STUDIES ON INFLUENCE OF SOWING TIME OF BEANS (*PHASEOLUS VULGARIS*) ON LEVEL OF INFESTATION AND PARASITISM OF THE BEAN STEM MAGGOT

By

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ABSTRACT

The influence of time of sowing of beans, *Phaseolus vulgaris*, on level of infestation and parasitism of the bean stem maggot (BSM) (*Ophiomyia* spp) was studied during off-season cropping of beans at Madira farm, Tengeru. Two bean varieties, Lyamungu 90 and ZPV 292, which are susceptible and tolerant to BSM, respectively, were sown in the field. Three sowing dates were adopted; early, normal calendar and late sowing in a split-plot design. The abundance of BSM pupae in bean stems and the number of cracked stems due to infestation were established. *Ophiomyia spencerella* were the dominant bean fly maggots infesting the crop. Sowing dates had significant ($p < 0.001$) influence on BSM infestation. Early sown beans experienced low BSM infestation. The bean variety ZPV 292, was relatively less infested. Braconids were the dominant parasitoids and the relationship to the host population was density dependent. Parasitism reduced emergence of BSM by about 68%. Variety and sowing time (factor) interaction had no significant ($p > 0.05$) influence on BSM infestation and natural enemies parasitism. The study shows that timely sowing of beans enable the crop to escape peak population of BSM at the most vulnerable plant growth stage. The study further shows that natural parasitism by Braconids play an important role in maintaining a low population of BSM.

DECLARATION

I, John Elias Sariah, do hereby declare to the Senate of Sokoine University of Agriculture that the content of this dissertation is my original work which not being submitted for a higher degree award in any other University.

Signature.....Date.....04/04/2003.....

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Last and most important, I thank Jesus Christ for making all this possible and more.

DEDICATION

This dissertation is dedicated to my beloved late mother Elilimika E. Sariah who suddenly died at home in Moshi on December 2002 and could not see this work go to completion. Her constant inspiration made these all possible.

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LIST OF ABBREVIATION AND ACRONYMS

AVRDC = Asian Vegetable Research and Development Centre

BSM = Bean Stem Maggot.

CIAT = Centro Internacional de Agricultura Tropical.

DMRT = Duncan Multiple Range Test.

RBFRN = Regional Beanfly Resistance Nursery.

CHAPTER ONE

1.INTRODUCTION

1.1 Importance and production level

Beans (*Phaseolus vulgaris* L) form an important food and cash crop in Africa, particularly in the eastern, southern, and Great Lakes regions of the continent. Of all agricultural commodities produced in these regions of Africa, beans are considered the second most important source of human dietary protein (after maize) and the third most important source of calories (after maize and cassava) (Pachico, 1993). The common beans (*Phaseolus vulgaris* L) is an important leguminous source of protein and carbohydrates to people in the tropical and subtropical countries of Africa, South East Asia and Latin America. In these countries, beans are cultivated mainly by small scale farmers. Leaky (1970) reported that up to 20g of protein can be derived from every 100g of dry shelled seeds of common beans consumed. Beans are grown in the majority of the African countries, but most production is in Burundi, Rwanda, Kenya, Uganda Tanzania, Zaire, Malawi and Mozambique, with annual estimated total area under cultivation of approximately 3.9 million hectares (Wortmann and Allen, 1994). The major producers (metric tonnes) are Kenya (414000), Uganda (395000), Tanzania (283000), Zaire (269000), Rwanda (220000), Burundi (169000), Ethiopia (120000), and South Africa (104000) (Abate and Ampofo, 1996). Together, African nations produce over 2.5 million metric tonnes (approximately 25% of the global production) of dry beans annually, with an average per capital consumption of 14.4 kg per year (Pachico, 1993). Beans

originated in the highlands of Central and South America (Gept and Debout, 1991).

Beans were introduced into Africa some 400 years ago (Leaky, 1970, Parseglove, 1974). The crop was introduced without many of its field pests. The pest spectrum for beans in Africa therefore differs significantly from that attacking the crop in its ancestral region with exception of storage pests, which are cosmopolitan in their distribution (Abate and Ampofo, 1996).

Beans production systems, and farmers practices, vary widely across geographic regions. They range from low latitudes, sub-humid eastern African highlands with high potential productivity to mid-latitude, semiarid areas at mid-altitudes with acidic soil and low potential for productivity (Abate and Ampofo, 1996). Depending on the environment, beans can be grown either as sole crop or in intercropped with other crops (Assefa, 1994).

Yield potentials in the range of 3-4 tonnes per hectare are frequently reported, but bean yields in traditional cropping systems remain low (0.6 tons/ha) because of lack of improved varieties, poor management practices and the ravages of pests, especially bean stem maggot (BSM) and diseases (Abate and Ampofo, 1996).

1.2 Constraints

Karel (1983) reported that there are eight pest species of economic importance attacking beans in Tanzania. These are the bean fly (*Ophiomyia phaseoli*), aphids (*Aphis fabae*), flower thrips (*Taeniothrips sjostedti*), pod borers (*Maruca testulalis*) and (*Helicorvepa armigera*), Bruchids (*Acanthocelides obtectus*), *Ootheca beningseni* and *Acanthomia horrida*. Among these pests, the beanfly (*Ophiomyia* spp Diptera: Agromyzidae) has been reported to be one of the most important pests limiting beans production in Africa, Asia and Australia. In Tanzania there are two species of Bean Stem Maggots (BSM) *Ophiomyia phaseoli* (Tryon) and *Ophomyia spencerella* (Greathead). *Ophiomyia phaseoli* is predominant in the early season while *O. spencerella* is dominant in the late season (Oree, 1990). The chemical control of these BSM is difficult and uneconomical. However they can be easily and cheaply controlled by cultural methods (Otanes, 1918). Presently the control of these pests involves an integrated approach. Chemical control has been the most widely used method (Okinda, 1979; Jones, 1965; Wickeramasinghe and Fernando, 1962; Walker, 1960). Biological control by parasites has been reported to be effective (Greathead, 1969). Cultural practices recommended to farmers in attempt to avoid or reduce effects of beanfly infestation on beans have been employed (Irving, 1986; Karel *et al.*, 1981).

The incorporation of characteristics that impart resistance to this pest in beans could be the cheapest and environmentally safe technique of control of beanfly. This has so far been difficult to achieve because such characteristics have not

been discovered in beans (Talekar, 1986). Screening bean varieties for resistance to *Ophiomyia* spp has been undertaken by some workers (Karel and Maerere, 1985; Rwamugira and Karel, 1984; CIAT, 1981).

Progress in screening bean germplasm for resistance to bean fly has been hampered by lack of consistence in results by different workers (Oree, 1990). Studies conducted by regional beanfly resistance nursery (RBFRN) of the International Center for Tropical Agriculture (CIAT) in Zambia have indicated two important facts. First they found that resistance of one bean accession to one species of *Ophiomyia* does not necessarily mean effective resistance against another, although some host genotype (Xan58, G4489) were reported to have partial resistance to both *O. phaseoli* and *O. spencerella* (Cardona *et al*; 1986). They also reported that in eastern Africa, bean accession A62 A74, and G5653 are known to be consistently tolerant at various sites. Lines A161 and G5711 have variable performance. At Msekere in Zambia, where *Ophiomyia* species identification has bean undertaken, the variety A161 was reported to be resistant to *O. phaseoli* but susceptible to *O. spencerella*. The same accession has also been reported susceptible at Morogoro (Kornegay, 1986).

It was observed that the three species of *Ophiomyia* that existed at a single site (Msekere) located at 1025 meters above sea level (masl) in Zambia tended to change in predominance within a season (Irving, 1986; Allen, 1986). Antrique *et al.*, (1989) in a recent study at Imbo (800 masl) in Burundi also reported

temporal changes in the populations of the three beanfly species (*O. phaseoli*, *O. spencerella*, and *O. centrocematis*).

