THE ROLE OF PARASITOIDS IN REGULATION OF BEANFLY OPHIOMYIA SPP. COMPLEX, AT KAKAMEGA, KENYA.

BERNARD M. NGARI. B.Sc. (Agric.)

UNIVERSITY OF NAIROBI.

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE OF THE UNIVERSITY OF NAIROBI

8/99

DECLARATION

This thesis is my original work and has not been submitted for a degree in any other University

Signed ______________ Date 24/11/97

BERNARD MUTUGI NGARI

Thesis submitted for examination with our approval as the University Supervisors.

Signed ______________ Date 24.11.97

Dr. GIDEON. H. N. NYAMASYO

Signed ______________ Date 24.11.97

Dr. JOHN H.. NDERITU

Date submitted 22/12/97

Dedication

To my parents

Acknowledgments.

I express my appreciation and gratitude to my supervisors Drs. G.H.N Nyamasyo and J.H. Nderitu for the guidance offered to me throughout this study. The outcome of this study is indeed a product of my effort and also theirs.

I am indebted to the Centre Director Kenya Agricultural Research Institute(KARI) for providing me not only adequate research facilities during my field work but also for the good working atmosphere I shared with his staff at Kakamega. I also thank Joe, Peter and Nginda for the technical assistance accorded to me as well as to my colleague and friend Dr. F. Nang'ayo for his help in statistical analysis.

A number of organizations contributed in various ways to the success of this study. KARI, through the Director Dr C.G. Nderitu granted a two-year study leave to pursue postgraduate training while the International Institute of Tropical Agriculture (IITA) offered the M.Sc Scholarship which was administered by the International Livestock Research Institute(ILRI).

Finally, I am indebted to my wife Martha my children Eustus and Margaret, my parents, brothers and sisters for

their endless support and prayers during this study.

TABLE OF CONTENTS **Page**

LIST OF TABLES: **PAGE**

LIST OF FIGURES PAGE

ABSTRACT

Investigations were carried out on the phenology of beanflies (*Ophiomyia* spp.) and their parasitoids under different cultural practices (cropping system and different fertilizer levels) in the field in Kakamega, Western Kenya. Three species of beanflies *Ophiomyia spencerella* (Greathead), *Ophiomyia phaseoli* (Tryon) and *Ophiomyia centrosemantis* (de Meij) were recorded. Of these, *O. spencerella* was the dominant species constituting over 94% of the beanfly complex in Kakamega while *O. phaseoli* and *O. centrosemantis* constituted 4% and 2% respectively. Beanflies appeared in the field 1-2 weeks after crop emergence and their population rose significantly to a peak 3-4 weeks after crop emergence only to stabilize thereafter. This trend was observed on the April, June and September 1996 crops. Three species of parasitoids emerged from samples of the beanfly pupae collected from the field. These comprised of a braconid *Opius phaseoli* which emerged from *Ophiomyia phaseoli* and *O. spencerella*; a cynipid *Eucoilidea* sp. and a Pteromalid *Mesopolobus* sp which emerged from *O. spencerella*. Of these, *Opius phaseoli* was the most dominant species parasitizing *Ophiomyia phaseoli*, while *Eucoilidea* sp. was the most dominant species

parasitizing *O. spencerella*. *Mesopolobus* sp. appeared in very small numbers. The percentage parasitism of the beanfly increased progressively to a peak during the 7-8 week after emergence suggesting a lack of synchrony in the phenology of these parasitoids with that of their beanfly host. Apparently, the parasite populations build up too late well after the beans had been attacked suggesting that parasites alone cannot keep the pest population under check. Intercropping and fertilizer application appeared not to have an effect on the abundance of beanflies and parasitoids and may not therefore be useful control options against the stem maggot as previously thought.

CHAPTER I: INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

The common bean *Phaseolus vulgaris L.* is an important legume and a major source of protein to the people in tropical and subtropical countries of Africa, South East Asia and Latin America. Africa produces 2.43 million tonnes annually equivalent to 33% of the world production (Pachico, 1993). In Africa, beans are cultivated mainly by small scale farmers with small acreage of land, low income and where animal protein is not easily available or affordable. Leakey (1970) reported that up to 20 grams of protein can be derived from every 100gms of dry shelled seeds of common beans consumed. In East Africa, bean production is mostly found in the medium altitude areas from 800 to 2000 metres above sea level (m.a.s.l) although some of it is grown at an altitude as high as 2700 m.a.s.l (Acland, 1971; Wortman and Allen, 1994).

In Kenya, beans are the second most important staple diet after maize and only surplus is sold in the market (Okinda 1979; Nderitu, *et al.*, 1990c). Beans are mainly grown for their dry seeds but the green ripe seeds, green pods and green tender leaves are also consumed as vegetables. The crop is also important in improving soil fertility because of its ability to fix nitrogen (Purseglove, 1974).

Okinda (1979) reported that yields of up to 3000 kg/ha can be obtained on experimental stations. Most farmers, however only achieve low production figures of between 400 to 500kg/ha (Acland 1971; Okinda, 1979; Ministry of Agriculture, Kenya, 1994). Among the reasons for the wide production gap between the actual yield of beans at farmers level and potential yields obtainable from research stations are poor cropping practices, planting low yielding cultivars, moisture stress, low soil fertility, diseases and pests.

In Kenya, beans are attacked by several insect pests. These include beanfly *Ophiomyia* spp), aphids, (*Aphis fabae*) flower thrips (*Megalurothrips sjostedti*) pod borers (*Maruca testulalis* and *Helicoverpa armigera*, bruchids (*Acanthoselides obtectus*, *Ootheca bennigseni* and *Acanthomia horrida*) (Le Pelley, 1959). Among these pests, the beanfly (*Ophiomyia* spp Diptera: Agromyzidae) has been reported as one of the most important pests of beans in Africa, Asia and Australia (Talekar and Chen, 1985)

In East Africa, three species of beanfly namely *Ophiomyia phaseoli* (Tryon), *Ophiomyia spencerella*

(Greathead) and *Ophiomyia centrosemantis* (de meiji) have so far been reported attacking beans. Although estimates of losses due to the bean fly infestation are lacking, reports of 100% crop damage due to the beanfly attack from various parts of East Africa are known (Wallace, 1939; De lima, 1983; Ampofo, 1991). In India loss of up to 90% has been reported (Bhattacherjee, 1976). In the Philippines, the beanfly has been described as the worst pest of young beans and cowpeas especially during the period between January to April(Otane and Quesales, 1918) and in Taiwan, it has been reported to be a severe pest of soyabeans, mungbeans, yardlong beans as well as common beans (Rose. et al., 1978).

Currently the control of this pest involves an integrated approach. Chemical control has been the most widely practiced method (Mountia, 1944; Taylor, 1958; Walker, 1960; Wickramasinghe and Fernendo, 1962; Jones, 1965; Okinda, 1979; De lima, 1983; Negasi and Abate 1986; Moorthy *et al.*, 1987; Kibata, 1990; Nderitu, 1990d; Kundu and Srivastava 1991;). Cultural practices such as early planting, recommended to farmers in an attempt to avoid or reduce effects of beanfly infestation on beans have also been employed (Wallace, 1939; Ho, 1967; Rose et al.,1978;

Irving, 1986; Karel, 1991; Ampofo, 1993; Hirano *et al.*, 1993). The search for resistant cultivars have been tried and some tolerant cultivars have been identified (Nderitu, 1988; Abate, 1990; Oree, 1990). Breeding for resistance to incorporate the resistance characteristic is in progress (Ampofo, 1993). However, breeding for resistance is a long term process. There has also been attempts to use biological control but this remains fairly limited in the absence of adequate research to determine the real potential for this control strategy.

Most small scale farmers in Eastern Africa grow beans as an intercrop along side other crops like maize (Acland, 1971). This approach of farming is thought to reduce incidence of insect pest attack (Farell, 1976; Perrin and Phillips, 1978) an observation that is believed to enhance the role of insect natural enemies especially parasites (Huffaker, 1958; van Emden, 1963; Southwood, 1975). Gethi (1996) recently reported significantly lower beanfly larvae in intercropped plots compared with pure stand plots in Embu. This was in contrast to the results obtained by Kayitare and Ampong-Nyarko(1992) who observed a significantly lower beanfly population in the bean monocrop compared with maize-bean intercrop in Oyugis. As a result of these contradictory findings, it was important that a study be carried out to establish the effect of farming system and soil fertility on the (pest status) population dynamics of beanflies and their natural enemies in the field.

1.2: LITERATURE REVIEW

1.2.1 Taxonomy of the beanfly

The beanfly *(Ophiomyia spp)* was first described by Tryon in 1895 who gave it the name *Oscinis phaseoli* (Tryon). *Ophiomyia* spp. reported by various names from Africa, Indonesia, Java and several islands in the Indian Ocean. Coquillet (1899) and Malloch (1916) classified them as *Agromyza phaseoli* and *Agromyza destructor* respectively. Spencer (1959) transferred them to the genus *Melanagromyza*. These flies were considered as one species in East Africa until when Greathead (1969) further studied their taxonomy. He reported beanfly complex of *Melanogromyza phaseoli* (Tryon), *Melanagromyza spencerella* (Greathead) and *Melanagromyza centrosemantis* (de Meiji). Spencer (1973) revised the classification of Agromyzidae and transferred all the three species to the genus *Ophiomyia*. Spencer (1985) further revised the classification and reported that

O. spencerella is the major bean fly species in East Africa. Besides "beanfly", other common names for *Ophiomyia spp.* are the snap beanfly, the stem mining fly, the stemfly and the bean stem maggot.

Other species of *Ophiomyia* and *Melanagromyza* such as *Ophiomyia spencerella* (Greathead), *Ophiomyia centrosemantis* (de Meij), *Melanogromyza dolichostigma* (de Meijere) bore stems of beans and other legumes and may have been considered as *Ophiomyia phaseoli* in some literature. For example, the cases of beanfly oviposition on stems mentioned by Walker (1960) was probably due to *O. spencerella* (not described until 1969) and not *O. phaseoli*. *O. spencerella* is now known to be more important than *O. phaseoli* while *O. centrosemantis* is least important on beans in East Africa (Greathead 1969, Spencer 1985).

Adults of the three spp. namely *O. phaseoli, O. spencerella* and *O. centrosemantis* are apparently morphologically similar (Goot, 1930; Greathead 1969;). The adults are shiny black insects and often with bluish reflections (Otanes and Quensales 1918, Goot 1930; Greathead 1969). Adult body size measures 1.5 to 2.0 mm in length and has a wingspan of nearly 3.0mm (Talekar and Chen, 1985). Sexes of all the three species are readily distinguished with the male having a bulb-like structure at its abdominal tip whereas the female has a tapered and truncated abdominal tip (Greathead, 1969; Irving, 1986).

Due to the apparent external similarities of adults of the three species, other distinguishing characters peculiar to each species are used in their separations. These include adult male genitalia, larval and pupal characters (Greathead, 1969; Irving, 1986). Adult *O. centrosemantis* is distinguished from the other two species by its characteristic shape of the orbital triangle which is equilateral and more elongated in both *O. phaseoli* and *O. spencerella* (Spencer, 1973; 1985; Greathead, 1969). The aedeagus (characters of the ovipositor) of *O. spencerella* is distinctive in shape and solidly chitinized throughout, whereas that of *O. phaseoli* which is less distinctive in shape is less chitinized. The aedeagus of *O. centrosemantis* has two tiny spines at the tip with small teeth behind them (Talekar and Chen, 1985; Irving, 1986; Spencer, 1973; Greathead, 1969). Pupal characters vary with each species of the beanfly.

Both *O. phaseoli* and *O. Spencerella* pupal spiracles are large and have between eight and nine spiracular openings each, whereas *O. centrosemantis* has a comparatively smaller pupal spiracle than the other two species and the tip of its spiracle is three lobed (Irving, 1986; Greathead, 1969). *O. spencerella* pupae are shiny black; *O. phaseoli* pupae are generally translucent yellow brown; and *O. centrosemantis* pupae are translucent red to yellow-brown (Greathead, 1969). The third instar larval stages of the three species, *O. centrosemantis* can be distinguished from *O. centrosemantis* and *O. phaseoli* by its much longer larval spiracles compared to that in larvae of the latter two species (Greathead, 1969). Both larval and pupal characters are therefore diagnostic of the beanfly species. However, pupal characters are easier to identify than the larval characters which may be time consuming (Irving, 1986).

Behaviourally, the species may be distinguished by the ovipositional sites and host preference. *O. phaseoli* probes and oviposits in the leaves and the larva travels to the base of the stem where it pupates leaving a characteristic subepidermal mine in the stem. *O. spencerella* and *O. centrosemantis* oviposit directly into the stem and hence the larval feeding mine seen in *O. phaseoli* is not easily seen in the latter two species (Irving, 1986).

1.2.2. Geographical distribution, seasonal incidence and host plants.

The beanfly, *O. phaseoli* is believed to have originated from South east Asia as shown by the native wild host plant records from Java (Goot, 1930). To date, it is widely distributed in the tropical and subtropical regions of Africa (IAPSC, 1985), Asia, Australia, the middle East and Pacific Islands including Hawii (Spencer, 1973; Hill, 1983; Greathead, 1969). It has not been reported in the New world. *O. centrosemantis* is distributed throughout Australia, tropical Asia and East Africa (Spencer, 1973). *O. spencerella* was described from East Africa (Greathead, 1969) but is known to occur widely throughout Eastern, Central and Southern Africa.

