical for subsistence farmers. Although insecticides may be effective, they are expensive and their application must be precisely time to control borers before they enter the stalk (Mathez, 1972; Ingram, 1983)

Commercial farming was not very common in early 1980's (SMZ, 1987); most farmers only sold some surplus produce to provide for daily necessity. Maize is harvested when it is green because the price of green maize is more profitable. About 60% of farmers interviewed engaged in agriculture for food and income, they sold short maturity crops, e.g. vegetables, maize, sweet potato, yams etc. Very little was retained for daily use on their meals. 50% of farmers are now adopting improved varieties, although I recommend farmers not to abandon the local variety, which is more resistant to drought and pest attack. Local variety seems to perform well in coral rag areas. 44% of farmers interviewed started to control pest when the maize infestation was 1%, while 36% of them applied pesticide when 10% of their maize was infested. Performance of *Co. flavipes* in Zanzibar is improving; however, the results showed that more social education was required to improve the awareness of the effects of *Co. flavipes* in Unguja. Among 50 farmers, about 40% mentioned the *Co. flavipes* is performing fairly, 24% mentioned the performance is good or very good, and 36% mentioned that they had no alternative to the new biocontrol program.

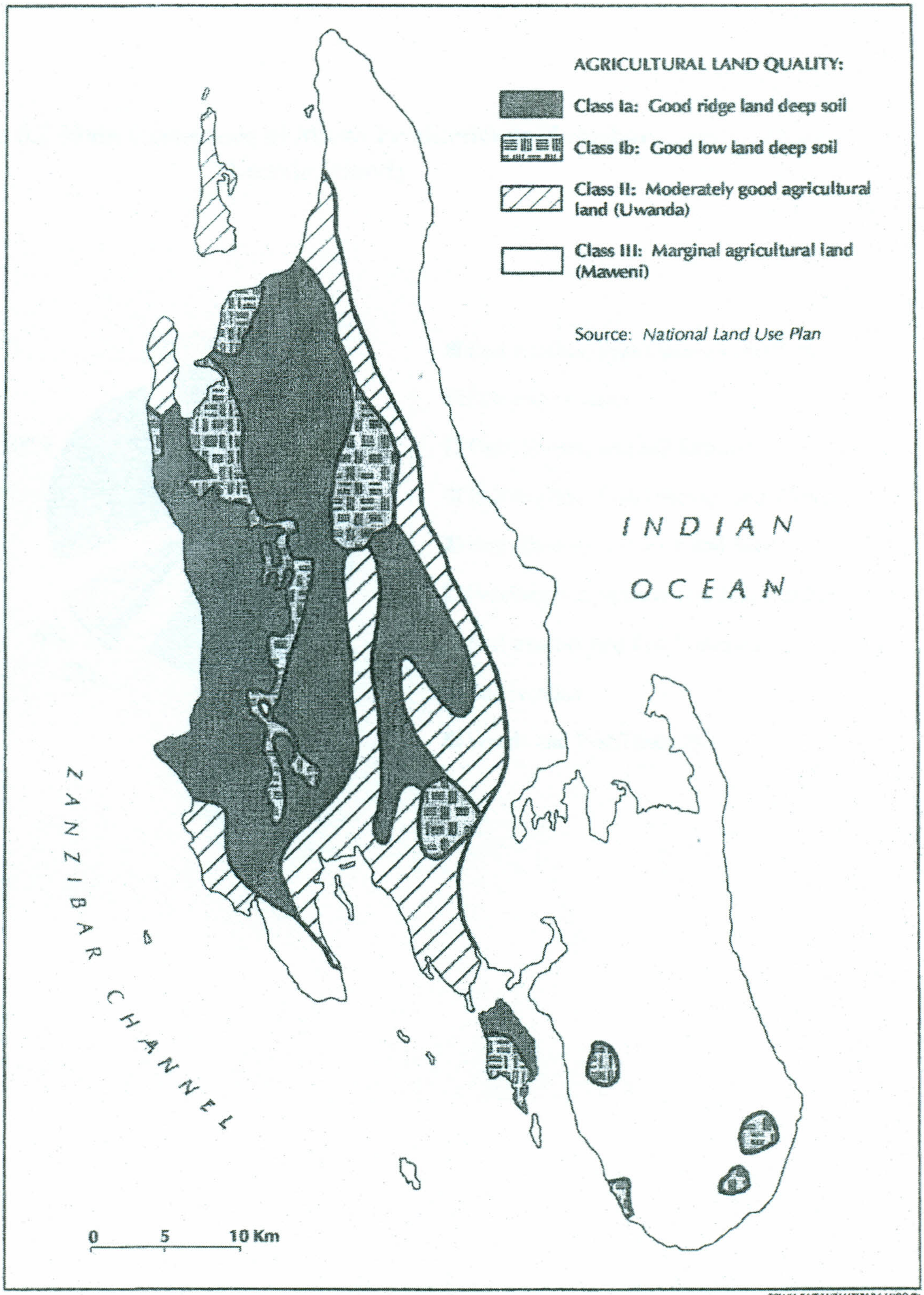


Fig. 5.1 Agricultural land quality distribution of Zanzibar (Unguja Island)

Fig 5.2 Main Constrains of Maize Production in Zanzibar (Unguja Island)