While the effort to identify germplasm resistant to beanfly through screening is underway, it seems most important to study the cultural and biological methods for control of beanfly infestation on beans. No such study has been carried out in northern Tanzania. A study on these aspects was thus conducted in the off-season cropping of 2001-2002 at Madira farm Arusha in northern Tanzania, with the following objectives:

i) To establish the optimum period for sowing of beans that will escape peak population density of BSM.

ii) To establish the optimum period when the BSM are highly parasitized by their natural enemies.

iii) To establish the frequency of parasitism of BSM.

iv) To establish the numerical response of parasites to changing population size of the host.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Taxonomy of beanflies

Numerous insect pests attack the common beans during growth and storage (Abate and Ampofo, 1996). The economic importance varies from one environment to another, but it is generally agreed that BSM (*Ophiomyia* spp) and bean bruchids are the most important field and storage pests, respectively. The beanfly (*Ophiomyia* spp) was described by Tryon in 1895 from specimens collected near Brisbanne, Australia, in 1888 (Tryon, 1895) and referred to it as *Oscinis fabae.* Coquillet (1899) re-described the insect as *Agromyza phaseoli* using adult specimens from New South Wales, Australia. Meijere (1922) published a further re-description using larval and pupal as well as adult characteristics. He considered *Agromyza destructer* Malloch (1916) to be a junior synonym of *A. phaseoli. Agromyza fabalis* Jack (1913) is a junior synonym originally devised by Coquillet (1899), but apparently not published by the latter. Presumably, Coquillet (1899) decided it was the same species as *phaseoli.* Spencer (1959) put *A. phaseoli* in the genus *Melanogromyza* and later in *Ophomyia.* Besides beanfly, other common names for *Ophiomyia* spp are the snap beanfly, stem mining fly, the stemfly and the bean stem maggot (BSM).

2.1.1 Identification

The Bean Stem Maggot (Diptera: Agromyzidae), also known as Bean flies (*Ophiomyia* spp) are the most important field pests of beans in Africa. *Ophiomyia phaseoli* was thought to be the only BSM species that attacked beans

in Africa until studies by Greathead (1969) revealed the presence of two other species in East Africa, namely *Ophiomyia specerella* and *Ophiomyia centrosematis* (Abate and Ampofo, 1996). Until recent years, *O. phaseoli* was regarded as the principal and most wide spread BSM species in Africa (Abate 1991, 1992). Recent reports indicate that at least one of these three BSM species is common in each of the major bean growing countries in Africa (Antrique *et al* 1989). *O. phaseoli* and *O. spencerella* are the most important of the three species. *O. centrosematis* usually occurs rarely and in small numbers (Abate, 1990; Abate and Ampofo, 1996). The distribution of both *O. phaseoli* and *O. centrosematis* ranges through tropical and subtropical Africa, Asia and Australia, but *O. spencerella* has not been recorded outside Africa (Abate and Ampofo, 1996).

2.1.2 Eggs

Morgan (1937) found that beanfly oviposition was confined to the first 15 days of beans seedling stage. Swaine (1968) reported similar results from his studies on the biology of the pest. Okinda (1979) reported that infestation began when seedlings were one day old until four weeks later, when it gradually decreased. He found the highest mean number of larvae and pupae of beanfly 21 days after emergence, after which the numbers remained stable.

The eggs of BSM are white, slender and about 1mm long. They are laid singly on different parts of the seedling. *O. phaseoli* oviposit mostly on the newly emerging leaves, some eggs may also be laid on the stem and petiole in older

plants. *O. spencerella* deposit its eggs mostly in the hypocotyl, although sometimes it may lay them on the stem as well. *O. centrocematis* prefers the stem for egg laying. Each female can lay approximately 100 eggs in her lifetime. Incubation takes 2-4 days, depending on the temperature. On hatching, the small white maggots mine in the leaf and then bore into the stem, which produces cracks near the soil level (Abate and Ampofo, 1996).

2.1.3 Larvae

The eggs hatch in three days in warm climates. After two days, the white to cream coloured larva mines through the epidermis till it meets a vein that it follows to the midrib and then passes into petiole where it moults. The larva then mines down towards the stem and it moults again in a cavity it makes at the base of the petiole. The third instar larva bores down the stem of the plant. The larvae travel down the stem into the root. It may return to pupate just above the soil surface in the stem, or may occur in the root (Ho, 1967). Larvae from eggs laid in upper leaves of older plants frequently pupate in the main stem just below the node before reaching the soil surface (Greathead, 1969).

The larvae pass through three instars over a period of 6-14 days. The mature larvae pupate mostly in the stem and sometimes in the petiole or in the soil (Abate and Ampofo, 1996).

2.1.4 Pupae

The puparium forms beneath the stem epidermis with head pointing upwards and the ventral surface of the body adjacent to the epidermis of the stem. In *O. phaseoli* and *O. spencerella* a thin transparent "window" is made on the epidermis that facilitates emergence of the adult. *O. centrocematis* does not produce this "window', the last larval instars eat completely through the stem epidermis (Greathead, 1969). The pupal stage lasts between seven to nine days in warm weather (Swaine, 1968) but can take as much as 55 days in cool weather (Rogers, 1974).

Pupae are distinguished by their colour and by the characteristics of posterial spiracles (Allen, 1986). Pupae of *O. phaseoli* are yellow-brown and *O. spencerella* are shinny black, with a grey ventral surface (Plate 1). The pupae are barrel-shaped and are about 3mm long. The Pupal period lasts for about seven days, after which the shinny black adult flies, measuring approximately 2mm long, emerge (Abate and Ampofo, 1996).

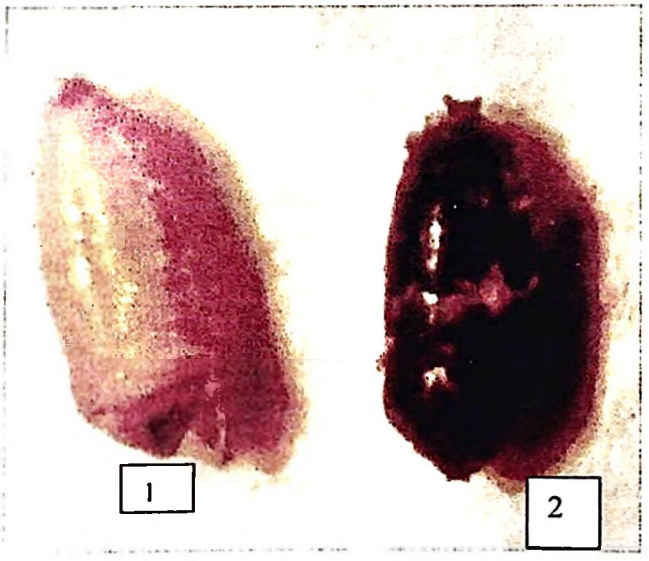

Plate: 1 Pupae of *O. phaseoli* (1) and *O. spencerella* (2)

2.1.5. Adult

Adults of the three BSM species have similar external morphological features. The male aedeagal characters are used to distinguish them. The adults emerge in the morning hours and are light brown in colour before they turn black. They have a pre-mating period of three days (Babu, 1978; Greathead, 1969). Mating takes place 2-6 days after emerging, and egg laying begins 2-4 days after mating depending on the temperature (Abate and Ampofo, 1996). Longevity average is 38 days for the female and 37 days for the male (Otanes, 1918). The entire life cycle from egg to adult for *Ophiomyia* spp. may last for three weeks in hot weather to 12 weeks in cool weather (Davis, 1969; Greathead, 1969; Caldwell 1945).

2.1.6 Biology

The biology of the three species of *Ophiomyia* on beans is similar although notable differences between the species exist. Raros (1975) found that the *O. phaseoli* adult had three sources of food, namely droplets of water, natural plants secretions and host plant sap. He found that the last source was the major one. Raros (1975) also observed that oviposition occurs during day-light hours following a series of actions carried out by the female *O. phaseoli* on the leaf surface. He, however, found that these actions were for both eggs laying and feeding purposes. Oviposition of *O. phaseoli* on beans usually occurs on the upper epidermis of the leaf surface but a few eggs are laid in the lower epidermis (Greathead, 1969; Abul-Nasr, 1977). However, Manohar and Balasubramanian (1980) found that four and half times as many eggs were laid in the lower

surface. Agarawal and Pandey (1961), and Ali (1957) also observed greater oviposition on the lower leaf surface of peas and beans respectively. Davis (1969) stated that oviposition on the lower surface of leaf epidermis of beans occurred mainly during rainy weather. The most preferred site for oviposition on beans was near the midrib at the base of recently unfolded two trifoliate (Rogers, 1979; Davis, 1969; Greathead, 1969; Ho, 1967). Greathead (1969) reported that most eggs of *O. spencerella* were laid on the hypocotyl at ground level two to three days after germination and few eggs were deposited in young stems above the cotyledon or rarely in the leaves. Greathead (1969) also observed that *O. centrosematis* laid its eggs in the stem and hypocotyls. *O. spencerella* and *O. centrosematis* were indistinguishable.

2.2 Geographical distribution

O. phaseoli is known from many parts of the tropics and sub-tropics of Africa, Asia, Australia. (Greathead, 1969; Spencer, 1959). *O. centrosematis* has been found generally distributed throughout Australia, tropical Asia and East Africa (Spencer, 1973). *O. spencerella* was described from East Africa, but is now known to occur widely throughout eastern and southern Africa (Greathead, 1969).