In recent studies conducted in Kenya, it has been reported that *O. spencerella* is the most dominant species in Central Kenya (Nderitu, 1988; Tengecho *et al.*, 1988). From those records it appears to be the most important species of the beanfly in African highlands while *O. phaseoli* is the most important in the lowlands.

Reports on seasonal incidence of the beanfly species are available from studies conducted at various geographical locations. In East Africa, Swaine (1969) and

Wallace (1939) reported that beanfly incidence was more pronounced during the hotter drier seasons than during the cooler wetter seasons. In India similar records have been reported showing that crops planted in the dry season have higher infestation (Kooner *et al.*, 1977; Singh *et al.*, 1981). In Java, Goot (1930) reported that late planted crops suffer higher incidence of the beanfly. In Taiwan, Talekar and Chen, (1983) reported that two peaks of *O. phaseoli* population occurs in each season. They observed that soil moisture, soil pH, solar intensity and relative humidity were the factors influencing 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*. He, however, found this factor more important on the latter species than on the former species. Other observations on population fluctuations of *Ophiomyia* species have been reported by Monahar and Balasubramanian, (1980b), Singh, *et al.*,(1981) all from India and recently by Irving (1986) and Autrique (1989) from Zambia and Burundi, respectively. In Kenya Kibata (1978) and Nderitu et al.,(1990b) have reported similar observations. Nsibande (1992) reported similar observation in Swaziland.

Autrique (1989) found, from monthly bean sowing between October 1987 to November, 1988 at three sites in Burundi, that *O. spencerella* formed 99.7% of the total population of the three beanfly species; O. spencerella, O. phaseoli and *O. centrosemantis* at Gizozi (1200 m.a.s.l) and 95.7% of the total population at Murongwe (1450 m.a.s.l). *O. phaseoli* made up only 0.3% at Gizozi while *O. centrosemantis* was absent, and in Murongwe *O. phaseoli* made up 0.06% while *O. centrosemantis* made up 3.6% of the total population. He thus concluded that *O. spencerella* was the most predominant species at high altitude location in Burundi, while *O. centrosemantis* was present in low numbers on beans sown between March 1988 and July 1988. *O. phaseoli* and *O. spencerella,* however showed temporal changes in predominance. *O. phaseoli* population rose in numbers early in the season but later declined to low levels as the season progressed. *O. spencerella* found in low numbers at the beginning of the season becomes predominant from the middle to the end of the season. Irving (1986) reported similar observations in beanfly populations from Msekera (1025 m.a.s.l) in Zambia. He found that *O. phaseoli* was predominant on the first of the two successive sown bean crops in a season while *O. spencerella* was present in very low numbers. On the second crop, however, *O. spencerella* was found to be predominant while *O. phaseoli* was missing. *O. centrosemantis* which was absent on the first crop occurred in low numbers on the second crop. In Imbo (800masl), which was the lowest altitude location in the study both *O. phaseoli* and *O. spencerella* were present in large numbers. Therefore species of the beanfly vary in composition depending on the prevailing local conditions.

Kibata (1979) reported that the highest incidence of beanfly coincides with months with less rainfall with peaks in January to March and second peak in June to September and low in long rains. However, Nderitu *et. al* (1990, a,b) showed that severe beanfly infestation was found during the crop planted off-season.

Several authors have recorded several hosts of *Ophiomyia phaseoli*. They include the genera *Cajanus*, *Canavalia*, *Glycine*, *Lablab*, *Macroptilium*, *Mucuna*, and *Phaseolus* which belong to the phaseoleae tribe of Leguminousae. *Carthamus tinctorus* (saff flower) and *Solanum nigrum* (nightshade) are the only non-leguminous hosts reported in review by Gonzales and Menendes (1986).

O. phaseoli has generally been cited to be a severe pest of common beans (Otanes, 1918; Goot, 1930; Ali, 1957; Abul-Nasr and Assem 1968; Greathead, 1969; Spencer, 1973;), Soyabeans (Taylor, 1958; Hirano *et. al.*, 1993), Mungbeans, pea (Singh, *et al.*, 1981), Cowpea, green-gram (Ooi, 1973) and black gram. Several hosts such as broadbean, pigeon peas, hyacinth bean and sunhemp do not seem to be significantly attacked in most areas.

Hosts of *O. centrosemantis* are reported to be *Crotalaria mucronata* (Desv), *Calapogonium Mucunoides* (Desv), *Centrosema pubescens* (Benth.D.C), *Vigna unguiculatus*, *Glycine max*, *Phaseolus lunata*, *Phaseolus vulgaris* and *Tephrosia candida* (Roxb) but only *C. mucronota* seem to be the most important host in E. Africa (Spencer, 1973; Greathead, 1969). Greathead (1969) reported *O. spencerella* on *P. vulgaris*, in East Africa and it has also been detected attacking beans in Nigeria (Deeming, 1979). Greathead (1969) observed it in small numbers on *Vigna umbrellata*, *Phaseolus lunatus*, *Phaseolus mungo*, *Lablab niger* and *Vigna unguiculata*.

1.2.3. Biology

1.2.3.1 Comparison of bean fly species

The biology of the three species of *Ophicmyia* on beans is similar although some slight differences between species exist. *O. phaseoli* adult has three sources of food mainly droplets of water, natural plant secretions and host sap. (Raros, 1975). Oviposition occurs on leaf surface and not all punctures are used for oviposition (Lall, 1959; Agarwal and Pandey, 1961; Ho, 1967; Abul-Nasr and Assem 1968; Swaine, 1969; Bidra and Singh 1969; Greathead, 1969; Monahor and Balasubramanian, 1980a; Singh *et. al.*, 1991). Oviposition of *O. phaseoli* on beans usually occurs on the upper epidermis of the leaf surface but a few eggs are also laid in the lower epidermis (Greathead, 1969; Nderitu *et. al.*, 1990; Singh *et. al.*, 1991). *O. spencerella* will also scarify (make punctures with its ovipositor) on leaf tissue for feeding purposes although it rarely oviposits in the leaves (Greathead, 1969). He also reported that most eggs of *O. spencerella* were laid in the hypocotyl at ground level two or three days after germination and a few eggs were deposited in young stems above the cotyledons or rarely in the leaves. *O. centrosemantis* laid its eggs in the stems and hypocotyl with similar frequency, and hence oviposition sites of *O. spencerella* and *O. centrosemantis* were indistinguishable.

1.2.3.2 Life cycle of the Ophiomyia species complex

Ophiomyia phaseoli oviposits on young leaves, both in the upper and lower surfaces (Ali, 1957; Agarwal and Pandey, 1961; Ho, 1967; Greathead, 1969; Rogers, 1979; Gupta *et al.*, 1984). The eggs are ovoid, opaque white and are inserted into a pocket in the mesophyll tissue in the leaves (Greathead 1969). A single female can lay up to 300 eggs in a 2-week period (Otanes, 1918; Raros, 1975). The eggs hatch in two to four days. The larvae form a short leaf mine, enter the nearest vein, proceed into the petiole and down the stem where pupation takes place. (Goot, 1930; Ho, 1967; Greathead 1969). In young plants, most feeding takes place in the lower cortical layers of the stem, but some larvae penetrate into the tap root (Goot, 1930; Ho, 1967). Under heavy infestation, larvae feed deep inside the stem as well as higher up on the plant. The larval stage lasts for ten days, and the pupal stage lasts an additional nine or ten days. Both periods are shorter under high temperatures or longer under lower temperatures.

In Zimbabwe, the complete life cycle can take as little as three weeks when temperatures are high (Taylor, 1958). In Indonesian highlands, the larval stage can last from 17 to 22 days, and the pupal stage can take as long as 13 to 20 days (Goot, 1930). Hassal (1947) reported that the life cycle in Egypt can be completed in 17 days. In East Africa, Greathead (1969) reported that at 21°C it took 17-31 days to complete its life cycle. The puparium is formed beneath the epidermis, head upwards and ventral surface toward the axis of the stem. Before pupation it forms a semi transparent window which aids the emergence of the adult (Greathead, 1969). However eggs laid in upper leaves of older plants, the larvae frequently pupate in the main stem just above a node before reaching the soil surface (Greathead, 1969; Monohar and Balasubrianian, 1980a)

O. spencerella scarifies (make ovipuncture) the leaves tissue in the same way as *O. phaseoli,* but rarely oviposits in leaves. It oviposits its eggs on the hypocotyl, although few eggs are deposited in the leaves (Greathead, 1969). He also observed that *O. centosemantis* laid its eggs in the stem and hypocotyl with similar frequency, and oviposition sites of *O. spencerella* and *O. centrosemantis* were indistinguishable. In Taiwan, Lee

(1976) found that eggs of *O. centrosemantis* were laid in the soybean leaf tissue. In East Africa, the duration from egg to adult for *O. spencerella* was recorded to be 28 to 35 days at 21°C, while at the same temperature *O. centrosemantis* was 30 days in the laboratory (Greathead, 1969)

1.2.3.3. Damage of beanfly

Damage caused by the feeding adult fly is considered to be insignificant (Rogers 1979; Nderitu et al., 1990a; Nderitu, 1993). The major damage is caused by the larvae especially the third instar which destroys the medullary tissue of the stem at ground level. The tissue around the larvae dies, rots, and dries up, frequently splits revealing the flys' puparia inside. The presence of the beanfly in beans is detected by yellowing of leaves; bean seedlings normally become stunted, wilt and often die. If the plant attacked are growing vigorously they may recover by producing adventitious roots (Ho, 1967). In older plants the mines apparently cause little economic damage (Greathead, 1969), except when the plants break at pupation sites due to wind or mechanical damage (Cadwell, 1939).

1.2.4. Control of beanfly

The methods currently recommended for beanfly control include chemical, biological and cultural control measures. Nevertheless, these methods are rarely utilized by farmers. A combination of two or three methods which are compatible i.e. an integrated pest management approach would be advisable.

1.2.4.1 Chemical control

A great diversity of chemical products are used to control beanfly in different countries where it has been reported. Before the introduction of synthetic organic insecticides, various chemical products were used to control beanfly damage. These were white oil and nicotine sulphate sprays (Morgan, 1938). In the 1960's organochlorine and organophosphorous insecticides were assayed (Braithwaite, 1957; Walker, 1960; Wickramasinghe and Fernando, 1962) and organochlorine insecticides such as aldrin, dieldrin and endrin were reported most effective when applied as wet seed dressing to bean seeds before sowing (Taylor, 1958; Walker, 1960). Indeed, endrin was later reported superior to all others in seed dressing for beanfly control (Walker, 1960; Jones, 1965; Abul-Nasr and Assem 1968; Passlov, 1969)

Although endrin is the most effective insecticide, it has high oral and dermal toxicity for mammals (acute LD_{50} for white rat 3 to 45mg/kg; 12 to 19mg/kg dermal). Moreover, endrin has been reported responsible for reducing seed germination (Wickramasingle and Fernando, 1962), seedling establishment and vigour of *P. vulgaris*, *V. radiata* and *V. unguiculata* (Jones, (1965). Jones (1965) also reported that other recommended insecticides for seed treatment were aldrin, heptachlor, DDT, dieldrin and HCH. Although dieldrin was found to be more effective than aldrin as the insecticide for seed treatment, they reduced *P. vulgaris* germination. Abul-Nasr and Assem (1968) reported that a mixture of DDT and HCH had marked detrimental effects on the growth of beans.

In East Africa, aldrin 40% at a rate of 29g AI/kg seed and applied as seed dressing prior to planting has been over the years, popularly recommended for beanfly control (Kibata, 1978; Okinda, 1979). Hussein (1978) found that it also reduced bean seed germination. Thus, despite the effectiveness of this chemical, it has been deregistered in Kenya (Kibata, 1991), thus alternative control measures by use of natural occurring enemies requires to be studied in detail so that an effective parasitoid or entomopathogens with no effect to the environment can be used.

Foliar sprays for bean fly control are recommended particularly in areas where infestations of the pest are usually light. In some areas where heavy stem fly attacks occur, both soil treatment plus foliar sprays may be necessary to prevent significant damage (Khamala, 1978). Among the insecticides used as sprays for beanfly control, diazinon (0.02%Al), in water was regarded as the most economical in Malaysia (Ho, 1967). Other sprays including fenitrothion (0.125% AI), dimethoate (0.08% AI), trichlorophon (0.1%AI), DDT (0.15%AP), BHC (0.05% AI), endosulfan (0.15%AI), diedrin (0.03% AI) and Parathion (0.025% AI) were also used but often too expensive (Kibata, 1991). Although aldrin and dieldrin have been used to control beanfly, less toxic insecticides are presently being preferred. Irving (1986) reported that in Zambia endosulfan, Carbofuran and primiphos-elthyl gave effective control and are less toxic than organochlorine insecticides discussed earlier. True systemic insecticides are very toxic to mammals and should never be applied at seedling stage, where bean foliage may be used as vegetable. This is because these insecticides may persist in significant quantities in the young tender leaves which are consumed. The efficacy, phytotoxicity and persistence of insecticides used for controlling stem flies on beans need further study. The ideal insecticides for controlling this pest will have to be cheap, effective, non-phytotoxic and with minimum residue in bean seeds and leaves.

1.2.4.2. Host- plant Resistance:

Host-plant resistance offers a promising solution to the beanfly problem in Africa. Several studies have been conducted on resistance of beans and other legumes to *Ophiomyia* spp. Greathead (1969) reported that most of the locally adapted lines in Uganda were somewhat resistant to beanfly damage due to their ability to produce adventitious roots and their thickened hypocotyls. The local Mauritian bean was observed to be more resistant than the introduced varieties (Mountia, 1942). Therefore, efforts are being made in screening bean cultivars for resistance to beanfly. Abate (1990) evaluated several germplasm and recorded some tolerant varieties. Similarly Nderitu, (1988) recorded some tolerant bean varieties in Kenya. These sources of resistance are being used in breeding. Nevertheless, this is a long term process and as such other control measures are required.