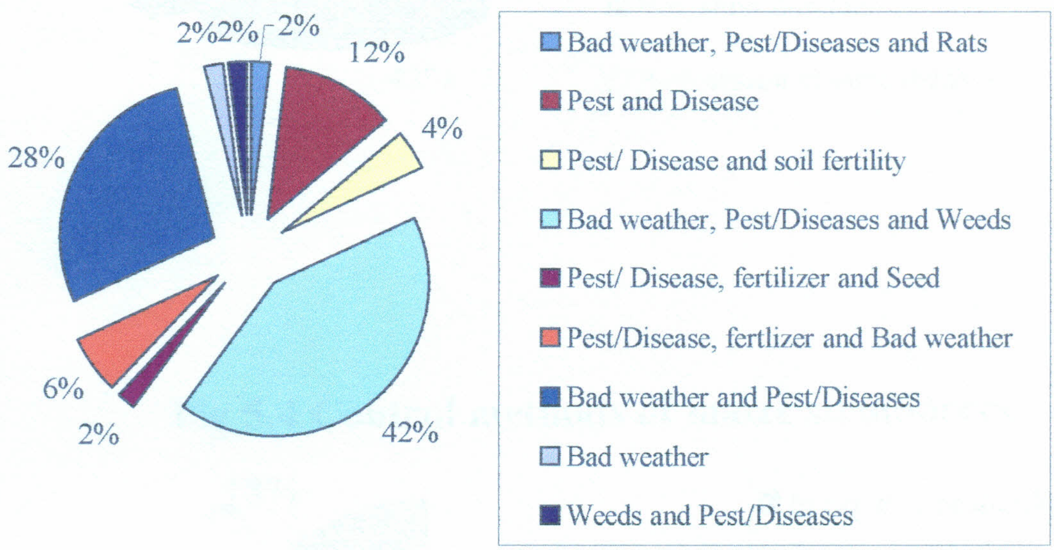


Fig 5.3 Percentage stemborer damage by rain season

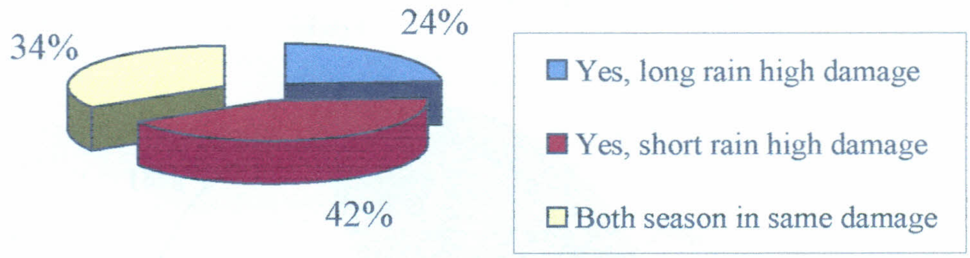


Fig 5.4 Control methods of maize stemborers