2.2.1 Ecology

The prevalence of BSM species is highly influenced by several climatic factors and agronomic practices Abate and Ampofo (1996). Abate and Ampofo (1996) reported that *O. phaseoli* and *O. centrosematis* are more prevalent at lower altitudes and warmer climatic conditions, whereas *O. spencerella* is more abundant in higher altitudes and cooler wet environment. In most instances, *O. phaseoli* is more common in early sown beans, whereas *O. spencerella* is the dominant species in the late sown beans (Abate and Ampofo, 1996). Letourneau and Altieri (1983) reported that *O. phaseoli* and *O. spencerella* distribution pattern varied with the varietal mixture, soil fertility and cropping patterns. Abate (1990) reported that pest damage is reduced in mixed-cropped beans. Abate *et al.* (1982) suggested that BSM infestation level and species composition are influenced by one or combination of several environmental factors and cultural practices, including temperature, crop variety, growth stage of the host plant, soil fertility and cropping patterns.

2.2.2 Seasonal incidence

Reports on seasonal incidence of the beanfly species are available from studies conducted at various geographical locations. In East Africa, Swaine (1968) and Wallace (1939) reported that beanfly incidence was more pronounced during the hotter drier season than during the cooler wet season. Kooner *et al.* (1977) working on peas sown on a number of dates during 1973/74 and 1974/75 in Punjab, observed that *O. phaseoli* severely affected the crops sown in October, whereas November crops remained completely free of the pest. In Taiwan,

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Lin *et al.* (1977) reported that two peaks of *O. phaseoli* populations occurred in each season. They observed that soil moisture, soil pH, solar intensity and relative humidity were factors that influenced the observed fluctuations in *O. phaseoli* population density. Okinda (1979) also reported from his studies in Kenya that rainfall was an important factor that controlled *O. phaseoli* and *O. spencerella* population on beans. He however indicated that, this factor was more important on the latter than on the former species. In Zambia, marked seasonal differences between *O. phaseoli* and *O. spencerella* were observed (Zambia Ministry of Agriculture and Water Development, 1985). *O. phaseoli* was predominant in early part of the season, both occurred in mid-season and *O. spencerella* was predominant in the late part of the season.

2.3 Host range

More than 30 species of cultivated and wild plants in the family Leguminosae serve as hosts of the BSM (Abate and Ampofo, 1996). Sunnhemp (*Crotalaria juncea*) and several species of wild *Crotalaria* are important source of infestation (Abate and Ampofo, 1996). The list of host plants of *O. phaseoli* is given in Table 1. Despite the long list of its host plants, *O. phaseoli* has generally been cited to be a severe pest of the common beans (Spencer, 1973; FAO, 1968; Greathead, 1969), soybeans (Taylor, 1958), mungbean and peas (Singh *et al.*, 1981).

Table 1: Hosts of Bean Stem Maggot (*Ophiomyia* spp) and their geographical distribution.

Host.	Geographical distribution.	Reference.
Canavalia ensiformis.	Java.	Ho (1967).
Crotalaria juncea.	Java, Egypt, East Indies.	Ho (1967), Abul-Nasr and Assem (1966), Agarawal and Pandey (1961).
Cyamopsis tetragonoba (L).	Malaysia.	Ho (1967).
Crotalaria mucronata.	East Africa, Australia.	Greathead (1969), Agarawal and Pandey (1961).
Dolichos axillaris E. Mey.	Australia.	Jones (1965).
Macrotyloma uniflora.	India.	Babu (1978).
Neonotonia weghtii.	Zimbabwe.	Taylor (1958).
Glycine max. (L) Merr.	Egypt, Asia.	Abul-Nasr and Assem (1966), Taylor (1958).
Macroptilium atropurpureus.	Egypt.	Abul-Nasr and Assem (1966).
Macroptilium lathyroides (L).	Urban Australia.	Jones (1965).
Medicago sativa L.	Zimbabwe.	Taylor (1958)

Mucuna pruriens Var. *utilis.*	Malaysia.	Ho (1967).
Phaseolus lunatus.	East Africa, Egypt.	Greathead (1969), Abul-Nasr Assam (1966).
Phaseolus vulgaris L.	Australia, Africa,Asia, Egypt, USA-Hawii, India, Malaysia, Uganda, Tanzania.	Jones (1965), Spencer (1973), Abul-Nasr and Assem (1966), FAO (1968), Greathead (1969), Jagtap, *et al* (1979), Ho (1967), CIAT (1983), Walker (1960).
Pisium sativum.	India, Java.	Singh, *et al* (1981), Greathead 1969).
Psophocarpus tetragonolobus (L).	Papua New guinea.	Khan *et al.*, (1974).
Vicia faba (L).	Egypt.	El-Kifl *et al.*, (1973).
Vigna marina (Burman Merr.).	Australia.	Jones (1965).

2.4 Damage

The damage caused by feeding of the adult fly is considered to be insignificant (Rogers, 1979). The larvae cause the major damage, especially the third instars that destroy the medullary tissue of the stem at ground level. The insect feeds within the stem, thus no obvious sign of damage except a tiny hole where the adult escapes after the damage has already been done. The most vulnerable stage as far as yield losses are concerned is the seedling (Talekar, 1986).

Many larvae may pupate at the base of one plant, and this causes tissue around the pupa to rot, die and dry up and frequently splits revealing the puparia inside. Damaged plants become yellowish, wilted and stunted and may eventually die unless they form adventitious roots (Plate 2 and 3). The success of adventitious roots depends on the amount of moisture available to the plant (Abate, 1990). In older plants, the mines apparently cause little economic damage except when the plants break at the site of the puparium due to wind or mechanical damage (Greathead, 1969).

Plate 2: Wilted bean plant caused by BSM damage.

Plate: 3 Wilted bean plant caused by BSM damage.

2.5 Control

The bean stem maggot is controlled by various measures including insecticides (seed dressing, soil treatment, foliar treatment), biological control (parasites, predators), cultural control (change of time of planting, increased plant density, earthing up, mulching, enhanced soil fertility, removal of wild and alternate hosts, intercropping), and integrated pest management (IPM) (Nderitu and Anyango, 1997). Insecticides have been found effective for control of bean stem maggots in Africa (Trutman *et al.*, 1992). However farmers rarely use insecticides on their bean crop except on snap beans, which are of commercial value (Nderitu and Anyango, 1997).

2.5.1 Cultural management

Cultural practices by farmers may play an important role in the integrated pest management of the beanfly. This component, together with biological control may be especially important where high levels of resistance in beans have not been found. Various cultural management practices have been found effective for BSM. Sowing beans during drier, hotter, seasons should be avoided where practical (Karel *et al.*, 1981). Early and uniform planting by farmers to avoid peak infestation periods is also recommended (Irving, 1986). Reservoirs of the insect such as volunteer plants or wild hosts should be eliminated as far as possible (Rose *et al.*, 1978). Irving (1986) also suggested that rotations with non-hosts could be a useful control practice. In Malaysia, crop rotation is one of the recommendations for control of beanfly damage (Ho, 1967). In Taiwan, intercropping mungbean with pearl millet, tomato, okra, rice bean, jute and cowpea was also found to reduce beanfly infestation on mungbean (AVRDC, 1980). Kayitare and Ampong-Nyarko (1992) found that monocropping of beans reduced the incidence of BSM. Karel (1991) and Negesi and Abate (1986) reported that BSM infestation increased in wide spacing than in close spacing. Other results (Nderitu *et al.*, 1990; Oree *et al.*, 1990; Kayitare and Ampong-Nyarko, 1992; Okinda, 1979) have indicated that early planting reduced BSM infestation, while rainfall and temperature accounted for higher rates of maggot population in successive plantings. Ridging, which is possible only when beans are cultivated in loose soil that is easily ridged, is recommended as a way of permitting damaged root regeneration and formation of new roots system, to enable plants to grow through the infestation (Nderitu and Anyango, 1997). This

practice has been reported by Irving (1986) to bar hypocotyls infestation, besides encouraging adventitious root formation.

2.5.2 Host plant resistant

The benefit of using both plant resistance and biological control have been demonstrated for the management of several insect pests (Bergman and Tingey, 1979). A number of studies have been reported on the search for resistance in beans and other legumes. Greathead (1969) reported that most of the locally adapted lines in Uganda were somewhat resistant to beanfly damage due to their thickened hypocotyls. Resistant materials to beanfly have also been reported in Malawi (Edje *et al.*, 1981) and Tanzania (Karel *et al.*, 1981).

At the Asian Vegetable Research and Development Centre (AVRDC) in Taiwan, 370 accession of *Phaseolus* spp. from CIAT were screened for resistance to beanfly in the period 1977 to 1979. Two accessions, G05478 "Tara" (*Phaseolus vulgaris*) and G35023 (*Phaseolus coccineus*) are being used as a source of resistance in the CIAT breeding programme, and the F_2 seed is screened at AVRDC (CIAT, 1981).