1.2.4.3 Biological Control

Parasites of *O. phaseoli* have been reported from various sources where the pest occurs. It is possible that the host species of these parasites were not always *O. phaseoli* but other species of *Ophiomyia* since before Greathead (1969), beanflies on beans were generally considered to be *O. phaseoli*. Greathead (1969) reported from East Africa a parasite complex of nine species which were reared from the three species of *Ophiomyia*. He was also the first to report that *Opius phaseoli* (Fischer) is an important biotic factor in regulating the natural populations of *O. phaseoli* in East Africa. He further showed the life cycle of *Opius phaseoli* to be highly synchronized with that of its host. 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. In Thailand, a larval-pupal parasite of *Ophiomyia phaseoli*, *Plutarchia* sp. was considered important because its biology was well synchronized with that of its host (Burikam, 1978).

The most important parasite of *O. spencerella*, *Eucoilidae* sp. showed delayed density dependence and was ineffective in controlling its host. It was suggested that since *O. spencerella* lays most of its eggs in the hypocotyl and not in the leaves, the larvae are protected from attack by soil so that pupal parasitism is not common. Lack of effective parasitism may partly account for the significant economic importance of *O. spencerella* in East Africa (Greathead, 1969).

Opius phaseoli also parasitizes *O. spencerella* and to some extent *O. centrosemantis*. Agyen-Sampong(1978) listed the following hymenopteran parasites of *Ophiomyia* sp. on cowpeas in Ghana, *Eucoilidea* sp, *Dinarmus basali* (Pteromalidae), *Eurytoma* sp., *Plutarchia giraulti* (Eurytomidae), *Fidenus* sp. and *Pediobius* sp (Eulophidae). Recently, Abate (1991) from surveys conducted in Ethiopia found seventeen parasitoid species. Of these, Pteromalids *Sphegigaster stepticola* Bonci and *S. brunneicornis* were the most common on the wild hosts accounting for 44.5% of beanfly's parasitism. However, on haricot bean a braconid, *Opius phaseoli* Fischer was the major parasitoid with over 87% parasitism. He suggested that there is a possibility of the host plant playing an important role in the beanfly population dynamics.

Opius importatus and *O. phaseoli* were imported to Hawaii from Uganda to control *Ophiomyia phaseoli*, itself an inadevently introduced insects to those Islands. Control was achieved mainly by *Opius importatus* and further shipments of the parasites were sent to Brunei and Taiwan (Fischer 1971; Greathead, 1975). However, the information on their impact on the beanfly population is not known.

1.2.4.4. Cultural control

Cultural practices by farmers play an important role in the integrated pest management of beanfly (Ampofo, 1993). This component together with biological control may be especially useful where high level of resistance has not been found. Sowing beans during drier, hotter seasons should be avoided (Nderitu *et. al.* 1990b). Early and uniform planting by farmers to avoid peak infestation is also recommended (Acland, 1971; Kibata, 1978; Irving, 1986; Negasi and Abate 1986; Karel and Autrique, 1989; Abate, 1990; Nsibande, 1992). Reservoirs of the insect such as volunteer crops or wild host should be eliminated as much as possible (Wallace, 1939; Rose *et. al.*, 1978;). Irving

(1986) suggested that rotations with non-host could be a useful control practice. In Malaysia, crop rotation, is already recommended to farmers to avoid damage by beanflies (Ho, 1967). Karel (1991) also found that Intercropping reduced beanfly infestation. Studies by Floor, *et al.*, (1984) showed that improved soil fertility helped the plants to tolerate damage but did not reduce the beanfly population.

Earthing up bean plants encourages the formation of adventitious roots from the damaged stem (Cadwell, 1939; Wallace, 1939, Ampofo, 1993, Ampofo and Massomo, 1996). Irving (1986) stated that, this practice bars hypocotyl infestation besides encouraging adventitious root formation. Mulching with rice straw helped reduce damage by *O. phaseoli* to soyabeans in Java (Goot, 1930). This practice has also been reported to be effective against *O. spencerella* and *O. centrosemantis* in places where both mulching material and labour are available and have been used (Irving, 1986).

In dry conditions plants are more stressed than in wet conditions. However, application of irrigation and proper use of fertilizer have been found to help keep plants growing vigorously in dry weather and under poor soil conditions and thus making the plants suffer less damage under beanfly attack (Autrique 1989; 1991). For cultural practices to succeed, cooperation of most farmers in a given locality is inevitable. In practice strict observance of above practices in a locality where beanfly is serious pest may be difficult to attain.

Improving soil fertility increases the beanfly population. However, the infested plants in fertilized soils compensated for the damage and grew quickly to pass the critical stages (Kayitare and Ampong-Nyarko, 1992). The plants growing under such conditions are enhanced by producing adventitious roots without significant yield loss. The mortality due to bean fly infestation is reduced (Leutourneau, et al. in press; Ampofo and Massomo, 1996). Intercropping beans with other crops has been reported to reduce the bean fly population. Karel (1991) reported that intercropping maize and beans reduced beanfly. Similarly, Gethi (1996) reported found similar results where the number of beanfly larvae were low in intercrop than pure stand. He attributed his findings (reduction of the beanfly population) to the shading effect of maize that never favoured the development of the larvae of beanfly. He also reported that no significant difference was observed with respect to pupal population. Other workers have conflicting reports. Leutorneau (in press) found that bean/maize dicultures had higher beanfly levels in intercropped fields when fertilizer was applied compared to pure stand with no fertilizer applied. In Java, Goot (1930) found that intermixing maize and beans did not reduce the beanfly population, a fact he attributed to the initial slow growth of maize. Strip cropping maize and beans was reported not to have any effect on beanfly population in Ethiopia (Abate, 1990). Ongecha and Magenya (1991) and Nderitu (1990d) found that intercropping beans with maize had no significant effect on the beanfly populations. Kayitare and Ampong-Nyarko (1992), found lower beanfly population in pure stand of maize compared with maize-bean intercrop. These differences on the effect of cropping could be attributed in part due to cropping systems, sampling technique and time of sampling.

1.2.6 Objectives:

A single field experiment was conducted in April, June and September, 1996 with the following objectives:

(i) To determine beanfly species composition and their natural enemies at Kakamega Regional Research Station.

(ii) To determine the effect of cropping systems and different fertilizer application rates on the beanfly infestation levels.

iii) To investigate the effects of cropping systems, fertilizer application and age of the crop on the levels of beanfly parasitization in the field.

(v) To investigate the physiological reactions of beans due to beanfly attack under different cropping systems and fertilizer application levels.

CHAPTER 2: MATERIALS AND METHODS

2.1 GENERAL MATERIALS AND METHODS

The project was based at Kakamega Regional Research Centre (RRC) which is located in Kakamega district about 400km west of Nairobi. The RRC lies at an altitude of 1585m, latitude 0' 19 N and longitude 34 30'E. The area receives a bimodal rainfall of 1900mm. The long rainy season lasts from February to May, while the short rainy season starts in August and ends in December. The mean annual temperature is 20°C. The relative humidity is high and ranges from 70-90%. The soils are deep, red to dark reddish, well drained dystric humic nitosols with high moisture content. The experimental field was located at an elevation of 1520m above sea level. It was ploughed and harrowed by a tractor. This was to ensure that a fine tilth required for bean production was attained before laying out the trial.

A large plot measuring 4.5 by 49 metres and made up of 10 subplots (4.5 by 4 m) separated by a metre, was marked out. Treatments, farming systems (Bean pure stand versus maize-bean intercrop) and inorganic fertilizer application in kilogramme Diammonium phosphate (DAP) per hectare(0, 50, 100, 150, 200) were assigned randomly to each subplot (Figure 1). This was replicated four times constituting a 2 x 5 Factorial design.

1	3	7	6	2	5	10	4	9	8

4	5	7	8	3	6	10	2	1	9

1	7	10	2	9	3	4	5	6	8

10	4	3	9	6	1	2	5	8	7

Fig 1. The field layout of a block with treatments assigned at random.

key:
1= Pure beans with no fertilizer application.

2= pure stand of beans with 50kgDAP/ha applied.
3= pure stand of beans with 100kgDAP/ha applied
4= pure stand of beans with 150kgDAP/ha applied.
5= Pure stand of bean with 200kgDAP/ha applied.
6= maize and bean intercrop with no fertilizer applied.
7-10 maize was provided with the same rate of 200kgDAP/ha with 50, 100, 150 and 200kgDAP/ha on beans respectively.

The bean variety used was GLP-2 (Rose coco) while the maize cultivar Hybrid 614D was planted during April 1996 and June 1996 while hybrid 511 during September 1996 planting dates. In both pure stand and intercrop treatments, beans received DAP fertilizer at varying rates of 0, 50, 100, 150 and 200kg/ha while in the intercrop, maize received a constant rate of fertilizer of 200kg/ha except on the control where no fertilizer was applied to maize or beans. Before planting, beans were treated in a slurry of Benomyl and Metalaxyl at a rate of 15gms and 10gms, respectively per kg of seeds (Trutmann, *et al.*,1992) to control root rot.

During planting, furrows (5 cm deep) were manually made at a spacing of 50cm between rows for pure stand and 25 cm apart for maize-bean intercrop. Fertilizer was applied in the furrows and well mixed with the soil before planting for every level of application. The spacing between maize rows in the intercrop was 75cm apart while maize to maize was 25 cm. The spacing between maize-bean rows was 25cm. The spacing of bean plant to plant in pure stand and intercrop was 10cm within rows. This was carried out in April, June and September, 1996. For each crop planted, weeding was conducted at an interval of approximately two week until flowering. This made a total of three weeding.

2.2. SPECIFIC METHODS:

2.2.1 Beanfly species composition and their natural enemies.

In each planting (Fig.1), systematic sampling technique was used (Cochran, 1977) serially for eight weeks. Every fifteenth plant was uprooted and kept in paper bags until ten plants were sampled. The ten sampled plants were transported to the Laboratory. These were then dissected from the first internode to the tap root to record the number of beanfly pupae per plant. Beanfly species were determined using the pupae colour (Greathead 1969; Irving, 1986). Using this classification, *O. spencerella* pupae are shiny black; *O. phaseoli* pupae are generally translucent yellow brown; and *O. centrosemantis* pupae are translucent red to yellow-brown. The total number of pupae per planting was used to determine the proportion of each beanfly species. The total number of pupae for each species was expressed as percentages of the total pupal population.

The pupae collected were kept in moist filter paper in a petri dish for 3-4 weeks. The cumulative number of beanfly and parastoids that emerged from the pupae were recorded and identified. The total sum of the parasites collected were recorded. The number of specific beanfly parasite was expressed as percentage of the total number of parasites.

2.2.2 The effect of cropping systems, fertilizer application and time of sampling on beanfly population.

The experimental layout is shown in fig. 1. From each plot, 10 plants were sampled weekly as described in section 2.1.1. The plants sampled were dissected from the first internode to the tap root to observe and record the number of larvae and pupae per plot. The larval and pupal data were square root transformed ($\sqrt{(x+1)}$) and subjected to a three way Analysis of Variance (ANOVA) with cropping system (pure stand and intercrop), fertilizer application (five levels) and time of sampling as main treatment effects. Where treatment effects were significant, means were separated using Duncan New Multiple Range Test (DMRT) (Sokal and Rolhf, 1981). All the analysis were conducted using SAS computer package for statistical data analysis (SAS, 1988). In all cases, means of untransformed data are presented in text, tables and figures.

2.2.3 The effect of cropping systems, fertilizer application and time of sampling on beanfly parasitism.

The pupae collected in section 2.1.2 above were kept in moist filter paper per plot in a petri dish for 3-4 weeks to observe parasite emergence. The parasites that emerged were classified according to species and their total numbers expressed as percentage of the total beanfly and parasite counts. The data was then transformed to angles and analyzed as 3-way ANOVA with cropping system, fertilizer application and time of sampling as maim effects. Where treatment effects were significant, means were separated using DMRT at p=0.05.

2.1.4 Physiological response to beanfly attack in different cropping systems and fertilizer application.

The layout of the study was as shown in figure 1. On the 21st day after plant emergence. Ten plants were sampled using systematic sampling technique where every fifteenth plant was uprooted . The sampled plants were packed in paper bags and taken to the laboratory. They were later rated for beanfly damage using modified Schoonhoven and Pastor-Corrales method (CIAT, 1987) where, 1 represented infested plant with no signs of damage on the stem but on dissection, larvae and pupae found; 3 represented infested plant with light epidermal and light swelling; 5 represented infested plant with average epidermal damage and average swelling; 7 represented infested plant showing considerable damage and swelling while 9 represented infested plants showing badly damaged epidermis with large cracks and extensively swollen stem.

The same plants were also rated for adventitious root formation score. The adventitious root formation score was used as shown by Ampofo (1991), where scale 1 represented plant with 6 adventitious roots; 3 the plants with 3 well developed adventitious roots; 5 represented infested plant with young adventitious roots; 7 represented infested plant with one developing adventitious root and 9 showed infested plants with no adventitious roots. On this scale only adventitious roots above the root collar were considered.

The first internode lengths were also measured from the primary leaves to the first trifoliate leaf nodes for plants in each plot in centimetres. The mean internode length per plot was used in the analysis.

To determine plant mortality due to beanfly attack, the number of dead plants were counted and the percentage plant mortality calculated based on data which was collected 21 days after plant emergence.