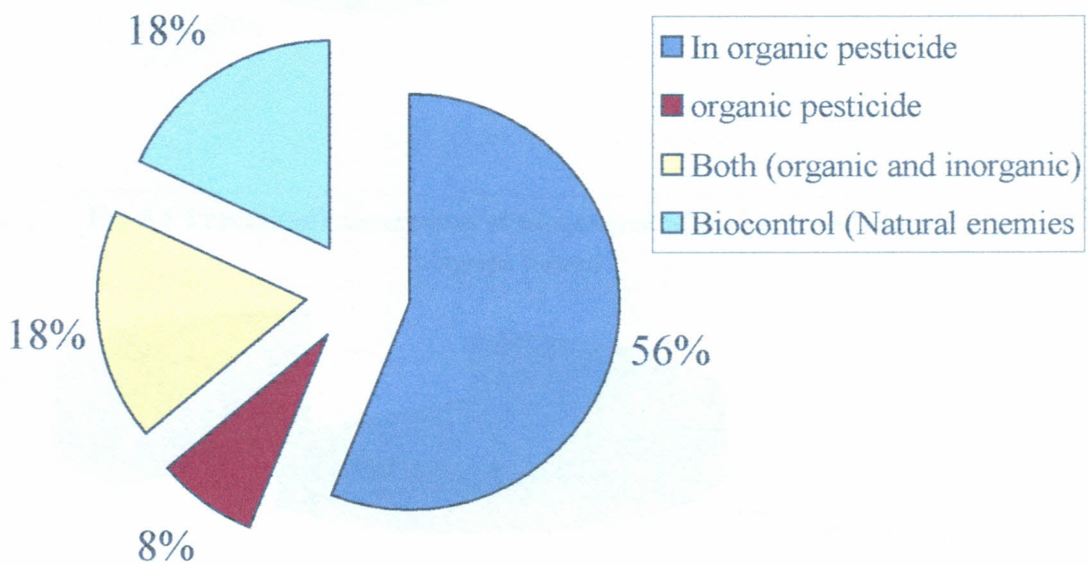


Fig 5.5 Farmers assessment on the use of *Co. flavipes* in Unguja island

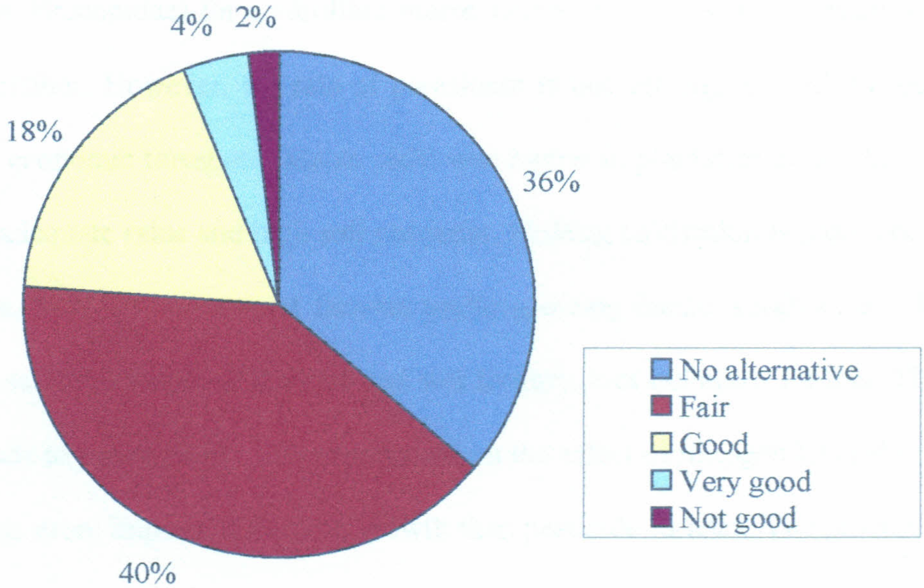
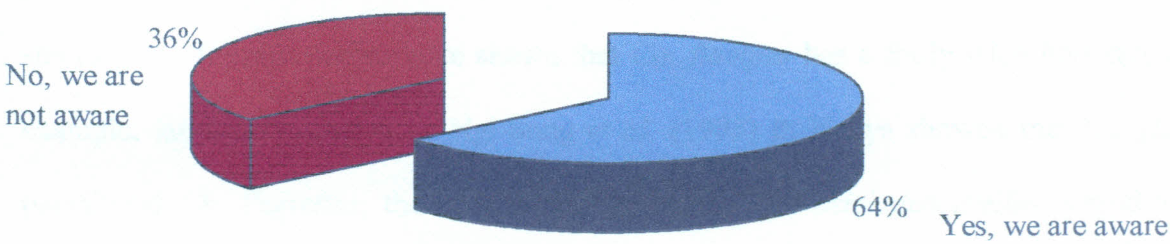