Rogers (1974; 1979) compared 14-bean cultivars for reaction to *O. phaseoli*. When ovipositing females were caged on all the cultivars together, fewer eggs were found on those materials with denser pubescence, thinner stems and longer internodes. There were, however, no differences in larval motality, development rate or size of emerged beanfly adult between the cultivars. A high concentration

of a phenolic compound was found in stems with beanfly damage suggesting antibiosis as a possible mechanism of resistance (AVRDC, 1982).

Karel (1984) using a visual rating score reported significant differences in stem damage by beanfly larvae to 70 *Phaseolus* beans cultivars he evaluated. None of the cultivars was, however, found to be highly resistant to beanfly. In another study, Karel and Maerere (1985) found significant differences between varieties in number of beanfly larvae and pupae, bean plant stem damage and vigour. They however, found a low negative correlation between the number of beanfly larvae and pupae and plant vigour. It was also noted that the accessions they evaluated were sown on soil which was treated with fertilizer prior to sowing. Msangi and Karel (1984) reported similar results on a number of beanfly larvae and pupae, stem damage and plant vigour on 21 bean cultivars evaluated for resistance. However, no variety was found to be completely resistant to beanfly attack.

Lin and Mitchell (1981) found a negative correlation between numbers of larvae and puparia of *O. phaseoli* and trichome density of leaves of *Vigna radiata, Vigna. mungo, Vigna. umbellata, Phaseolus. vulgaris* and *Vigna. angularis*. Leaf thickness was negatively correlated with resistance in *V. radiata, V. mungo* and *V. umbellate* and the insects preferred *V. radiata* leaves with higher moisture content.

Jones (1965) compared *P. vulgaris*, *M. atropurpureum*, *M. lathyroides*, *V. marina* and *V. radiata* for reaction to *O. phaseoli* and found differences in the percentages of plants killed. Fernando (1941) screened 93 cultivars of *V. unguiculata* and found significant differences in percentage of plants infested by *O. phaseoli*. Comparing five *V. radiata* cultivars, Balboa (1972) found that the proportions of plants infested by *O. phaseoli* ranged from 14.8% to 62.6%. In Taiwan, a total of 6775 soybean and 3713 mungbean accessions were screened for resistance to *O. phaseoli*, *O. centrosematis* and *M. sojae* over two years. Four wild soybean accessions (G 3089, G 3091, G 3104, G 3122) and three *V. radiata* accessions (V 2396, V 3495, V 4281) were least affected at six locations by all three species of the pest (Chiang and Talekar, 1986).

Chiang and Norris (1983) observed that soybean resistance to the bean flies *Melanagromyza sojae*, *O. centrosematis* and *O. phaseoli* was correlated with higher trichome density on the abaxial surface of leaves, smaller leaf area, higher leaf moisture content and narrow stems. Soybean resistance to *O. phaseoli* seemed to be due to the earlier differentiation of primary and secondary phloem fibres and thinner cortical layer in the stem. These properties plus the earlier differentiation of the periderm in the lower portion of the soybean stem and/or roots, seemed to contribute to resistance to *O. centrosematis* (Chiang and Norris, 1983). The authors speculated that agromyzid stem borers and *Glycine* spp. have a long history of coevolution.

In Hawaii field studies in 1976/78 showed that two mungbean varieties (LM 192, Ms 9552 and LM 189, 97002/2) had moderate resistance to *O. phaseoli*. These varieties had relatively high levels of pubescence, and resistance was thought to be due to non-preference (Lin and Mitchel, 1981). In peas, it was observed that *O. phaseoli* preferred varieties with succulent, thick stems to those with tougher, thin stems (Singh and Mishra, 1977).

Although many studies on resistance have been reported in literature little has indicated the population pressure of the pest under which the results were obtained. Singh *et al* (1981) reported that in Pantnagar three pea varieties sown weekly on seven dates suffered equally when the population pressure of *O. centrosematis* was higher in early sowing dates.

Derris extract was sprayed on the root necks of lima beans (*Phaseolus lunatus*) and was found to be effective (Nderitu and Anyango, 1997). Moorthy and Srinivasan (1993) used been plant ash sprays for control of BSM and found them effective. Ampofo J. K. O (Personal communication, 1995) evaluated foliar application of extracts of neem seed powder and *Tephrosia* leaves and found that bean yield increased after their application. Application of botanical pesticides, which are of no monetary cost to the farmer, could be adopted in subsistence bean farming (Nderitu and Anyango, 1997).

2.5.3 Biological control

To be most effective, biological and/ or integrated control programs should be based on extensive studies of ecology and natural control of arthropod species affecting the crop, especially the principal pest species (Oatman *et al.*, 1967). Collection of gypsy moth pupae made on the Delmarva Peninsula during 1989-1994 for the purpose of recovering the recently introduced pupal parasite, *Coccygomimus disparis* (Viereck) showed that parasitism was 4.5%. The level of parasitism by this species was not affected by host density (host density independent). Habitat or latitude, temperature and rainfall were the most important factors affecting parasitism (Rogers, 1979).

A study conducted by Oatman *et al.* (1967) during August, September and October 1967; found that parasitism of cabbage looper eggs by *Trichogramma pretiosum* reached its highest peak in October. Parasites of *O. phaseoli* have been reported from various places where this pest occurs (Table 2). Greathead (1969) reported from East Africa a parasite complex of nine species that were reared from three species of *Ophiomyia.* He reported that *Opius phaseoli* (Fischer) is an important biotic factor in regulating the natural population of *O. phaseoli* in East Africa. He found the life cycle of *Opius phaseoli* to be highly synchronized with that of its host *O. phaseoli.* It is a density dependent larval parasite that emerges from the host pupa. Greathead (1969) concluded that it was the most effective parasite of *O. phaseoli* in the area. The most important parasite of *O. spencerella*, *Eucolidae* spp. showed delayed density dependent and was inefficient in controlling its host. It was suggested that since *O.*

spencerella lays most of its eggs in the hypocotyl and not on the leaves, the larvae are protected from attack by the soil so that pupal parasitism is not common. Lack of effective parasitism may in part account for the economic importance of *O. spencerella* in East Africa (Greathead, 1969).

Opius phaseoli also parasitises *O. spencerella* and has been reared in low numbers from *O. centrocematis*. A larval-pupal parasite of *O. phaseoli*, *Phitarchia* spp. was considered important in Thailand because its biology was well synchronized with that of its host (Burikan, 1978). Agyen-sampong (1978) listed the following hymenopteran parasites from *Ophiomyia* spp. on cowpea in Ghana: *Eucolidea* spp., *Dinarmus basalis*, (Pteromalidae), *Euritoma* spp., *Plutarchia girault* (Eurytomidae), *Fuderus* sp. and *Pediobius* spp. (Eulophidae). *Opius importatus* and *Opius phaseoli* were imported to Hawaii from Uganda to control *O. phaseoli*. Control was achieved mainly by *O. importatus* and further shipments of the parasites were sent to Brunei and Taiwan (Greathead, 1969). Hayes and Turner (1971), reported high parasitism of face fly. They also reported high percentage mortality of collected pupae, which they suggested that the cause was probably due to superparasitsm or multiple stings or host defensive reactions.

2.5.2.1 Parasitoid identification

2.5.2.2 Ichneumonids wasp (Hymenoptera: Ichneumonids)

Ichneumonid wasps are slender bodied and range in length from 5-36 mm. Females usually have a long, needle-like egg-laying structure (ovipositor) at the end of their abdomen. The ovipositor is longer than the body of the wasp and is commonly taken to be a "stinger," but its real purpose is to inject eggs into host insects. Larval forms of ichneumonids are parasitic within the immature stages of the host insects. The length of the ovipositor allows the insect to inject her eggs into hidden hosts such as leaf-rolling or stem-boring caterpillars. Examples of such ichneumonids are *Apophua* spp. (Gillespie, 2000).

2.5.2.3 Braconidae wasps (Hymenoptera: Braconidae)

Braconid wasps are smaller than ichneumonids, up to 12mm in length, their body shape is shorter and stouter. They have an ovipositor, but it is carried inside the body until it is needed to inject an egg into a host. Braconids parasitize a broader range of hosts than ichneumonids. After a female injects the eggs into a host, the larva feeds slowly on that single host. By the time the host dies, the larva is fully-grown. It pupates inside or near the dead host, sometimes in a silken cocoon, to emerge later as an adult wasp (Gillespie, 2000).

Table 2: Hymenopterous parasites of *Ophiomyia phaseoli* (Tryon).