At harvest 12 plants were randomly sampled per plot and the weight of seeds were weighed as a measure of yields.

Data on damage score, adventitious root formation score, internode length, plant mortality and yields at harvest were analyzed using a two - way ANOVA with cropping system and fertilizer application as the main effect. In all cases where treatment effects were significant, means were separated by Duncan New Multiple Range Test(DMRT) (Sokal and Rohlf, 1981). A computer package SAS was used in the data analysis (SAS, 1988). In all cases, means of untransformed data are presented in the text, tables and figures.

CHAPTER 3: RESULTS

3.1 Beanfly and parasitoid species composition in Kakamega.

The major bean fly species was *O. spencerella* which occurred in all planting months. It ranged from 94 to 99% of the beanfly species encountered. By comparison, *O. phaseoli* and *O. centrosemantis* occurred in very low proportions (Table 1).

Table 1. Beanfly species composition during the three planting months in Kakamega in 1996.

Planting Month	Total pupal Count	Percent beanfly species composition* O. spencerella	O. phaseoli	O. centrosemantis
April, 1996	5188	98.1	1.2	0.9
June, 1996	3788	94.2	3.4	2.4
Sept, 1996	5251	98.8	1.0	0.2

*The percentage of beanfly species expressed as the percentage proportion of the total pupal population on each crop.

Opius phaseoli was the only parasitoid reared from *O. phaseoli* pupae. In contrast, three parasitoid species, *Eucoilidea* sp, *O. phaseoli* and *Mesopolobus* sp. emerged from *O. spencerella* pupae. No parasitoid emerged from pupae of *O. centrosemantis* pupae. The most dominant parasite of *O. spencerella* was *Eucoilidea* sp. accounting for 40% to 75% of the total number of parasites collected (Table 2). A pteromalid *Mesopolobus* sp. rarely occurred.

Table 2. Beanfly parasitoid species composition during the three planting months in Kakamega in 1996.

Planting Month	Total Parasite count	Percent parasitoid species composition* *Opius* Sp.	*Eucoilidea* Sp.	*Mesopolobus* Sp.
April, 1996	546	15.70	74.10	10.20
June, 1996	639	17.06	61.81	21.13
Sept, 1996	350	37.14	40.57	22.28

*Percentage expressed as the proportion of the specific parasite on the total numbers of parasites counted.

3.2 The effect of cropping system, fertilizer application and population dynamics of beanfly in Kakamega.

With respect to the crop planted on April, 1996, the population of beanfly larvae was higher in the pure stand of beans compared with maize-bean intercrop. Similar results was observed on the pupal population (Table 3). However, these differences were not statistically significant (F=1.34, df= 1,240, P>0.05 for larvae and F=0.41 df = 1,240; P>0.05 for pupae).

Table 3. Mean (±S.E) number of beanfly larvae and pupae per ten plants in pure stand of bean and maize-bean intercrop for April, 1996 crop.(N=160)

Cropping system	larvae	pupae
Pure beans	3.7±0.5a*	16.5±0.9a
maize-bean intercrop	3.1±0.4a	15.9±0.9a
CV	37.14%	23.46%
LSD(5%)	0.72	0.82

*In each column, values followed by the same letter are not significantly different at 5% significance level(Duncan Multiple Range Test)

Similar observations were recorded on the September crop, but not on the June 1996 crop, where significantly higher beanfly pupae were recorded in pure stand compared with maize-bean intercrop($F=5.77$, $df=1,240$; $p<0.05$) (Table 4).

Table 4. Mean (±S.E) number of beanfly larvae and pupae per ten plants in pure stand of bean and maize-bean intercrop for June and September, 1996 crops.

Cropping system	Month of planting			
	June, 1996		September, 1996	
	Larvae	Pupae	Larvae	Pupae
Pure beans	3.2±0.5a*	12.4±0.7a	6.8±0.6a	16.4±0.7a
Intercrop	3.0±0.3a	11.1±0.7b	6.3±0.6a	16.2±0.7a
CV	33.31%	20.06%	26.20%	18.07%
LSD(5%)	0.77	0.73	0.74	0.71

* In each column, values followed by the same letter are not significantly different at 5% significance level (Duncan Multiple Range Tests)

The number of both larvae and pupae did not vary with respect to the rate of fertilizer application on the April planted crop (F=0.82, df=1,240; P>0.05 for larvae and F=1.08, df=4,240; P>0.05 for pupae)(Appendices 1a and 1b). However, a clear trend showing a gradual increase in pupal population with increased fertilizer application was observed from 0 up to 150 kgDAP/ha (Table 5).

Table 5. Mean (±S.E) number of beanfly larvae and pupae per ten plants under different fertilizer application levels for April, 1996 bean crop (N=64).

Fertilizer application (KgDAP/ha)	Number of beanfly immature stages	
	larvae	pupae
0	3.5±0.7a*	14.6±1.2a
50	3.0±0.6a	15.9±1.4a
100	3.2±0.8a	16.9±1.4a
150	3.7±0.8a	17.3±1.4a
200	3.7±0.9a	16.4±0.6a
CV	37.14%	24.39%

* In each column , values followed by the same letter are not significantly different at 5% significance level (DMRT)

Similar observations were recorded on the June and September 1996 crop (F=1.24, df=4,240,; P>0.05 for larvae and F=2.22, df=4,240; P>0.05 for pupae, June, 1996 crop; F=0.72, df=4,240,; P>0.05 for larvae and F=0.74, df=4, 240,;P>0.05 for September 1996 crop)(Table 6) (Appendices 2a, 2b, and 3b).

Table 6. Mean (±S.E) number of beanfly larvae and pupae per ten plants under different fertilizer application for June and September, 1996 bean crops.(N=64)

Fertilizer application (kg DAP/ha)	Month of planting June, 1996 larvae	pupae	September, 1996 larvae	pupae
0	2.8+0.5a*	11.3+1.0a	6.3+0.9a	16.4+1.2a
50	3.3+0.6a	12.3+0.5a	5.9+0.8a	16.2+1.2a
100	2.8+0.5a	11.6+1.0a	6.4+0.9a	16.8+1.3a
150	2.8+0.6a	10.6+1.1a	6.7+0.9a	17.3+1.3a
200	3.6+0.6a	12.8+1.1a	5.9+0.8a	15.6+1.2a
CV	31.31%	20.06%	26.20%	18.07%

* In each column, values followed by the same letter are not significantly different at 5% significance level (DMRT).

The beanfly population (larvae and pupae) differed significantly from one week of sampling to the other (F=61.33, df=7,240, P<0.05 for larvae and F= 69.97, df= 7,240, P<0.05 for pupae) (Appendices 1a&b, 2a&b, 3a&b.). The number of larvae was higher during the first week and declined gradually through to the eighth week of sampling (Fig. 2a). However the number of pupae was higher during the second to third week of sampling and declined gradually through to the eight week for the April, 1996 crop. (Fig. 2a). Similar results were obtained on the June and September planted crops (F=75.55 df=7,240; P<0.05 for larvae and F=140.84 df=7,240; P<0.05 for pupae for June crops and F=137.02, df= 7,240,; P<0.05 for larvae and

F=140.39: df=7,240,; P<0.05 for pupae for September 1996 crop) (fig. 2b and 2c respectively). There was no interaction effect between fertilizer application and weeks of sampling nor with cropping system with respect to larval and pupal population.

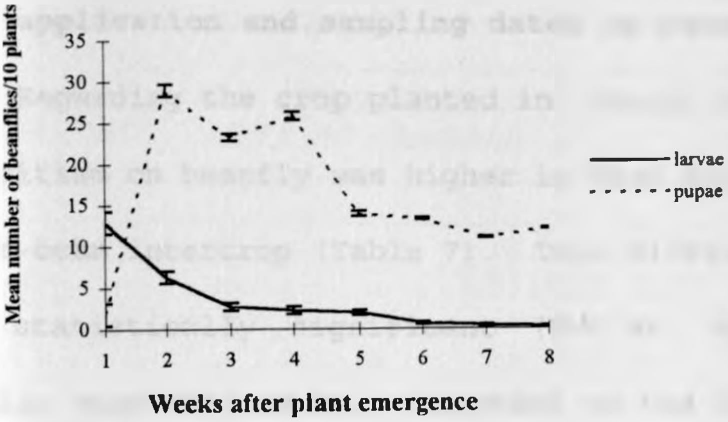

Fig. 2a. The population of beanfly larvae and pupae on the April, 1996 crop (vertical lines shows standard error bands).

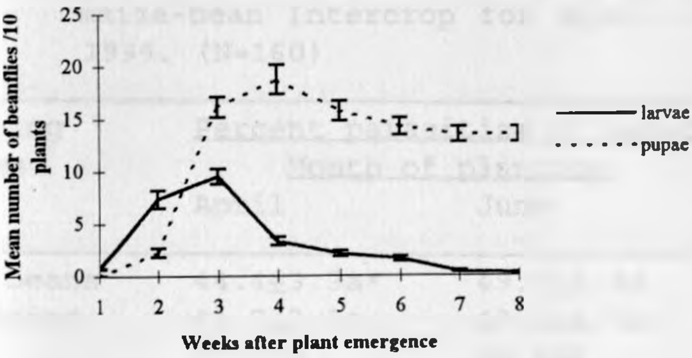

Fig. 2b. The population of beanfly larvae and pupae per ten plants on the June ,1996 crop (vertical lines shows standard error bands).

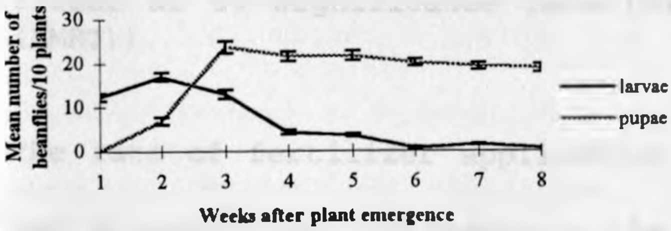

Fig 2c. The population of beanfly larvae and pupae per ten plants on the september 1996 crop (vertical lines shows standard error bands).

3.3 The effect of cropping system , fertilizer application and sampling dates on beanfly parasitism.

Regarding the crop planted in April, 1996, the level of parasitism on beanfly was higher in bean monocrop than in the maize-bean intercrop (Table 7). This difference was however, not statistically significant (F=0.96, df=1,237,;P>0.05). Similar observations were recorded on the June and September 1996 crops.

Table 7. Mean (±S.E) percentage parasitism of beanfly pupae per ten plants in pure stand of beans and maize-bean intercrop for April, June and September 1996. (N=160)

Cropping System	Percent parasitism of beanfly Month of planting April	 June	 September
Pure beans	44.4±3.3a*	49.7±3.3a	26.9±3.0a
Intercrop	41.2±3.3a	48.3±0.7a	27.9±0.6a
CV	37.11%	50.89%	96.11%
LSD	2.37	0.10	0.01

* In each column, values followed by the same letter are not significant at 5% significance level(Duncan Multiple range test (DMRT)).

The rate of fertilizer application for the April crop also had no significant influence on the level of parasitism of beanflies (F=0.70 df=4,237,; P>0.05)(Table 8). Similar observations were recorded on the June and September 1996 crops (Table 8).

Table 8. The effect of fertilizer application on beanfly parasitism under different fertilizer application levels for April, June and September 1996 bean crop.

Fertilizer application (kgDAP/ha)	Percentage beanfly parasitism Month of planting April 1996	June 1996	September 1996
0	42.8± 5.5a*	46.7±5.3a	28.9±5.1a
50	38.3± 5.2a	54.6±5.3a	27.7±4.8a
100	45.9± 5.0a	48.7±5.2a	23.5±5.2a
150	44.6± 5.6a	44.8±5.2a	29.5±4.7a
200	66.7±33.3a	50.6±5.3a	28.4±4.8a
CV	37.11%	50.89%	96.31%

*In each column, values followed by the same letter are not significantly different at 5% significance level(Duncan Multiple range test).

The level of parasitism depended on the time of sampling in April 1996 crop (F=13.74, df=7,237,; P<0.05) (Appendix 3). Percentage parasitism of beanflies increased steadily from the second week after plant emergence through to 8th week (Figure 3). Similar trends on beanfly parasitism were recorded on the June and September 1996 crops, (F=74.90, df=7,240,; P<0.05 and F=21.06, df= 6,207,; P<0.05 for June and September respectively) (Figure 3, Appendices 4 and 5 respectively). In all planting months, no significant interaction between cropping system, fertilizer application and time of sampling was recorded (Appendices 4, 5 and 6).

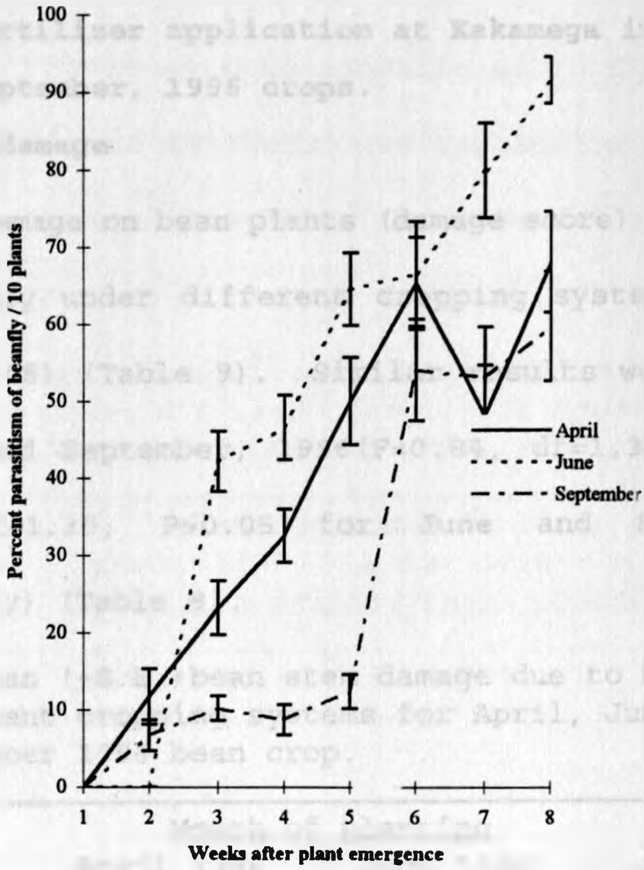

Fig. 3. The incidence of beanfly parasitism during April, June and September, 1996 crops at Kakamega Research Centre, Kenya (vertical lines shows standard error bands).