Fig 5.6 Percentage awareness of biocontrol of maize stemborers Unguja Island



CHAPTER SIX

GENERAL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

6.1General discussions

This study indicated that the establishment of exotic larval parasitoids *Co. flavipes* (Hymenopteran: Braconidae) for controlling maize stemborers has been successful in all the Districts in Zanzibar. However, the rate of parasitism is not yet high enough to reduce the damage below economic threshold. Maize yield was higher in plantation zone; this is due to availability of adequate rains and high soil nutrients. Shifting cultivation is more common in coral rag zones. In these zones most farmers prefer growing maize, sorghum and legumes than rice because of the nature of the land and soil fertility does not allow for that. The lower soil fertility leads to lower yields. The experiment on the effect of nitrogen level showed that this nutrient was more important for crop growth than pesticide furadan. The process may be interfered with by the use of synthetic pesticides and inadequate application of nitrogenous fertilizers by farmers. Based on the research results at Bambi research station, it showed that nitrogen fertilizer was a crucial factor that increased population of stemborers and the parasitism in Zanzibar, and the yield was not dependent on the use of pesticides to control stemborers. Various studies have shown that *Co. flavipes* has a fairly wide host range. For example, laboratory studies by Ngi-Song *et al.* (1995) in Kenya showed that *Co. flavipes* parasitized *Ch. Partellus*, the indigenous stemborers *Ch. orichalcociliellus* Strand and *S. calamistis*. Similar results were obtained from the research experiments in Zanzibar. This is not surprising since *Co. flavipes* is a co-evolved old association natural enemy of *Ch. partellus* whereas the association with *S. calamistis* is new in Zanzibar. Analysis of its abundance has showed that the stemborer population has declined in successive seasons since its introduction and that the stemborer mortality due to larval parasitoids has increased exponentially (Zhou *et al.*, 2001; Omwega *et al.,* 2006). Old associations are usually more successful compared to new associations between pest and natural enemies in the biological control of stemborers (Smith *et al.,* 1993). *Co. flavipes* has not yet become an important mortality factor of stemborers in Zanzibar. The survey finding showed the parasitism of larval parasitoids of cereal stemborers by *Cotesia sp* has increased from 4% in 2001 to 8.74% by 2005. Narkagati and Nair (1973) reported 25-44% parasitism in India. The ultimate impact of *Co. flavipes* on *Ch. partellus* in Africa cannot be measured until the population has stabilized at an equilibrium density (Overholt *et al.,* 1997). Awareness campaign must be initiated in Zanzibar in the next 2 years to enable farmers to understand the negative impact of using pesticides that are harmful to *Co. flavipes* and other natural enemies of maize stemborer. Saxena *et al.* (1990) suggested that cultural practices e.g. early planting, intercropping of appropriate crop combinations and destruction of crop residues might help to suppress borer attack. However, many farmers cannot adopt early planting because of lack of farm laborers and appropriate farm implements such as tractor, maize seeds and fertilizer. Beside, stemborers attack, bad weather, weeds, soil fertility, diseases, rats and seed are other factors that contribute to low yield on maize in Zanzibar. Some farmers use pesticides, but the misuse of pesticides that was hazardous is due to poor information offered to farmers (Saxena *et al.*, 1990). This situation must be discouraged and emphasis should be made to other control tactics such as early planting, timely weeding, application of recommended rate of fertilizers, the use of resistance varieties and early maturity.