Family and species	Location	Reference
Braconidae.	Thailand.	Burikam (1978).
Biosteres spp.	Egypt.	Abul-Nasr and Assem (1968).
Daieretus rapae Curt.	Sri Lanka.	Subasinghe and Fellowes (1978).
O. spp. nr. Importatus.	Zimbabwe.	Taylor (1958).
O. liogaster Szepl.	Thailand.	Burikam (1978).
	East Africa.	Greathead (1969).
O. phaseoli Fischer.	Madagascar, Mauritius, Botswana and Ethiopia.	Burikam (1978).
Opius spp.	Thailand, Taiwan.	Rose *et al* (1978).
Callitula spp.	Egypt.	Abul-Nasr and Assem (1968).
Crytoprymna spp.	Uganda.	Greathead (1969).
Halicoptera spp.	Uganda.	Greathead (1969).
Norbanus spp.	Uganda.	Greathead (1969).
Sphegigaster agromyzae.	Sri Lanka.	Fellowes and Amarasena (1977).

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Site selection

The study was carried out at Madira Farm in Arusha Region, Tanzania. The selected site for these investigation had a relatively gentle slope. This site is a "hot spot" for BSM infestation (Ampofo, 1993). The land was cleared, ploughed and harrowed on 3rd November 2001. Before clearing and ploughing, alternate host plants for BSM and volunteer bean plants were collected and dissected to establish the presence of BSM pupae. A total of 162 pupae of BSM were collected and reared in the laboratory. The pupae were kept in a sealed perforated paper bag to prevent BSM and parasitoids from escaping during adult emergence. The bags were kept for 15 days, during which BSM and parasitoids emerged. The paper bag was then opened and dead adult BSM and parasitoids were counted and recorded. BSM and parasitoids were not identified to species at this level.

3.2 Land marking and trial laying

An area measuring 21.5m x 10.8m was demarcated in the farm and divided into four blocks (replicates). Each replication was sub-divided into six equal units (plots). The size of each plot was 6.0m^2 (whole plot) and the net plot area was 3.8m^2, which constituted the inner two rows.

3.3 Experimental design

The design for the experiment was split plot with two factors, namely (i) Bean varieties (main plot) and (ii) Time of sowing (sub-plot). The total number of plots was 24.

Table 3: Experimental design, source of variation and degree of freedom.

Source of Variation	Degree of freedom
Block (ß*i*)	3
Variety (A*j*)	1
Error (Є*ij*)	3
Time of sowing (B*k*)	2
Time of sowing x Variety (AB*jk*)	2
Error (Є*ijk*)	12
Total	23

3.3.1 Statistical model

The following statistical model was applied to the data.

$X_{ijk} = \mu + \beta_i + A_j + \epsilon_{ij} + B_k + AB_{jk} + \epsilon_{ijk}$

X_{ijk} = Response.

μ = General effect.

β_i = Block effect.

A_j = Main factor effect.

ϵ_{ij} = Whole plot error.

B_k = Sub-factor effect.

Ab_{jk} = Interaction effect.

ϵ_{ijk} = Random sub factor error.

3.4 Sowing

Two bean varieties with different level of BSM susceptibility ware sown. The bean varieties were Lyamungu 90 (V1) (susceptible) and ZPV 292 (V2) (tolerant). Three levels of sowing dates were adopted. These are early planting (T1), normal calendar planting (T2) (control) and late planting (T3). Planting time interval was seven days. The early sowing was done on 6th November 2001, the second on 13th November 2001 and the late sowing on 20th November 2001.

3.4.1 Sampling

Sampling of infested plants from each plot was done at weekly intervals. Each plot was sampled three times at an interval of one week in order to capture the early, middle and late BSM infestation and parasitism. The first sampling was done immediately after signs of damage were observed. Damage was indicated by wilted beans plants (Plate 2 and 3). A total of 20 infested plants from the outer two rows, of each plot were sampled. The inner two rows were left for yield measurement at harvesting time. Infested plant stems were dissected and the number of pupae was counted and recorded. The pupae were taken to the laboratory and maintained until the parasitoid and BSM emerged.

3.4.2 Pupae parasitism

To obtain quantitative data on parasitism, pupae collected from each plot were identified and segregated into BSM species based on their colour, as described by Irving (1986), Spencer (1973) and Greathead (1969). Individuals of each species were separately put in a sealed perforated paper bag marked with plot number. These bags prevented emerging parasitoids and adult BSM from escaping. The bags containing pupae were kept in the laboratory at room temperature for 15 days. This duration was enough for parasitoids and BSM to emerge. The emerged BSM and parasitoids were left to die of starvation within the bags for easy counting. The emerged parasitoids were segregated to family level based on their morphological characteristics (Gillespie, 2000) and recorded. The intact pupae were dissected to establish whether they contained

dead mass or were empty. Pupae, which died naturally, contained black mass while an empty pupal shell indicated parasitoid or host emergence.

The following data were recorded:

(i) Number of plants germinated in the net plot (two inner rows of each plot) 10 days after sowing.

(ii) Number of parasitized pupae per plant at weekly intervals from 5 sample plants from each plot.

(iii) Numbers of pupae per plant at weekly intervals, from 5 sample plants from each plot.

(iv) Lodged plants in the net plot at pod physiological maturity.

(v) Dead plants in the net plot area.

(vi) Number of plants per plot during harvesting

(vii) Number of pods per plant at harvest.

(viii) Grains per pod at harvest.

(ix) 100 seeds weight per plot at harvest.

(x) Grain yields per plot at harvest.

3.2 Data analysis

Before analysis, the data were subjected to square root transformation using the formula $(x + 0.5)^{0.5}$ in order to normalize and make variances relatively independent of the means (Robert and Torrie, 1980). The data were analyzed using MSTAT-C statistical program. The mean values were separated using Duncan Multiple Range Test (DMRT) and t- test.

Regression analysis was used to determine host-parasitoid relationship.

The analysis was based on the following formula. $Y= AX + b$,

Where Y = number of parasitized pupae,

A = slope of the regression line,

X = number of host (BSM pupae),

b = intercept.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Beanfly and parasitoid species determination

4.1.1 Beanfly species identification

Two different types of beanfly pupae were found in dissected bean stem of each variety (Lyamungo 90 and ZPV 292) at Madira farm. One was shiny–black and the other was yellow-brown in colour (Plate 1). Compared to diagrams and descriptions by Irving (1986), Spencer (1973) and Greathead (1969), the shiny-black pupae belonged to *Ophiomyia spencerella* and the yellow-brown pupae belonged to *Ophiomyia phaseoli*. The abundance of these two BSM species differed significantly ($p < 0.001$) at this site (Table 4).

Table 4: Mean numbers per plot of *O. spencerella* and *O. phaseoli* pupae collected from Madira farm in 2001.

BSM species	Replication				Mean ± SE	CV (%)
	1	2	3	4		
O. spencerella	6.6	5.5	5.0	5.3	5.6 ± 0.46 b	21.25
O. phaseoli	2.2	2.1	2.0	2.5	2.2 ± 0.07 a	28.70
Df	23					
t- value	6.44					

Means in the same column followed by a different letter differ significantly at ($p < 0.001$) by t-test.

The results of the study show that the two beanfly species, *O. spencerella* and *O. phaseoli* are the common pests of beans at Madira. The mean number of *O. spencerella* pupae was higher than that of *O. phaseoli*. This suggests that the dominating BSM species at this site is *O. spencerella*. Similar results were reported by (Abate and Ampofo, 1996; Abate, 1990).

The factors that influence the dominance of *O. spencerella* during the off-season at this site are not well known. Probably the alternating high and low moisture contents of the soil, coupled with constant temperature and relatively high humidity during the cropping season in November – March favoured *O. spencerella* than *O. phaseoli* (Table 5).

Table 5: Mean monthly temperature (°c), rainfall (mm), and relative humidity (%) between September and March 2002 at Madira farm Tengeru.

Month	Temperature (°C)	Humidity (%)	Rainfall (mm)
September	16.06	21.15	6.5
October	26.89	23.23	2
November	24.23	23.43	28
December	24.50	25.45	6
January	24.50	22.50	10
February	24.75	25.50	15
March	24.60	35.00	25

4. 1.2 Parasitoids

The pupae collected from the field were reared in the laboratory for BSM and parasitoid emergence. Two parasitoid families namely Braconidae and Ichneumonidae were identified according to Gillespie (2000) description. The abundance of these two parasitoids families differed significantly ($p < 0.001$) (Table 6).

Table 6: Mean numbers of adult Braconids and Ichneumonids emerged per plot from pupae of *O. spencerella*.

Parasitoids	Replications				Mean ± SE	CV (%)
	1	2	3	4		
Braconids	3.4	2.9	2.2	3.3	2.95 ± 0.69b	36.49
Ichneumonids	0.7	1.2	0.9	0.9	0.93 ± 0.17a	42.63
Df	23					
t-value	6.94					

Means in the same column followed by different letter differ significantly at ($p < 0.001$) by t-test.