3.4 The physiological reactions of bean plants due to beanfly infestation under different cropping systems and fertilizer application at Kakamega in April, June and September, 1996 crops.

3.4.1 Stem damage

Stem damage on bean plants (damage score) did not differ significantly under different cropping systems (F=1.50, df 1,30,; P>0.05) (Table 9). Similar results were recorded on the June and September, 1996(F=0.84, df=1,30; P>0.05; and F=1.27, df=1,30; P>0.05 for June and September 1996 respectively) (Table 9).

Table 9. Mean (±S.E)bean stem damage due to beanfly under different cropping systems for April, June and September 1996 bean crop.

Cropping system	Month of planting April 1996	 June 1996	 September 1996
	Beanfly damage visual scores		
Pure beans	4.4±0.2a*	5.2±0.3a	5.9±0.2a
Maize-bean intercrop	4.1±0.2a	5.0±0.2a	5.6±0.2a
CV(%)	19.77	14.57	15.43
LSD(5%)	0.54	0.48	0.57

* In each column, values followed by the same letter are not significantly different at 5% significance level(DMRT).

Fertilizer application had no influence on the visual damage score in the April crop (F=0.93, df=4, 30,; P>0.05) (Table 10). Similar results were recorded on the June and

September, 1996 crops (F=0.9, df=4,30; P>0.05 and F=1.72 df=4,30,; P>0.05 for June and September 1996, respectively (Table 10). There were no significant interactions between the cropping system and fertilizer application with respect to bean stem damage scores (Appendices 7a, 7b and 7c respectively).

Table 10. Mean (+S.E)of bean stem damage due to beanfly attack under different fertilizer application in April, June and September 1996, bean crops.

Fertilizer application (kg DAP/ha)	Planting month April, 1996	June, 1996	Sept.1996
	Bean stem damage visual scores		
0	3.9±0.5a*	5.2±0.3a	5.1±0.3a
50	4.2±0.2a	5.0±0.3a	5.7±0.3a
100	4.5±0.2a	4.7±0.3a	6.2±0.3a
150	3.9±0.2a	6.3±0.3a	5.9±0.4a
200	4.5±0.4a	5.7±0.3a	5.7±0.3a
CV	19.77	14.57	15.40

* In each column, values followed by the same letter are not significantly different at 5% significance level (DMRT).

3.4.2 Adventitious roots formation score

Bean plants produced adventitious roots as a result of beanfly's infestation. However, there was no significant difference in the root formation score on pure bean stand compared with the maize-bean intercrop in April, 1996 (F=0.10 df=1,30,; P>0.05) (Table 11). A comparable root score of 3-4 was recorded on plants in pure stand as well as those in the maize-bean intercrop. Similar results were obtained for the crop planted in June, 1996 crop (F= 0.002, df=1,30; P>0.05) (Table 11). In contrast, pure stand of beans had a higher adventitious score compared with intercrop on the September, 1996 crop (F=9.51, df=1,30,; P<0.05) (Table 11).

Table 11. Mean (±S.E) of adventitious root formation score on beans in pure stand of beans and maize bean intercrop in April, June and September 1996.

Cropping system	Planting month April, 1996	June, 1996	Sept., 1996
	Adventitious root formation scores		
Pure beans	3.8±0.2a*	3.3±0.2a	2.0±0.2a
Maize-bean	3.7±0.3a	2.3±0.2a	2.9±0.3b
LSD (5%)	0.65	0.52	0.58
CV	26.85	24.66	37.11

*In each column, values followed by the same letter are not significantly different at 5% significance level (DMRT).

Although fertilizer application appeared to enhance adventitious root formation in April the crop, this effect was not statistically significant (F=2.26,,df=4.30,; P>0.05) (Table 12). A significant interaction between cropping systems and fertilizer application was observed between the cropping system and fertilizer application. Similar results were also obtained in the June and September 1996 crops, (F=0.002, df=4, 30,; P>0.05 and F= 0.84, df=4,30,;P>0.05 for June and September respectively) Table 12). However no significant interactions were recorded between the cropping system and fertilizer application (Appendices 8a, 8b and 8c).

Table 12. Mean (±S.E) adventitious root formation scores under different fertilizer application levels for April, June and September 1996 bean crops (N=20).

Fertilizer application (kgDAP/ha)	Planting month April 1996	 June 1996	 September 1996
	Adventitious root formation scores		
0	3.9±0.5a*	3.4±0.3a	5.1±0.3a
50	4.2±0.2a	3.6±0.3a	5.7±0.3a
100	4.5±0.2a	4.0±1.3a	6.2±0.3a
150	3.9±1.7a	3.3±1.3a	5.8±0.4a
200	4.5±0.4a	3.0±0.3a	5.7±0.3a
CV	26.85	24.66	37.11

*In each column, values followed by the same letter are not significantly different at 5% significance level (DMRT).

3.4.3 Internode length

The first internode length varied significantly under different cropping systems (F= 44.65, df=1,30,; P<0.05). Pure stand of beans had shorter internode lengths compared to maize-bean intercrop for the April crop (Table 13). However there was no significant difference with the crops planted in June and September 1996 (F=0.01, df=1,30,; P>0.05 and F=0.04 df=1,30,; P>0.05 for June and September crop (Table 13).

Table 13. Mean (±S.E) internode lengths in centimetres of beans under different cropping systems for April, June and September 1996 bean crops (N=20).

Cropping system	Planting Month		
	April 1996	June 1996	September, 1996
	Internode lengths of beans in centimetres		
Pure beans	1.7±0.1a*	1.3±0.1a	1.9±0.1a
Maize-bean intercrop	1.9±0.1b	1.3±0.6a	1.9±0.1a
CV	13.03	11.98	12.60
LSD(5%)	0.15	0.10	0.15

* In each column, values followed by same letter are not significantly different at 5% significance level (DMRT).

The rates of fertilizer application had no effect on the internode length (F=0.90, df=4,30,; P>0.05) in the April 1996 crop (Table 14). Similar results were obtained in the June and September 1996 crops (F= 1.54, df=4,30; P>0.05 and F=2.50, df=4,30,; P>0.05 for June and September respectively)(Table 16) In all the planting months no significant interactions between cropping system and fertilizer application was recorded (Appendices 9a and 9b).

Table 14. Mean (±S.E)of the first internode length in centimetres of bean plants under different fertilizer application levels for April, June and September 1996 crops.

Fertilizer application (kgDAP/ha)	Planting month April, 1996	June,1996	September, 1996.
	Internode lengths in centimetres		
0	1.7±0.1a*	1.2±0.1a	1.6±0.1a
50	1.8±0.8a	1.2±0.1a	1.9±0.3a
100	1.7±0.1a	1.4±0.1a	2.0±0.1a
150	1.7±0.1a	1.4±0.1a	1.9±0.1a
200	1.8±0.1a	1.4±0.1a	1.9±0.1a
CV(%)	13.03	11.98	12.60

* In each column, values followed by the same letter are not significantly different at 5% significance level (DMRT)

3.4.4 Plant mortality

Plant mortality due to the beanfly attack was significantly influenced by the cropping system (F=7.99 df= 1,30,; P<0.05). The pure stand had a higher percentage mortality compared with the maize-bean intercrop on the April 1996 crop (Table 15). Comparable results were recorded in June (F=5.64, df=1,30; P<0.05), but, no significant effect was recorded in the September 1996 crop (F=0.05, df=1,30,; P>0.05) .(Table 15).

Table 15. Mean (±S.E) percent bean plant mortality due to beanfly attack under different cropping systems for the April, June and September 1996 bean crops (N=40).

Cropping system	Planting month April 1996	June 1996	September 1996.
	Percentage bean plant mortality		
Pure bean	6.0±0.5a*	6.7±0.7a	2.6±0.3a
Maize-bean	4.5±0.6b	4.5±0.6b	2.5±0.3a
LSD(5%)	1.09	1.99	0.88
CV(5(%)	32.38	52.40	15.45

*In each column, values followed by the same letter are not significantly different at 5% significance level (DMRT)

The rate of fertilizer application had no significant effect on plant mortality in all the planting dates (F=1.00, df=4,30,;P>0.05 for April, 1996, (F=0.54, df=1,30; P>0.05 for June and F=1.59, df 4,30,; P>0.05 for September 1996) (Table 16) (Appendices 10a, 10b and 10c).

Table 16. Mean (±S.E) percent bean plant mortality due to beanfly attack under different fertilizer application levels for April, June and September 1996 bean crop(N=8).

Fertilizer application (kgDAP/ha)	Month of planting April, 1996	June, 1996	September,1996
	Percent bean plant mortality		
0	5.4±0.4a*	6.4±0.8a	2.9±0.5a
50	5.7±1.0a	5.3±1.6a	2.8±0.5a
100	5.9±0.3a	4.4±0.8a	1.9±0.3a
150	5.5±0.3a	6.3±1.3a	1.9±0.5a
200	4.8±0.4a	5.7±0.9a	3.3±0.4a
CV(%)	32.38	52.40	15.45

*In each column, values followed with the same letter are not significantly different at 5% significance level(DMRT).

3.4.6 Yield (weight of bean seeds)

The yield of beans was significantly higher in pure stand than in the Maize-bean intercrop on the April, 1996 bean crop (F=12.55 df=1,30,; P>0.05) (Table 17). Similar results were obtained on the June and September 1996 crop (F=43.87, df=1,30,; P>0.05 and F=149.86 df=1,30,; P>0.05 for April and June respectively).

Table 17. Mean(±S.E) bean yields in pure stand and maize-bean intercrop for April, June and September 1996 crops. (N=20)

Cropping system	Planting month April 1996;	June 1996	September 1996
	Yield of beans in gms per 12 plants		
Pure beans	88.4±27.1a*	91.9±27.3a	146.5±62.2a
Maize-bean intercrop	52.7±16.6b	50.4±16.4b	52.8±12.5b
LSD(5%)	20.62	12.80	35.20
CV(%)	44.95	27.85	27.85

*In each column, values followed by the same letter are not significantly different at 5% significance level (DMRT).

In April, the level of fertilizer application had no significant effect on the yield of beans (F=0.65, df=4,30; P>0.05) (Table 18). Similar results were recorded in the June and September 1996 crops (F=2.05, df=4,30,; P>0.05 and F=0.65, df=4,30,; P>0.05 for the June and September respectively (Table 18). On all the crops, there were no significant interactions between cropping system and fertilizer application (Appendices 11a, and 11b and 11c).

Table 18. Mean (+S.E) yields of beans under different fertilizer application per 12 plants in April, June and September 1996 crops (N=8)

Fertilizer application (kgDAP/ha)	Month of planting April 1996	June 1996	September 1996
	Bean yield in gms per 12 plants		
0	67.8±34.7a*	59.1±28.6a	95.6±62.2a
50	76.8±37.4a	68.9±32.6a	93.7±46.3a
100	75.3±38.5a	87.7±27.2a	103.9±49.3a
150	73.9±40.7a	72.8±27.5a	120.0±49.3a
200	77.9±32.2a	62.5±32.2a	97.7±56.0a
CV(%)	44.95	27.85	27.85

* In each column, values followed by the same letter are not significantly different at 5% significance level(DMRT).

Statistical analysis of the results using pearson correlation showed that the number of pupae per plant was not significantly correlated to the adventitious root formation score, bean stem damage, plant mortality, internode lengths and yields in the April, June and September 1996 crops. In June, a significant negative correlation between damage score and adventitious root formation score was recorded($r=-0.889$ df 4, $P<0.05$). However, in the September, 1996 bean crop, there was a significant correlation between the beanfly pupae and plant mortality ($r=-0.899$ df= 4; $P<0.05$).

CHAPTER 4. DISCUSSION

Ophiomyia spencerella was the most dominant beanfly species in Kakamega. Two other beanfly species (*O. phaseoli* and *O. centrosemantis*) were also recorded but in relatively low numbers. These observations suggest that *Ophiomyia spencerella* which is probably well adapted to the hot and humid conditions could be the only species of economic importance to the bean production in this region. A study conducted in Burundi at various elevations indicated that *O. spencerella* occurred in highland areas (1000-2200 metres above sea level) (Autrique, 1989). Similar results have been recorded in Tanzania where *O. spencerella* was the most dominant species in the Tanzanian highlands (Oree, 1990). In Kenya, studies conducted in Central highlands showed that the same species was the most dominant (Tengecho *et. al*., 1988). Elsewhere, in Central, Eastern and Southern African highlands, *O. spencerella* has been reported to be the most dominant and economically important pest of beans (Ampofo, 1991, Spencer 1985). The occurrence of *O. centrosemantis* and *O. phaseoli* at relatively low proportions probably suggests that they are poorly adapted to the environmental conditions at higher altitudes. Similar suggestions have been made by Oree (1990) and Autrique (1989). Indeed, *O. phaseoli* and *O. centrosemantis* have been recorded to be more at low lying sites (<1000 metres above sea level) than at higher elevations (Ampofo 1991). These results further confirm the findings of Greathead (1969); Spencer, (1985); Nderitu *et. al* (1990); Tengecho, *et. al* (1988) who found that *O. spencerella* to be the most important beanfly species in the highland areas in Eastern Africa. The possible explanation is that *O. spencerella* being indigenous to Africa could be best adapted to the local conditions than *O. phaseoli* which has been introduced to Africa more recently (Spencer, 1985).