Tunneling caused reduction of essential nutrients for growth and development of the plant. The development of phytophagous insects often depends on the physiological condition of the plant. Mineral nutrition is one of the major parameters influencing the health and thereby quality and quantity of plants as food for herbivores. Taylor *et al.* (1952) recorded higher survival and growth rates of the European corn borer, *Ostrinia nubilalis* (Hűbner) (Lepidoptera: Pyralidae) reared on maize plants growing on complete nutrient diet than on NPK stressed plant. Variation in agro-ecological zone and the level of soil nutrients between coral rag, semi-coral and plantation showed significant differences in maize yields on the island, which higher production was found in plantation zone than semi-coral areas. Maize production on the island is also based on the rainfall. The short rains were lower and not reliable, which led to poor yield and higher damage by stemborer. During long rainy seasons, maize yield was also very low but then was less damage by stemborers. Results from farmer's questionnaire also reflected that short rainy season had a higher maize infestation by cereal stemborers than long rains due to favorable temperature ranges between 25 to 33C°. In addition low fertility is a crucial problem in maize production in Unguja island of Zanzibar.

Co. flavipes is becoming an important mortality factor of stemborer and was found in all Districts in Zanzibar since it was released in 1999. The study showed that parasitism of *Co. flavipes* is higher compared to other parasitoids. *Co. flavipes* and *Co. sesamiae* were found to parasitize all borer species, which concur with previous studies (Niyibigira *et al.*, 2001b; Emana *et al.,* 2001). In addition to *Co. flavipes* and *Co. sesamiae*, other pupal, larval and hyperparasitoids belonging to the Hymenopteran family of Braconidae were found.

6.2 Conclusions

1. *Cotesia flavipes* can increase its population if farmers use fertilizer and avoid the use of insecticides in all maize growing areas.

2. *Cotesia flavipes* was found to parasitize *Chilo partellus, Sesamia calamistis* and *Chilo orichalcociliellus* stemborers species on the Island.

3. Both indigenous and exotic parasitoids were found to be preferentially attracted in Zanzibar and live with their aboriginal hosts (*Ch. partellus* for *Co. flavipes* and *S. calamistis* for *Co. sesamiae).*

4. The results showed that the niche of *Co. sesamiae* (indigenous larval parasitoid) would be overlapped by the release of *Co. flavipes*; therefore they are likely to compete for resources available.

5. Chemical control is not suitable for the stemborer when the soil fertility is low.

6. Farmers' education on biological, cultural and chemical control is very important to secure the objective of minimizing the cost of production in cereal crops and improve their live standard.

7. Additional studies of egg and pupal parasitoids of cereal stemborers would improve biocontrol in Zanzibar.

6.3 Recommendations

Further research and information in the following areas are required to provide more knowledge on stemborer control to small-scale farmers and will be useful for designing a classical biocontrol and can be used in IPM control programme of maize stemborers in Zanzibar:

1. There is need to understand the effect of hyperparasitoids and predators against *Cotesia spp*.
2. To evaluate the interaction between *Co. flavipes* and other natural enemies of maize and sorghum stemborers.
3. Factors that may cause poor performance and establishment of exotic larval parasitoid, *Co. flavipes*. For example, pesticides, predators, weather etc.
4. There is need to understand the population density of *Cotesia* spp and its prey (stemborers) during on and off-season.
5. Evaluate the effect of pesticides use against natural enemies, in particular larval parasitoids *Cotesia* spp of maize stemborers in Zanzibar.

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APPENDIX

Appendix 1: SURVEY QUESTIONNAIRE

Name (option) ……………………………………………… Quest. No……….
Name of interviewer……………………………………………………
Location ………………………………… **District…………………**
District ………………………….. **Sex ……………………..**
GPS…………………………………….. **Date ……………………………..**

1.1.3: Hypotheses

1. There are no differences in level of establishment between the released areas in the Island.
2. The level of parasitism on maize stemborers is the same between Vuli growing season (short rainy) and Masika growing season (long rainy).
3. Maize yield are not affected by borer attack at different nitrogen level.
4. Effect of pesticides on stem borer's population and maize yield is low.