The results show that two parasitoid families were present at Madira farm. The Braconids were the dominating family. The morphological characteristics were adequate criteria for separating the two parasitoid families.

4.2 Influence of varieties and sowing time on beanfly abundance and infestation

There were significant changes ($p < 0.05$) in the population abundance of *O. spencerella* during the season. There were no significant ($P > 0.05$) changes in number of *O. phaseoli* with time (Fig.1).

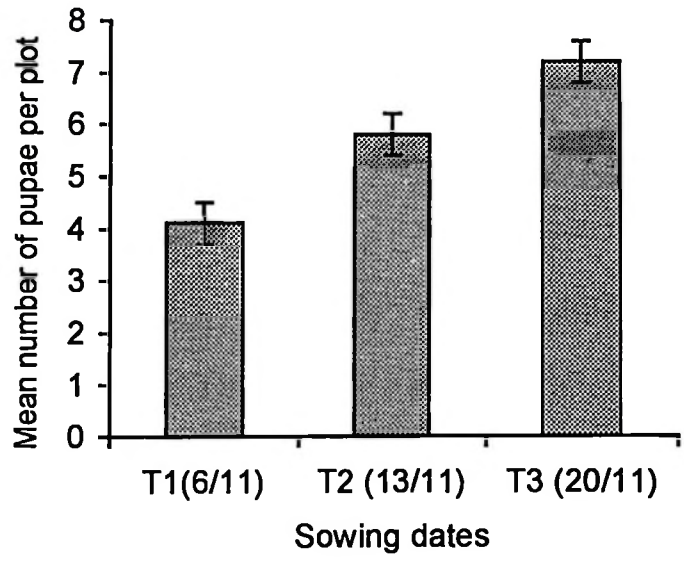


Figure 1: Mean number (± SE) of *O. spencerella* pupae at different sowing dates. (Numbers in the brackets are actual sowing dates).

The population of *O. spencerella* increased steadily with increasing sowing interval. The mean number of pupae per plot was 4.15± 0.42, 5.82 ± 0.42 and 7.07 ± 0.42 for early, normal and late sowing, respectively. The population of *O. phaseoli* was relatively higher in the early sown beans but decreased in the

normal calendar sown beans and increasing again in late sown. The mean number of pupae per plot was 2.45 ± 0.22, 2.01 ± 0.22, and 2.18 ± 0.22 for early, normal, and late sowing respectively (Fig. 2).

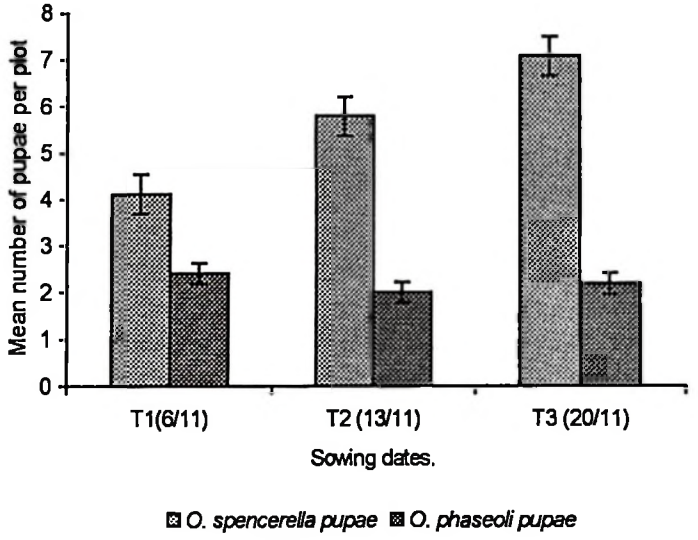


Figure 2: Mean number of *O. phaseoli* and *O. spencerella* pupae in beans sown at different time intervals. (Numbers in the brackets are actual sowing dates).

The mean number of *O. spencerella* pupae increased progressively depending on sowing time. This occurred in the two beans varieties (Lyamungu 90 (V1) and ZPV 292 (V2). There were also significant differences ($P < 0.05$) in the population size of *O. spencerella* in beans sown early (T1), normal calendar (T2) and late (T3) for Lyamungu 90. There were significant differences ($p < 0.05$) between the population size of *O. spencerella* in beans sown early (T1) and late (T3) sown for ZPV 292. However no significant differences ($P > 0.05$) were observed between normal calendar and late sown for Lyamungo 90. Also, no significant differences in numbers of *O. spencerella* were observed between early and normal calendar sown for ZPV 292 (Fig. 3).

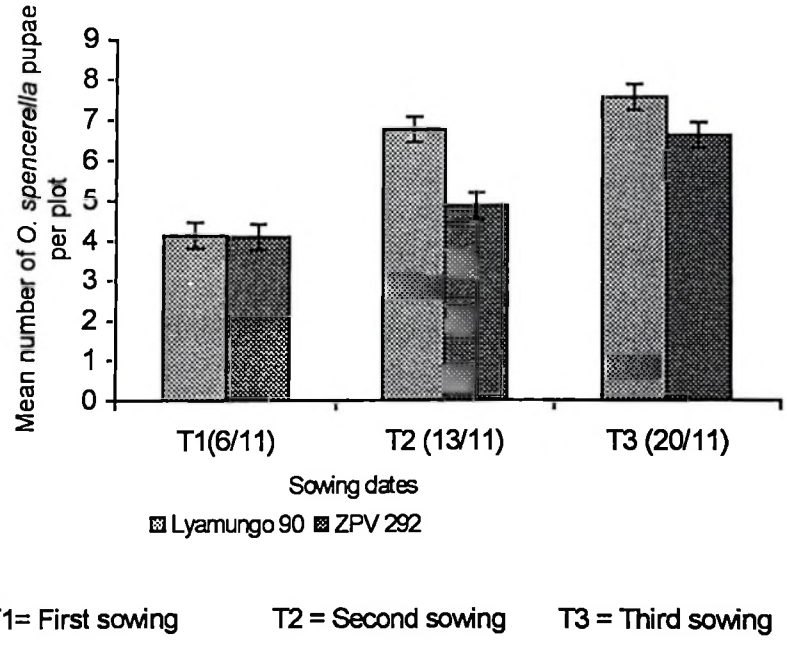


Figure 3: Mean number of *O. spencerella* pupae at different sowing dates. (Numbers in brackets are actual sowing dates).

Higher numbers of pupae were found in Lyamungo 90 compared to ZPV 292 and the differences were highly significant ($P < 0.001$) .The mean number of pupae per plot on Lyamungo 90 and ZPV 292 were 6.043 ± 0.09 and 5.262 ± 0.09, respectively.

Generally, there were significant differences ($p < 0.05$) in number of *O. spencerella* pupae between different sowing intervals on both bean varieties, but there were no significant differences ($p > 0.05$) in number of *O. spencerella* pupae between bean varieties on different sowing intervals.

In the early sowing, the mean number of pupae of *O. spencerella* in ZPV 292 and Lyamungu 90 were 3.3 ± 0.3 and 3.6 ± 0.3, respectively. In the normal calendar sowing, the numbers of pupae were 5.5 ± 0.3, and 6.8 ± 0.3 for ZPV 292 and Lyamungo 90, respectively, and in the late sowing the numbers of pupae were 6.9 ± 0.3 and 7.6 ± 0.3 for ZPV 292 and Lyamungo 90, respectively (Table 7). The differences in mean numbers of pupae of *O. spencerella* at different times of sowing were found to be highly significant ($P < 0.001$). Factor interaction had no significant ($p > 0.05$) influence on BSM infestation.