Three parasitoid species emerged from *O. spencerella* pupae during this study. These were *Eucoilidea sp.*, *Opius phaseoli* and *Mesopolobus* sp. These findings were similar to those recorded by Greathead (1969) and Kibata (1991). *Eucoilidea* sp., which was the most dominant parasitoid species and *O. phaseoli*, often emerged earlier (from samples from 2nd and 4th week after plant emergence) than *Mesopolobus* sp. which emerged from samples collected during the 5th to 8th week of sampling and in very low numbers. The emergence of *Mesopolobus* species later in the growing season suggest that it is a less economical important natural enemy of the beanfly to a farmer as it occurs in the field well after the bean plant has suffered the beanfly attack.

Ophiomyia phaseoli on the other hand was only attacked by one parasitoid species *Opius phaseoli*. This observation is similar to the findings recorded by Greathead(1969) and Abate (1991). None of the very few pupae of *O. centrosemantis* collected from the field was parasitized.

Crops grown in an intercropping system are sometimes less prone to outbreak of pests than are those grown in monoculture (Farell, 1976; Perrin and Phillips 1978). The results of the present study, showed that intercropping maize with bean did not significantly reduce the beanfly population compared with pure stand of beans in the April, June and September 1996 bean crops. These results are similar to those of Goot(1930) who reported that planting maize and beans intermixed did not reduce the beanfly population in Java, a fact he attributed to rapid growth of bean seedlings compared to maize. Similar results were reported by Gethi (1996) who found that the beanfly pupal population were not significantly different in the pure stand compared with the maize-bean intercrop. A recent study conducted in Malawi, Letourneau (in press), showed that neither the densities of beanfly (*O. phaseoli* (Tryon) and *O. spencerella* (Greathead) nor their rates of parasitism were changed significantly by diversifying the field with non host plant species (bean-maize dicultures). Other studies by Nderitu (1990d) and Ongecha and Magenya (1991) also showed that intercropping had no effect on the beanfly population. In Java, Talekar and Chen(1985) intercropped soyabean with plants from 14 different botanical families (60 field crops, vegetables, green manure or ornamentals) and found that none of the companion plant reduced or affected the beanfly population. The results reported here suggests that planting monocrop of beans or maize-beans intercropped does not reduce the beanfly population. This probably because when the two crops are planted on the same day, beans often exhibit a very vigorous growth compared with maize in the early stages and thus the olfactory stimuli they produce at that stage override those from maize plants. Therefore, the searching ability of beanfly is not affected by the presence of maize plants at the seedling stage. This may appear to contradict the hypothesis that intercropping reduces pest attack by diverting pests away from the companion crop in mixed cropping (Tahvanian and Roots 1972; Altieri et. al., 1977). Indeed, with respect to other insect species intercropping has been reported to reduce the population of *Empoasca fabae* and *Aphis fabae* on beans but raised the population of *Lygus lineolaris* (Palisot de Beavois) and *Systena frontalis* (F) (Tingey and Lamont, 1988).

Planting in fertile soil, using fertilizer in general, promotes favourable growing conditions that enable the bean plant to tolerate beanfly attack (Ampofo, 1991). Fertilizer application enhances plant tolerance to beanfly attack. However, the application of fertilizer had no effect on the beanfly population in this study. The possible explanation for this is that the distance between plot to plot in the layout was one metre. Due to the heavy rains in Kakamega and the soils having high water retention capacity, the fertilizer applied could have seeped from treated to control plots thereby neutralizing the effect of fertilizer application. As well, the soils at Kakamega Regional research station have been reported to have above average fertility levels for bean production due to frequent application of inorganic fertilizers (FURP, 1994; Anonymous, 1995;) and the continued application of fertilizer may not have any further effect on the beanfly population and the plant's growth. Similar results have been reported in Tanzania where the number of beanfly was not significantly affected by fertilizer application at one site with higher soil fertility compared with trials held at a lower soil fertility site (Ampofo and Massomo, 1996). Thus improving soil fertility as a measure to enhance plants' vigour and minimize beanflys' damage would only work in areas with highly impoverished soils.

In this study, the beanfly population (larvae) increased to a peak during the second week of plant emergence. The pupal population on the other hand increased progressively during the third and fourth week of the plants emergence and levelled off thereafter. These results are similar to the findings reported by Nderitu et. al (1990); Oree, (1990) Autrique (1989) and Okinda (1979). They found that the population of beanfly increased from the first week of emergence to the third week and thereafter stabilized. They also demonstrated that the bean plant is susceptible to attack during the first three weeks after emergence. This suggests that beanfly infestation would be the most prevalent at seedling stage (1-2 weeks after emergence), as this coincides with an increase in pest population in the field. Thus, effective control of this pest may be achieved by the use of systemic insecticides.

With respect to planting dates, the level of beanfly infestation was lower on the April 1996 crop than the September 1996 crop. Similar results have been reported by Kibata (1978) and Nderitu et. al., (1990b), who showed that crops planted during the long rains suffer lower beanfly attack compared with those planted during the short rains. However, the population of beanfly was lower in the off season (June crop) than the April crop. This difference was attributed to the effect of parasites that were migrating from the April crop to the June crop.

Several workers have theorized that plant diversity tend to intensify the impact of natural enemies thus, contributing to the relative infrequent pests outbreaks often associated with natural communities and mixed crop ecosystem (Southwood, 1975; Huffaker, 1958; van Emden, 1963). The results from this study, however indicated that intercropping did not increase the beanfly parasitism. Similar findings were reported in Malawi where planting in pure stand and intercrop had no effect on parasitization (Letourneau, in press). Apparently, diversifying the environment had no effect on the searching behaviour of the beanfly parasitoids. These parasitoids had been reported to attack the first instar larvae of beanfly (Greathead, 1969). It is therefore, possible that their searching behaviour was not affected by the presence of maize. External plant feeding insects are known to damage their host and thereby trigger production of volatile cues that may be exploited by their natural enemies during host searching (Vinson, 1976). However, internally feeding insects like the beanfly (seedling pest) may not damage their host in a similar fashion that would benefit their natural enemies. In such circumstances host finding may be a very complex process that is perhaps unaffected by the intercropping and other cultural practices. This may probably explain why intercropping had no significant effect on the beanfly parasitism during the present study.

The percentage parasitism increased with time of sampling. The highest level of parasitism was recorded during the 7-8 week of sampling. Although high parasitism was observed during the 7-8th week after crop emergence, the damage had already been caused. This suggests that the parasitoids arrived late and hence could not regulate the beanfly population. Thus, the parasitoids alone cannot provide a solution to beanfly menace. The results agrees with the findings by Greathead (1969) who found that the biology of the beanfly *O. spencerella* was not synchronized with its parasitoids.

The physiological parameters (beanfly damage score, adventitious root formation, internode lengths and plant mortality) did not differ significantly with respect to cropping system and fertilizer application. This indicates that these parameters may not be useful in assessing the beanfly infestation on a single variety of beans. They may be useful where different varieties are compared like in the case of insect resistance trials, since different varieties exhibit different growth patterns. However, the infested plants had numerous adventitious roots thus making them grow as if they were not infested and attacked by the beanfly.

The most interesting observation was that the yields were higher in the pure stand compared with the intercrop. This may have been an agronomic response rather than a matter of the beanfly infestation and attack since no significant difference was observed with respect to the cropping practice. Pure stand crops experiences no competition for light and water, and will undoubtedly yield more than their intercropped counterparts. Similarly, the internode lengths were greater on the intercropped beans than on pure stand beans due to stiffer competition for light in the intercrop set up. The plant mortality due to the beanfly attack did not differ with respect to the cropping system since these practices had no significant effect on the pest population.

Lack of significant correlation between the beanfly pupae and bean yields in this study could be explained as follows: The number of beanfly larvae could have been below yield depression response in which case there would be no correlation between the two. Similarly, since the beanfly attack usually occurs during the early developmental stages of the plant, the affected plant often recovers through the adventitious root formation. Consequently, these plants will produce to proceed to produce seeds later on as though they were not previously attacked. It then would appear that significant yield may only be evident where beanfly attack results in plants death. It is therefore possible that the plants that died had a higher number of larvae.

Stem swelling, plant mortality and production of adventitious roots are the general symptoms of the beanfly infestation, but no correlation was found between the number of the beanfly larvae and the bean stem damage score and the adventitious root formation. The abnormal thickening of plant roots caused by increased radial cell growth accompanied by reduced axial cell extension is associated with ethylene production that results from moisture stress (Salisbury and Ross, 1978). Since ethylene production can be autocatalytic, it is possible that its level of production due to stress produced by puparia/larvae could be below the damage threshold level. This probably explains why there was no significant correlation between the number of the beanfly larvae/puparia and the bean damage parameters (bean damage scores, plant mortality and the indirect effect on root formation scores).

CONCLUSIONS

The study has shown that the major beanfly species at Kakamega Regional Research Centre were *Ophiomyia spencerella* and was parasitized by three parasitoids namely *Opius phaseoli*, *Eucoiloidea* sp. and *Mesopolobus* sp. However their parasitization was not be effective since they arrive late in the field. The phenology (growth) of the parasitoids infestation did not synchronize with that of their hosts since they all appeared well after the peak of the pest population. Therefore parasites alone cannot provide reasonable control to the beanfly menace. Intercropping had no effect on the beanfly population and can not be recommended as a general control method against this pest at the high altitude level. Similarly, the application of fertilizer which did not affect the pest incidence, a phenomenon which was attributed to the average soil fertility at the study site cannot be recommended as a control method against the beanfly. In areas with highly impoverished soils this practice may be useful for reducing damage caused by the beanfly as a result of improving plant tolerance to the pest.

There is need to conduct further studies in the farmers fields where no fertilizer is applied every season. Even where soil fertility is adequate, a deliberate control method especially seed dressing should be attempted.

REFERENCES:

Abate, T. (1990). Studies on genetic, cultural and insecticidal controls against the beanfly *Ophiomyia phaseoli* (Tryon)(Diptera: Agromyzidae) in Ethiopia. PhD dissertation Simon Fraser University pp 172.

Abate, T. (1991). The beanfly *Ophiomyia phaseoli* (Tryon) (Diptera : Agromyzidae) and its parasitoids in Ethiopia. J. Appl. Entomol.111(3): 278-285

Abul-Nasr, S. and Assem, M.A.H.(1968). Study on the biological process of the bean fly Melanogromyza phaseoli Tryon) (Diptera: Agromyzidae). Bulletin de la Societe Entomolaquique de'Egypte, 52: 283-295.

Acland, J.D. (1971). Beans *Phaseolus vulgaris*. In "East African crops: an introduction to field production of field and plantation crops in Kenya, Tanzania and Uganda. London Longman Ltd. pp 20-25.

Agarwal, N.S., Pandey, N.D., (1961). Bionomics of Melanogromyza phaseoli Coq (Diptera: Agromyzidae) Indian. J. Entomol. 23: 293-298.

Agyen-Sampong, M.M (1978) Pest of cowpeas and their control in Ghana. In: Pest of grain legumes: Ecology and Control eds) Singh S.R, van Emden H.F and Taylor T.A. Academic press 85-92

Ali, A.M. (1957) On the bionomics and control of the beanfly *Agromyza phaseoli* Coq. Bull. Soc. Entom. XL1: 551- 554.

Altieri, M.A., van Schoonhoven, A., Doll, J. (1977). The ecological role of weeds in insect system. Pest Art News Summ. 23:195-205.

Ampofo, J.K.O. (1991). Bean stem maggot: Research methods. Training course at Bujumbura, Burundi, 1-8 NOV 1991. CIAT Occasional publication series No.7

Ampofo, J.K.O. (1993) Host plant resistance and cultural strategies for bean stem maggot management. In Ampofo, J.K.O (ed). Proceedings of the Second Meeting of the Pan- African Working Group on bean entomology. CIAT African. Workshop Series No. 25, Cali, Colombia: CIAT.

Ampofo, J.K.O. and Massomo, S.M (1996) Some cultural strategies for BSM (Diptera: Agromyzidae) management in beans Phaseolus vulgaris L fields in Tanzania. In: Fourie,D and Lienberge (eds) Proceedings of fourth SADC Regional Bean Research Workshop, Potchefstroom. SouthAfrica, 2-4 October 1995 Network on Beans Research in Africa, Workshop series No. 31, CIAT Dar es Salaam, Tanzania. pp15-19.

Anonymous,(1995). Soil test report Kakamega Regional Research Centre 2p. unpublished report.

Autrique, A. (1989). Bean pests in Burundi: their status and control. In: Ampofo J.K.O (ed) Proceedings of the first meeting of the Pan African Working Group on Bean Entomology. CIAT African Workshop series No. 11 Cali Colombia: CIAT.

Autrique, A. (1991). Synthesis of research work on beanfly in Burundi. CIAT Workshop series no. 9 pp 67-79

Bhattacharjee, N.S. (1976). Control of Soyabean stemfly Agromyza. Entomol. Newsl No 6:36.