1.1.4: Overall objective

To assess the establishment and efficacy of *Co.flavipes* released against stemborers of maize and sorghum in Zanzibar.

1.1.5: Specific Objectives:

1. To determine the rate of parasitism of *Co. flavipes* released in different sites in Zanzibar.
2. To assess the distribution and damage levels of stem borer species in relation to native and exotic parasitoids in Zanzibar.
3. Awareness building among smallholders of the importance of using biological control method compared with expensive chemicals method.
4. The effect of stemborer, nitrogen and pesticide on maize yield

1. What is the size of your farm?
2. a) What have been your major farm enterprises?
   b) What size of land was allocated to each of these enterprises?

MAIZE PRODUCTION

3. For how long have you been growing maize _____ Years?
4. a) How do you plant your maize?
   1. Mono crop 2. Intra-row planting
   3. Relay crop 4. Inter-row planting

   b) For the practice named in 5 (a) above, name the crops involved.

   ……………………………………………………………………
5. a) Did you plant some crops as edge rows in your maize field?
   Yes No

   b) If yes, Name the crops. ……………………………………

6.Rank the following purposes for growing maize in order of preference (*1 – very important, 2- moderate, 3- low, 4- very low)*

- Food

- Income
- Cultural
- Other (specify)……………………………

7. What maize varieties do you grow?
8. a) What yields did you obtain?

b) Using the scale of 1-5, rank the following in the order of significance in influencing maize yield. (*1 very significant 5 least significant)*

- ❑ Bad weather
- ❑ Pests and diseases
- ❑ Low soil fertility
- ❑ Poor seeds
- ❑ Weeds
- ❑ Others (specify)……………………………………..

9. What was the selling price per unit of the quantities sold? (Specify units).

STEM BORER

10. Do you recognize stem borer infestation in the farm? Yes No
11. Is stem borer (*Local name*) a common problem in the maize field?

Yes No

12. Please select the infestation level of stem borer in the maize farm.

Infestation	100%	75%	50%	25%	5%
Stem borer					
other pests					
Birds					
Rats					

13. What cropping season are they common? Long rain Short rain
14. a) Do you control stemborers in the field?

a. Yes No

b) If yes, how do you control them? If you use more than one measure, rank the measures in order of priority.

Measure *Rank*

- ❑ Spray with commercial insecticides ……..
- ❑ Used local insecticides ……..
- ❑ Put soil ……..

Others (specify)……………………… ….……………………

None

15. When do you start controlling the stemborers?
    - ❑ At specific time whether infested or not
    - ❑ When at least one plant infested
    - ❑ When 10% plants are infested
    - ❑ When over 50% of plants are infested
    - ❑ When close to 100% of the plants are infested
16. When did you apply pesticide?

First wk after planting

Once the first symptoms are seen
Before infestation
When majority of maize has been affected

17. Name of pesticide you used. .... How much did you spend to buy pesticide per season?

Natural enemies

18. a) Are you aware that there are some natural enemies (of stemborers) that can be used to control stemborers?

Yes No

b) Where did you get information about natural enemies?
Radio…….., Tv…………., News paper………, Extension service………, Seminars………, neighboring farmers…………, Village leader…………..,
Other specify
c) What is the incidence of maize stemborers after release of natural enemies?……………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………

Soil fertility

28. a) Did you have soil fertility problem? Yes No
b) If yes at which level 100%, 75%, 50%, 25% and 5%.
c) How did you overcome the problem? 1) Application of manures 2) application of inorganic fertilizer 3) No alternative.
d) Did you apply inorganic fertilizers Yes No. If yes?
Name…………………………………………… Season……………………………
e) Where did you obtain? Agric office……., Private company……, Local traders……
f) Did you afford to buy Yes No
g) Please indicate the price of inorganic fertilizer and organic manure fertilizer per 50kg /bag.

Appendix 2: Map of Zanzibar (Unguja Island) showing major released of *Co.flavipes* and survey study sites.