Table 7: Influence of varieties and sowing dates on the population size of *O. phaseoli* and *O. spencerella.*

BSM	Varieties		Sowing dates		
	Lyamungo 90	ZPV 292	Early	Normal	Late
O. spencerella	6.15 ± 0.03	5.18 ± 0.03	4.1± 0.43	5.83 ± 0.43	7.07 ± 0.43
O. phaseoli	1.97 ± 0.05	2.45 ± 0.05	2.45 ± 0.22	2.01± 0.22	2.18 ± 0.22

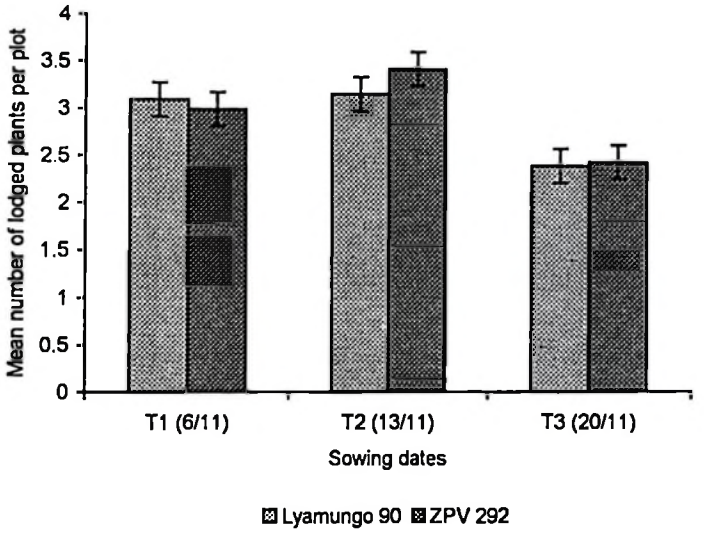
The sowing time had a significant ($p < 0.001$) influence on BSM infestation. There were lower numbers of *O. spencerella* in the early sown beans as compared to late sown. The reason for higher population of *O. spencerella* in the late sown compared to normal and early sown beans was probably due to re-infestation by the newly hatched BSM. However, the BSM populations in the late sown beans could have been higher in the absence of the parasitoids. The decline of the population of *O. phaseoli* during the normal sowing calendar compared to *O. spencerella*, might have been due to higher parasitism. This further suggests a parasitoid preference for *O. phaseoli* to *O. spencerella.* Since parasitism in the host population appears to be density dependent, the parasitoid shifted their effort to *O. spencerella* when the population of *O. phaseoli* was low during the normal calendar sowing, thus causing the population of *O. phaseoli* to increase again in late sown beans. Therefore it will be interesting to study the population dynamics of *O. phaseoli* under sequential sowings, if the assumption

of parasitoid host preference holds true. Also, a study of host preference of parasitoids should be conducted to have a clear understanding on the relationship between host and parasitoid population dynamics of the two species.

Since sowing time had significant effects on BSM infestation, sowing beans at the right time should reduce BSM infestation significantly. Bean grain yield was highest in the early sown beans. Also parasitism especially for *O. phaseoli* was high. This was evidence that, early sown beans had no deleterious effects on the parasitoids population. This study suggests that sowing beans relatively early would significantly reduce BSM infestation and give high grain yields, which is the ultimate goal of farmers, without negatively affecting the natural enemies population.

4.3 Plant lodging

There were significant differences ($P < 0.05$) in plant lodging between different sowing dates in both bean varieties. However no significant differences ($P > 0.05$) in plant lodging were found between varieties at any sowing time. The number of lodged plants increased from early to normal calendar sowing, but decreased towards late sown beans in both bean varieties (Fig. 4).



T1=First sowing T2 = Second sowing T3 = Third sowing

Figure 4: Mean number of lodged plants (± SE) at different sowing dates. (Numbers in the brackets are actual sowing dates).

BSM infestation weakened the plant stems, and heavy weight of the pods on weak stems facilitated further lodging. There were relatively higher numbers of lodged plants in early sowing, compared to normal and late sowing. However the differences were not statistically different ($p > 0.05$). Plant lodging that occurred in early sown plants was not entirely due to severe infestation, but also due to heavy bearing of pods. More BSM infestations were recorded in the normal and late sown beans, yet relatively few numbers of lodged plants were recorded. The reason was that most plants didn't bear pods, and the few plants that had pods had very small, shrunk and light seeds. This shows that bean

lodging can be caused by heavy bearing particularly in genotypes with weak stems, but becomes severe under BSM infestation.

4.4 Effect of BSM infestation on yield

4.4.1 Correlation between number of pupae and yield

There was a significant ($p < 0.05$) negative correlation (r) between mean number of *O. spencerella* pupae and mean yield for both bean varieties in all three different sowing dates. A sharp drop in yield occurred with increasing BSM population (Table 8).

Table 8: Correlation between *O. spencerella* infestation and mean beans yield at different sowing time.

Sowing time	Mean number of *O. spencerella* pupae	Mean grain yield (g/plot) ± SE	Correlation coefficient (r)	Significance level
Early	4.12	567.5 -± 22	-0.40	*
Normal	5.85	480.0 ± 23	-0.43	*
Late	7.07	218.1 ± 20	- 0.60	*

There was a negative correlation between yield and bean fly pupae population. A high number of pupae in bean stems resulted in reduced grain yield. The results therefore suggest that, BSM is a major factor contributing to low yield of beans at this location. Karel (1983) also attributed low yield of beans to BSM infestation.

4.4.2 Influence of sowing time and bean varieties on grain yield

Grain yield was affected by sowing time and variety. Yields of both varieties decreased progressively from early to late sown beans. Lyamungu 90 was more affected than ZPV 292. The yield of ZPV 292 was higher than Lyamungo 90 in all sowing dates. The average pods per plot were 7.25, 7.62, and 4.25 for early, normal, and late sown respectively. There were significant ($p < 0.001$) differences in the number of pods per plant occurring between sowing dates. Grains per pod were also found to be significantly affected ($p < 0.05$) by sowing dates. Grains per pod were 3.37, 3.62, and 2.75 for early, normal and late sown respectively. The mean 100 seeds weight was significantly ($p < 0.05$) different between different sowing dates. The mean weights of 100 seeds (g) per plot were 41.41, 40.61, and 35.87 for early, normal and late sown respectively. Generally there were highly significant differences ($p < 0.001$) in grain yield between sowing dates as well as between bean varieties (Fig. 5). The average yield of ZPV 292 and Lyamungo 90 in the early sown beans was 525g/plot, while in the late sown for the same varieties was 125g/plot. The differences between the yields were highly significant ($p < 0.001$) (Fig.5).

ZPV 292 produced average yield of 200g/plot in late sown crop, while Lyamungo 90 produced average yield of 50g/plot in the same sowing date. This indicated that ZPV 292 had some degree of tolerance or resistance against BSM relative to Lyamungu 90, thus, plant resistance or tolerance could be one of the options in maintaining high yield in areas with BSM infestation. Similar results were reported by Karel (1984); Karel and Maerere (1985) and Edje *et al.*,

(1981). Early and uniform planting to avoid peak infestation period was recommended (Irving, 1986).

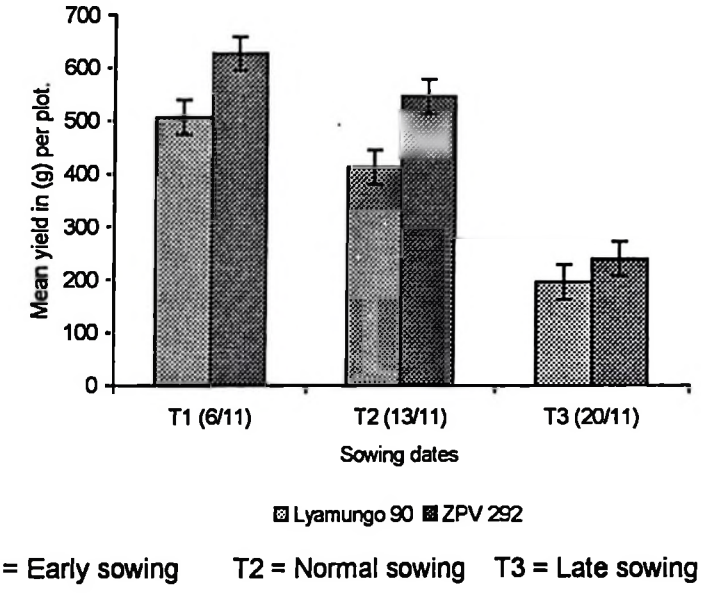


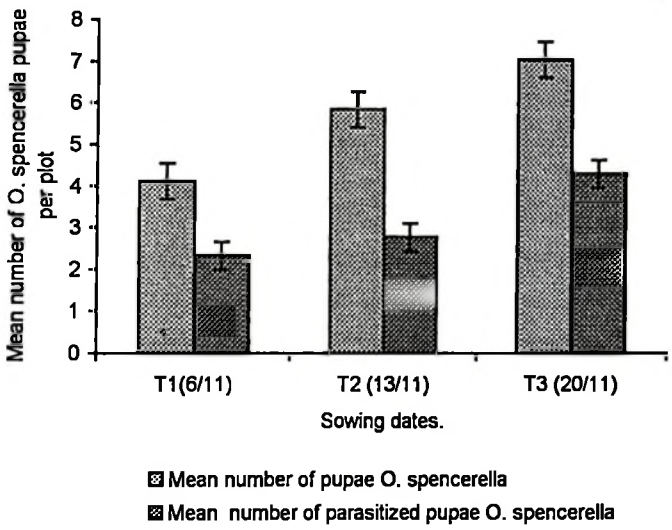
Figure 5: The effects of time of sowing and varieties on grain yield.
(Numbers in the brackets are actual sowing dates).