Bidra, O.S. and Singh, H. (1969) Pea stem borer *Melanagromyza phaseoli*(Diptera:Agromyzidae) Pesticide 1969: 19-20

Braithwaite, B.M.(1957) An experiment for control of beanfly. Agric. Gaz. N.S.W 68:95-177

Burikam, I. (1978). Ecological investigation of the beanfly, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae) and its natural enemies in Thailand, M.Sc thesis. Kasetsart University, Bangkok, Thailand.

Cadwell, N.E.H. (1939). Beanfly control in southern Queensland. Qd. Agric. J. 52(4): 54-60.

CIAT, (1987).(Centro Internacional de Agricultural Tropical).Standard system for evaluating bean germplasm. Van Schoonhoven, A. and Pastor-Corrales, M.A ed. Cali Colombia 54pp.

Cochran, W.G. (1977). Sampling techniques. Second edition. New York; Wiley 413pp

Coquillet, D.W. (1899). Description of Agromyza phaseoli, a new species of leaf-mining fly. Proc. Linn Soc. N.S.W 24:128.

Deeming, J. C. (1979). *Ophiomyia phaseoli* Tryon)(Diptera:Agromyzidae) attacking bean plants *Phaseolus vulgaris* Lin) in Northern Nigeria. Nigeria J. Entomol. 3(2):129-132.

De Lima, C.P.F. (1983). Management of pest of subsistence crops: Legumes and pulses. In Youndowei, A. and Service, M.W.(eds). Pest and vector Management in the tropics. pp.246-250. Longman, London

Farell, J.A.K. (1976). Effect of intersowing with beans on spread on the ground nut Rosset virus by *Aphis craviccivora* Koch (Homoptera: Aphididae) in Malawi. Bull.ent. Res 66:331-333.

Fischer, M. (1971). Two opius species imported from Uganda into Hawaii (Hymenoptera: Braconidae). Anzeiger fur

Schadlingskunde und Planzenschutz 44(1):10-22.(Denish)

Floor, J.; Stoetzer, H.A.I.; Okongo, A.O (1984). Increased tolerance of dry beans as a result of fertilizer application. Thika, Kenya, National Horticultural Research Station. Grain Legume Project. 2p.

FURP, (1994) Fertilizer use and recommendation project. KARI, Kenya. Vol.23 Kakamega district 23 pp.

Gethi, M. (1996) Effect of intercropping beans and maize on bean stem maggot (*Ophiomyia* ssp) infestation and damage:A cultural control option. In Fourie,D. and Leinberg A.J.(1996). Proceedings of fourth SADC Regional Bean Research Workshop, Potchestroom, South Africa, 2-4 October 1995. Network on bean Research in Africa, Workshop series No.31. CIAT, Dar Es Salaam, Tanzania. pp 15 - 19.

Gonzales, V.F. and Menendes, F.L(1986). The beanfly *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae). In: Omunyin M.E.,Muigai, S.G.S Phaseolus beans Newsletter for Eastern Africa no 5: 19-35. Ministry of Agriculture, Kenya. Agricultural Information Centre, Nairobi, Kenya.

Goot, P. (1930). Agromyzid flies of some native legume crops in Java. 98pp. AVRDC Publication 84-216, Shanhua, Taiwan; Asian Vegetable Research and Development Center.

Greathead, D.J. (1969). A study in East African beanflies Diptera : Agromyzidae) affecting *Phaseolus vulgaris* and their natural enemies with description of a new species *Melanogromyza* Hend. Bull. Entomol. Res. 59:541 -561.

Greathead, D.J. (1975). Biological control of beanfly by *Opius* sp. (Hymenoptera: Braconidae) in Hawii Island. Entomophaga 20(3): 313-316.

Gupta, P.K.(1984). Biology of bean stemfly *(Ophiomyia phaseoli* Tryon,(Diptera: Agromyzidae) J. Advanced Zoology, 5(1):34-41

Hassal, A.H. (1947). The beanfly Agromyzae phaseoli (Tryon) in Egypt. Bull. soc. Faud I'er Entomol 21: 217-224.

Hill, D.S (1983). Agricultural Insect pests of tropics and their control 2nd edition, Cambridge, University Press, London, New York, New Rochele, Melbourne, Sydney, 746pp.

Hirano, K., Hassal, K. and Alimoesa, S.(1993). Effects of rice straw mulch on controlling beanflies (Diptera: Agromyzidae in soyabeans in fields in Indonesia. Appl. Entomol. and zoology 28(2):260-262

Ho, T.H. (1967). The beanfly (*Melanagromyza phaseoli* Coq). and experiments on its control. Malaysian Agric. J. 46(2):147-157

Huffaker, C.B. (1958). Experimental studies on predation: dispersal factors and predator-prey oscillations. Hilgardia 27:343-383.

Hussein, M.Y. (1978). A preliminary study on seed treatment and foliar sprays for chemical control of beanfly. *Ophiomyia phaseoli* (Tryon) on long bean seedlings. Malaysian Agric J. 53(3): 255-260

IAPSC. (1985). Distribution maps of major pest and diseases in Africa. Map/cart no 250. Published by OAU and CAB, by Scientific secretariat of the IAPSC, Younde, Cameroon.

Irving, N.S. (1986). Species identification. In: Allen D.J and Smithson, J.B (eds). Proceedings of beanfly workshop 16-20 November, 1986, Arusha Tanzania. Pan African Workshop Series No. 1. SADCC/CIAT Regional programme on Beans, Arusha, Tanzania, pp. 8-10.

Jones, R.J. (1965). The use of cyclodiene insecticide as liquid seed dressing to control bean fly (*Melanagromyza phaseoli*) in species of *Phaseolus* and *Vigna* marina in South Eastern Queensland. Australian.

J. Exp. Agric. Animal husbandry 5:458-465.

Karel, A.K. (1991). Effects of plant populations and intercropping on the population patterns of bean flies on common beans. Environ. Entomol. 20(1):354-357.

Karel, A.K. and Autrique, A. (1989). Insects and other pest in Africa. In " Bean production problems in the Tropics"
2nd. Edition Swhwartz H.F and Pastor corrales M.A(Eds) Cali. Colombia pp 455-504.

Kayitare, J. and Ampong-Nyarko, K. (1992). Infestation of phaseolus vulgaris (L) by beanfly Ophiomyia spp (Diptera: Agromyzidae) and its management by cultural practices. 1992 ICIPE Annual report p47.

Khamala, C.P.M. (1978). Pest of grain legumes and their control in Kenya. In: Singh, S.R., van Emden, H.F.,Taylor, T.A (eds). Pests of grain legumes: Ecology and Control. London/New York; Academic. pp. 127-134.

Kibata, G.N. (1978). Experiment on control of beanfly, *Melanogromyza phaseoli*. NAL Annual report, Nairobi, Kenya pp. 7-10.

Kibata, G.N. (1979). An assessment of beanfly seasonal infestation and occurrence. NAL, Annual report pp 13 -

14.

Kibata, G.N. (1990). Control of beanfly *Ophiomyia* spp.(Diptera: Agromyzidae) on French beans. NARL Annual report.pp 87-91.

Kibata, G.N. (1991). Control of beanfly Ophiomyia spp.(Agromyzidae) on French beans (*Phaseolus vulgaris* L). In Recent advances in KARI's Research Programmes. Proceedings of the 2nd KARI Annual Scientific Conference Panafric Hotel, Nairobi, Kenya on 5- 7th September, 1990 pp 199-203.

Kooner, B.S,; Singh H. and Kumar,S (1977). Effects of sowing date on the incidence of stem fly *Melanagromyza phaseoli* (Tryon) in peas. J. Entomol. Res (1):100-103.

Kundu, G.G., Srivastava ,K.P (1991). Management of soyabeans stemfly *Melanogromyzae soja*e Zehnt in India J. Insect Sci. 4(1):50-53.

Lall, B.S. (1959). On the biology and control of the bean fly *Agromyza phaseol*i Coq. Diptera: Agromyzidae. Sci. Cult. 24(11): 531-532.

Leakey, C.L.A. (1970). The improvement of beans Phaseolus vulgaris L in Eastern Africa. In: Leakey C.L.O (eds). Crop improvement in Eastern Africa. Commonwealth Agricultural Bureaux, Farnham Royal England, pp 99-

128.

Lee, S.Y. (1976). Notes on some Agromyzidae flies destructive to soyabeans in Taiwan. Japanese J. 64: 54-60.

Lee Pelley, R.H. (1959). Agricultural insects of East Africa. 307pp. Nairobi, E.A High commission

Letourneau, D.K.,L.M. Kantiki, R.E O'Malley (in press). Comparison of insect pest and disease incidence in bean monocultures versus intercropped beans. Malawi J. Sci. Technol.

Letourneau, D.K.(in press). Associational susceptibility: effects of cropping pattern and fertilizer on beanfly infestation in Malawi. Ecological Applications.

Malloch, J.R. (1916). A new species of Agromyzidae destructive to bean in Philippines. Proc. Entomol. Soc. of Washington 18:93 (cited by Spencer, 1973)

Ministry of Agriculture, (1994). Western province Annual Report 1994, Kenya.

Monahar, S. and Balasubramania, M (1980a). Note on ovipositional behaviour of Agromyzidae fly *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae) in blackgram. Madras Agric. J. 67(1):470-471.

Monahar S. and Balasubriamania, M. (1980b). Study in the seasonal incidence of agromyzid stemfly *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae) in black gram. Madras Agric. J. 67(8):534-537.

Moorthy, P.N.K. and Tewari, G.C. (1987). Management of stemfly *Ophiomyia phaseoli* (Tryon) on french beans with reduced insecticidal doses. Entomon.12(4):363-366.

Morgan W.L. (1938) For beanfly control use white oil nicotine sulfate mixtures. Agric. Gaz. N.S.W. 49(1):22-24.

Mountia, A. (1942) The beanfly *Melanagromyza phaseoli* in: Annual Report, pp 16-17. Department of Agriculture, Mauritius, 1943, Port Louis, Mauritius(Cited from Gonzales and Menendes. Phaseolus Newsletter for Eastern Africa No.5 pp 19-35.

Mountia, A.(1944). The beanfly *Melanogromyza phaseoli* (Coq).In Annual report, 1943. Department of Agriculture Mauritius. p10 and p 17.

Nderitu, J.H. (1988). Evaluation of seven bean cutivars for resistance to beanflies. NAL Annual Report, Nairobi, Kenya. pp. 55-56.

Nderitu, J. H., Kayumbo, H. Y. and Mueke, J. M. (1990a). Effect of date of sowing on beanfly infestation of the bean crop. Insect Sci. Applic.11(1): 97.- 101

Nderitu J.H., Kayumbo H.Y. and Mueke J.M., (1990b). Beanfly infestation on common beans (*Phaseolus vulgaris* L.) in Kenya. Insect Sci. Applic.11(1): 35-41.

Nderitu, J.H., Mbuvi, B.D.M. and Ngatia, C.M. (1990c). Assessment of beanfly incidence, damage and losses in subsistence farmers fields. NARL, Annual Report. Nairobi, Kenya pp.78-83.

Nderitu, J.H., (1990d). Incidence of beanfly in bean monocrop and intercrop of maize and beans during the long rains of 1990. NAL Ann rep, Nairobi, Kenya. pp 91- 93

Nderitu, J.H.,(1993) Evaluation of bean cultivars at different stages of growth for resistance to beanflies. E. Afr Agric. For. J. 58(3), 133-134.

Negasi, F. and Abate, T. (1986). Studies on the control of the bean fly *Ophiomyia phaseoli* (Tryon) (Diptera:Agromyzidae). Ethiopian J. Agric. Sci. 8(1): 47-59.

Nsibande, M. (1992) Influence on the occurrence of the beanfly (Diptera: Agromyzidae) on beans. In: D.J. Allens(eds) Proceedings of the third SADC/CIAT Bean Research Workshop in Africa. CIAT Workshop series no.27 pp 165-168.

Okinda, A.F., (1979). The incidence of beanfly (Diptera: Agromyzidae) on performance of french beans Phaseolus vulgaris L and some aspects of control. M.Sc Thesis, University of Nairobi 76pp.

Ongecha, J., and Magenya, O. (1991). Effect of intercropping on incidence of stalk borers and beanfly. Technical Ann. Rep. KAR1 RRC, Kisii pp 43-45.

Ooi P. A.C., (1973). Some insect pest of green gram Phaseolus aurens. Malaysian Agric. J.49 (2): 131-142.

Oree, A. (1990). Studies on species composition and temporal changes in the beanfly populations at three sites in Tanzania, M.Sc thesis, Sokoine University of Agriculture 147pp

Otanes, y and Quesales, F.,(1918). The beanfly Philipp Agric.7:2-31

Pachico, D., (1993). The demand for bean technology. In Henry, G. (ed). Trends in CIAT commodities CIAT, Cali, Colombia pp 60-73.

Passlov, T., (1969). Pest control in navy beans. Qd. Agric. J. 95(10):711-712

Perrin, R.M., and Phillips M. L. (1978). Some effects of mixed cropping on population dynamics of insect pests. Entomolgia exp. appl. 24:583-593.

Purselglove, J.M., (1974). Tropical crops. Dicotyledon. Longman pp 304-310.

Raros, E. S., (1975). Bionomics of beanfly *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae) and its parasites in Hawaii. PhD thesis, University of Hawaii, Honolulu.(abstract).

Rose R.I.; Chiang, H.S.; and Harnoto, I. (1978). Pests of grain legumes and their control in Taiwan. In: Singh, S.R.; van Emden, H.F.; and Taylor, T.A. (eds). Pest of grain legumes: ecology and control. Academic Press, London, England. p 67-71.