Sowing date and variety had independent effects on bean yield. Lyamungu 90 yielded relatively low grain in the three sowing dates compared to ZPV 292. The difference in yield between the varieties was significant ($p < 0.05$) in the three sowing dates. These results suggest that sowing beans relatively early regardless of varietal level of resistance or tolerance to beanfly increase yield significantly than late or normal calendar sowing. Early planting has been reported to reduce bean fly infestation (Nderitu *et al.*, 1990; Oree *et al.*, 1990; Kayitare and

Ampong-Nyarko, 1992; Okinda, 1979). Biological control and plant resistance have been demonstrated for the management of several insect pests (John *et al.*, 1983). The results from the current study support these findings. Although Lyamungu 90 and ZPV 292 had almost equal load of bean fly, ZPV 292 had better yield. These results further confirm that ZPV 292 had some degree of tolerance against bean fly damage. The results clearly show that plant resistance or tolerance and naturally occurring parasitoids are complimentary methods for managing beanfly in beans. Host plant resistance or tolerance and naturally occurring BSM natural enemies can both be used in the development of integrated pest management programs for beans.

4.5 Relationship between *O. spencerella* and Braconid parasitism levels

A strong positive correlation between Braconid parasitism and number of *O. spencerella* pupae was observed during the three sowing periods. The numbers of parasitized pupae increased with increasing number of *O. spencerella* pupae (Fig.6). A highly significant ($p < 0.001$) correlation coefficient was observed ($r = 0.62$), ($b = 0.918 \pm 0.248$), (t-value = 3.706, $p < 0.001$).



T1 = First sowing T2 = Second sowing T3 = Third sowing

Figure 6: Mean number of pupae of *O. spencerella* and the mean proportion parasitized at different sowing dates. (Numbers in the brackets are actual sowing dates).

About 31.85% of *O. spencerella* were parasitized and consequently only a small fraction of BSM pupae survived to adult emergence (18.09%). Large numbers of parasitoids emerged at all sowing dates, associated with high mortality of BSM pupae (Table 9).

Table 9: Level of parasitism of *O. spencerella* pupae at Madira.

Total *O. spencerella* pupae collected	Total dead pupae	Total hatched BSM	Total parasitized pupae	% Normal emergence	% Dead pupae	% Parasitism
829	415	150	264	18.09	50.06	31.85

There was a strong positive correlation between Braconid parasitoids and *O. spencerella* population. However, parasitism rate was relatively low in the early sown beans when the BSM population was also low. A delayed density dependence effect causes the bean fly population to increase fast in the normal and late sown beans. Greathead (1967) reported that *O. spencerella* parasitoids showed delayed density dependence and thus are inefficient in controlling their hosts. For this reason, the damage that occurred in the normal calendar and late sown beans could have been lower if the parasitism was density dependent from the beginning. Although parasitism reduced normal emergence almost by 68%, significant damage in the normal and late sown beans occurred. This has shown that even at low population densities, beanflies can cause serious damage to the bean crop.

4.6 Numerical response of Braconids to the host (*O. spencerella*) population.

The number of parasitized pupae increased with increasing population density of *O. spencerella*. The rate of attack of BSM pupae increased sharply at relatively higher population density. Fig. 7 shows the numerical response of the Braconid parasitoids to changes in the population of BSM pupae.

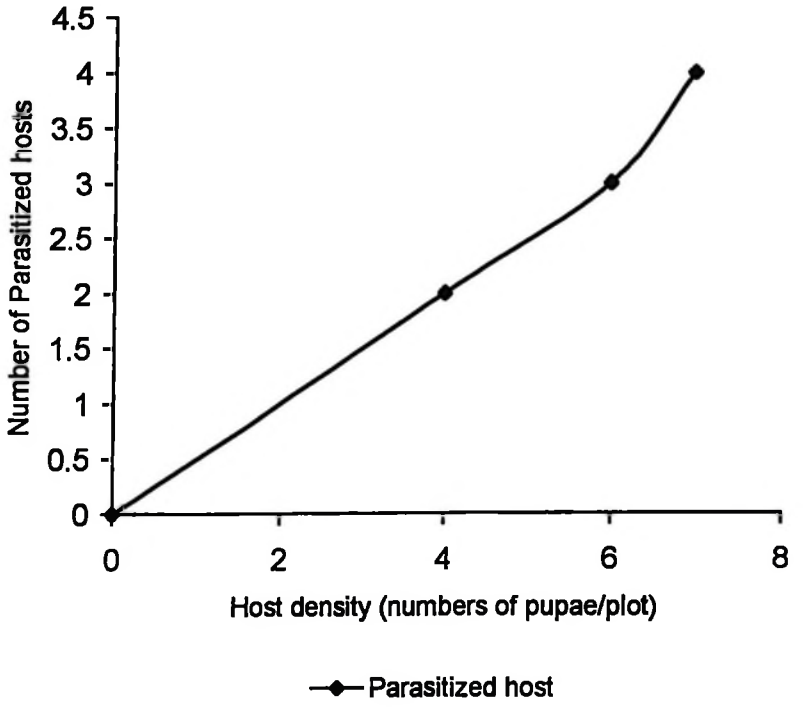


Figure 7: Functional response of Braconids to changes in population of *O. spencerella.*

There was a numerical response of Braconids to the host at lower pupae density. The numerical response was evident at later stages of sowing where increased parasitism occurred in response to increased population density of the BSM

pupae. The curve conforms to a typical parasitoid/host relationship described by Holling (1959).

These results suggest that, parasitism of BSM by Braconids is density dependent and therefore they are a key factor in controlling BSM infestation in beans at this site of study.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Ophiomyia spencerella and *Ophiomyia phaseoli* caused substantial damage to the two bean varieties (Lyamungo 90 and ZPV 292). *O. spencerella* was the dominant species, while *O. phaseoli* population remained low at Madira. ZPV 292, however, showed some tolerance to both BSM species. Lyamungu 90 was very susceptible to BSM infestation. Early sown beans, regardless of the variety, produced the highest grain yield relative to normal calendar and late sowing. The difference was highly significant because BSM population at early sowing dates was very low, attributed to parasitism and possibly other factors.

Braconids were the dominant parasitoids. There was a density dependent relationship between parasitoid and host population. Parasitism was very high and reduced the normal emergence by almost 68%. A numerical response of Braconids to host population was evident in the different sowing dates.

Plant resistance/tolerance and naturally occurring parasitoids are complementary methods for managing beanfly, both can be used in the development of integrated pest management programs for beans

5.2 Recommendations

1) Studies to determine appropriate time of sowing beans in order to escape peak population of BSM should be extended to various agro-ecological zones in Tanzania.

2) Since there are several species of bean fly natural enemies, investigations to show the most effective species and the possibility of mass rearing and their release should be considered.

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APPENDICES

Appendix 1a: Mean square for number of pupae studied at Madira farm during off season cropping 2001/2002.

Source of variation	DF	Lodged plant	Number of pupae		Grain yield per plot
			O. phaseoli	*O. spencerella*	
T	2	1.62*	0.39ns	17.61**	264396.88**
V	1	0.03ns	1.30**	5.58ns	59501.04ns
T X V	2	-0.07ns	0.91ns	1.78ns	4788ns
Error	12	0.36	0.41	1.45	12737.15
CV%		20.6	28.7	21.25	26.75

Appendix 1b: Mean square for hatched Braconids from *O. phaseoli* and *O. spencerella* pupae studied at Madira farm during off season cropping 2001/2002.

Source of variation	DF	100 seeds wt	Hatched Braconids from		Grain per pod	Pods per plant
			O. phaseoli pupae	*O. spencerella* pupae		
T	2	71.67**	0.26ns	6.18**	1.63**	27.38**
V	1	20.54ns	0.54ns	0.51ns	0.67ns	2.04ns
T X V	2	13.25ns	0.40ns	0.60ns	0.54ns	0.54ns
Error	12	11.11	0.39	1.16	0.36	1.29
CV%		8.48	41.63	36.49	18.49	17.83

Appendix 1c: Mean square for hatched Ichneumonids from *O. phaseoli* and *O. spencerella* pupae studied at Madira farm during off season cropping 2001/ 2002.

Source of variation	DF	Cracked stem	Hatched Ichneumonids from		Dead pupae	
			O. phaseoli pupae	*O. spencerella* pupae	*O. phaseoli*	*O. spencerella*
T	2	41.17ns	0.000ns	0.000ns	1.221*	4.279ns
V	1	77.04**	0.089ns	0.35ns	0.356ns	0.791ns
T X V	2	155.7ns	0.000ns	0.275ns	0.644ns	1.414
Error	12	116.28	0.268	1.846	3.030	11.150
CV%		63.59	19.92	42.63	33.64	24.14

T = Sowing date (Factor B)

V = Variety (Factor A)

Ns = Not significant ($p > 0.05$)