Rogers, D.J. (1979). Host selection to Ophiomyia phaseoli (Tryon) (Diptera: Agromyzidae) in phaseolus vulgaris. J. Australian Entomol Soc. 18(3):245-250.

Salisbury, F.B. and Ross, C.W. (1978). Plant physiology. Wadsworth Publishing Company, Inc., Belmont. California.

SAS, (1988). SAS Procedures Guide, Release 6.03 Edition. Cary, NC: SAS Institute USA 433p.

Singh G., Misra, P.N., Srivastava, B.K. (1981). Effect of date of sowing pea on damage caused by *Ophiomyia* *centrosemantis*. Indian J. Agric. Sci. 51(5): 340-343.

Singh, T.V.K., Satyanarayana, P. and Gond, T.R.(1991). Studies on the biology of french bean fly *Ophiomyia phaseoli* (Tryon). J. Insect Sci.4 (2): 172-173.

Sokal, R.R. and Rohlf, F.G. (1981). Biometry. The principles and Practice of Statistics in Biological Research. W.H Freeman and Co. New York pp 858.

Southwood, T.R.E. (1975). The dynamics of insect population pp 151-199 in Pimentel, D (ed) Insects, Science and Society-284pp New York Academic Press.

Spencer, K.A. (1973). Agromyzidae (Diptera) of economic importance, X11 and 488, The Hague, The Netherlands.

Spencer, K.A. (1959). A synopsis of Ethiopian Agromyzidae (Diptera). Trans. Royal Entomol. Soc. of London 111, 237-329.

Spencer, K.A. (1985). East African Agromyzidae(Diptera). Further descriptions, revisionary notes and records. J. Nat. His. 19(5):168-169.

Swaine, G. (1969). Studies on the biology and control of seed beans *Phaseolus vulgaris* in northern Tanzania. Bull. Entomol. Res. 59:323-338.

Tahavanianen, J.O. and Root R.B. (1972). The influence of vegetational diversity of a specialized herbivore Phyllotreta cruciferae (Coleoptera: Crysomelidae). Oecologia 10:321-324.

Talekar N.S. and Chen B.S. (1985). The beanfly pest complex of tropical soyabean. Soyabeans in tropical and subtropical cropping system. AVRDC 1985 Taiwan 257-274.

Talekar, N.S. and Chen, B.S. (1983). Seasonality of insect pest of mung beans in Taiwan. J. econ. entomol 76(1): 34-37.

Taylor, C.E. (1958). The bean stem maggot. Rhodesia Agric. J. 55(6):634-636.

Tengecho, *B., Coulson, C.L., and Souza H. A. D. (1988)* Distribution and effect of bean flies *Ophiomyia phaseoli* and *O. spencerella* at Kabete, Kenya. Insect Sci. Applic. 9(4): 505-508.

Tingey, W.M. and Lamont, W.J.(1988). Insect abundance in field beans altered by intercropping . Bull ent. Res. 78:527-535.

Trutmann, P., Paul K.B., and Cishabayo D.C. (1992) Seed treatments increase yields of farmer varietal field bean mixtures in Central Africa highlands through multiple disease and beanfly control. Crop protection

Vol 2:458-464.

Tryon (1895) The bean maggot. Tran. Natural History Society of Queensland 1: 4-7.(Cited by Spencer 1973)

van Emden, H.F. (1963). Observation on the effect of flowers on activity of a parasitic Hymenoptera Entomologist mon. mag. 98:265-270.

Vinson, S.B. (1976). Host selection by insect parasitoids. Ann. Rev. Entomol. 21:109-133.

Walker, P.T. (1960). Insecticide studies on East African agricultural pest, 111: Seed dressing for control of bean flies *Melanogromyza phaseoli*(Coq) in Tanganyika. Bull. Ent. Res. 50(4): 781-793.

Wallace, G.B. (1939). The french bean diseases and beanfly in East Africa. E. Afric. For. J. 5:170-175.

Wickramasinghe, N. and Fernando, H.E. (1962). Investigations on insecticidal seed dressing, soil treatment and foliar sprays for the control of *Melanagromyza phaseoli* (Tryon) in Ceylon. Bull. Ent. Res, 53: 223-240.

Wortman, C.S., and Allen, D.J. (1994). African bean production environments: their definition, characteristics and constraints. CIAT Occasional Publication Series No. 11.47pp.

APPENDICES

Appendix 1a. The ANOVA table for the date of sampling (WEEK), Cropping systems (SYT) and Fertilizer application (TRT) on the population of larvae per 10 plants For the April planted crops.

Source	DF	SS	MSS	F value	P value
SYT	1	0.62	0.62	1.34	0.2481
TRT	4	1.51	0.38	0.82	0.5131
SYT*TRT	4	0.40	0.10	0.22	0.9292
WEEK	7	198.04	28.29	61.33	0.0001
SYT*WEEK	7	0.89	0.13	0.28	0.9623
TRT*WEEK	28	21.27	0.76	1.65	0.0253
SYT*TRT*WEEK	28	6.26	0.22	0.48	0.9878
ERROR	240	110.72	0.46		
CORRECTED TOTAL	319	339.14			
CV	37.14%				

Appendix 1b. The ANOVA table for the date of sampling (WEEK),Cropping system(SYT) and Fertilizer application(TRT)on the population of Pupae per 10 plants For the April planted crops.

Source	DF	SS	MS	F value	P value
SYT	1	0.31	0.31	0.37	0.5448
TRT	4	3.63	0.91	1.08	0.3647
SYT*TRT	4	1.00	0.25	0.30	0.8784
WEEK	7	409.65	58.52	69.97	0.001*
SYT*WEEK	7	4.36	0.62	0.75	0.6338
TRT*WEEK	28	11.55	0.41	0.49	0.9862
SYT*TRT*WEEK	28	12.64	0.45	0.54	0.9734
ERROR	240	200.73	0.84		
CORRECTED TOTAL	319	643.87			
CV	23.46%				

Appendix 2a. ANOVA table for the cropping system,(SYT) fertilizer application(TRT) and sampling dates (WEEK)for the June planting date with respect to beanfly larval population.

Source	DF	SS	MS	F value	P value
SYT	1	0.004	0.004	0.10	0.9100
TRT	4	1.560	0.39	1.24	0.2962
SYT*TRT	4	2.38	0.59	1.88	0.1144
WEEK	7	167.30	23.90	75.60	0.001*
SYT*WEEK	7	2.69	0.38	1.21	0.2963
TRT*WEEK	28	12.74	0.46	1.44	0.0775
SYT*TRT*WEEK	28	6.07	0.22	0.69	0.8838
ERROR	240	75.92	0.32		
CORRECTED TOTAL	319	268.66			
CV	31.31%				

Appendix 2b. ANOVA table for the number of beanfly pupae with regards to cropping system(SYT),fertilizer application(TRT) and sampling dates(WEEK).

Source	DF	SS	MS	F value	P value
SYT	1	2.54	2.54	5.77	0.1710
TRT	4	3.91	0.98	2.22	0.0671
SYT*TRT	4	0.40	0.10	0.23	0.9230
WEEK	7	433.64	61.98	140.84	0.0001
SYT*WEEK	7	7.93	1.13	2.58	0.0141
TRT*WEEK	28	16.41	0.41	1.33	0.1300
SYT*TRT *WEEK	28	8.30	0.58	0.67	0.8942
ERROR	240	105.56	0.30		
CORRECTED TOTAL	319	578.69			
CV	20.06%				

Appendix 3a. ANOVA table for the number of larvae in cropping system(SYT), fertilizer application (TRT) and sampling dates during the September planted crops.

Source	DF	SS	MS	F value	P value
SYT	1	0.44	0.44	1.06	0.3032
TRT	4	1.18	0.29	0.72	0.5789
SYT*TRT	4	1.59	0.40	0.97	0.4225
WEEK	7	392.59	56.08	75.6	0.0001
SYT*WEEK	7	3.62	0.52	1.21	0.2684
TRT*WEEK	28	8.32	0.30	1.44	0.8420
SYT*TRT *WEEK	28	10.24	0.37	0.69	0.6239
ERROR	240	98.24	0.41		
CORRECTED TOTAL	319	516.24			
CV	26.20%				

Appendix 3b. ANOVA table for the number of pupae during the September planted crops in different cropping system (SYT) and fertilizer application (TRT).

Source	DF	SS	MSS	F value	P value
SYT	1	0.05	0.05	0.10	0.7545
TRT	4	1.49	0.37	0.74	0.5640
SYT*TRT	4	4.43	1.10	2.22	0.0680
WEEK	7	519.60	74.23	148.39	0.0001
SYT*WEEK	7	3.07	0.44	0.88	0.5248
TRT*WEEK	28	10.53	0.38	0.75	0.8143
SYT*TRT *WEEK	28	9.09	0.32	0.65	0.9140
ERROR	240	120.05	0.50		
CORRECTED TOTAL	319	668.32			
CV	18.07%				

Appendix 4. The ANOVA table for the effect of cropping system(SYT), fertilizer application and sampling dates after emergence(WEEK) on beanfly parasitism on the April planted crops.

Source	DF	SS	MSS	F value	P value
SYT	1	2714.48	678.73	0.70	P>0.05
TRT	4	929.84	929.84	0.96	P>0.05
SYT*TRT	4	5889.64	1472.40	1.52	P>0.05
WEEK	7	93052.75	13294.25	13.74	P<0.01
SYT*WEEK	7	2662.90	380.41	1.25	P>0.05
TRT*WEEK	28	33855.75	1209.13	0.39	P>0.05
SYT*TRT *WEEK	28	31016.81	1107.74	1.14	P>0.05
ERROR	237	229311.24	967.56		
CORRECTED TOTAL	319	406633.32			
CV	37.11%				

Appendix 5. The ANOVA table for the effect of cropping system(SYT), fertilizer application(TRT), and sampling dates after emergence(WEEK) on beanfly parasitism on the June planted crops.

Source	DF	SS	MS	F value	P value
SYT	1	606.49	606.49	1.17	0.2803
TRT	4	2761.03	609.26	1.33	0.2584
SYT*TRT	4	416.47	104.12	0.20	0.9376
WEEK	7	271578.40	38796.91	74.90	0.0001
SYT*WEEK	7	4379.39	625.63	1.21	0.2990
TRT*WEEK	28	13416.83	479.17	0.93	0.5782
SYT*TRT *WEEK	28	15926.11	568.81	1.10	0.3412
ERROR	240	124309.11	517.95		
CORRECTED TOTAL	319	433394.48			
CV	50.89%				

Appendix 6. The ANOVA table for the effect of cropping system(SYT), fertilizer application and sampling dates after emergence(WEEK) on beanfly parasitism on the September 1996 crops.

Source	DF	SS	MSS	F value	P value
SYT	1	130.28	130.28	0.19	0.6639
TRT	4	1095.32	273.83	0.40	0.8100
SYT*TRT	4	2711.02	677.75	0.98	0.4168
WEEK	6	86972.81	14495.47	21.06	0.0001
SYT*WEEK	6	1046.64	174.44	0.25	0.9575
TRT*WEEK	24	140092.51	587.19	0.85	0.6654
SYT*TRT *WEEK	24	8792.79	366.37	0.53	0.9654
ERROR	209	143832.11	688.19		
CORRECTED TOTAL	278	258673.47			
CV	96.31%				

Table 7a. ANOVA table for the beanfly damage score in different cropping system(SYT), and fertilizer application (TRT) in April planted crops.

Sources	DF	SS	MSS	F-value	P-value
SYT	1	1.04	1.04.	1.50	0.2307
TRT	4	2.57	0.64	0.93	0.4604
SYT*TRT	4	5.66	1.42	2.04	0.1136
ERROR	30	20.79	0.69		
CORRECTED TOTAL	39	30.06			
CV	19.77%				

Appendix 7b. ANOVA table for the beanfly damage score in various cropping system (SYT) and fertilizer application (TRT) for June planted crops.

Source	DF	SS	MS	F-value	P-value
SYT	1	0.46	0.46	0.84	0.3677
TRT	4	1.98	0.49	0.90	0.4784
SYT*TRT	4	5.29	1.32	0.32	0.8646
ERROR	30	16.58	0.55		
CORRECTED					
TOTAL	39	24.31			
CV	14.57				

Appendix 7c. ANOVA table for the beanfly damage score in various cropping system (SYT) and fertilizer application (TRT) for September planted crops.

Source	DF	SS	MSS	F-value	P-value
SYT	1	0.99	0.99	1.27	0.0685
TRT	4	5.38	1.34	1.72	0.1711
SYT*TRT	4	1.77	0.44	0.57	0.6890
ERROR	30	23.42	0.78		
CORRECTED					
TOTAL	39	31.56			
CV	15.43				

Appendix 8a. ANOVA table for the effect of cropping system (SYT)and fertilizer application (TRT)on the adventitious root formation scores for April, 1996 crop.

Sources	DF	SS	MSS	F-value	P-value
SYT	1	0.10	0.10	0.10	0.7575
TRT	4	9.23	2.30	2.26	0.0863
SYT*TRT	4	16.79	4.19	4.12	0.0089
ERROR	30	30.59	1.02		
CORRECTED					
TOTAL	39	56.69			
CV	26.85%				

Appendix 8b. ANOVA for adventitious root formation score in two cropping system (SYT) and fertilizer application (TRT) for June planted crops.

Sources	DF	SS	MSS	F-value	P-value
SYT	1	0.001	0.001	0.002	0.9688
TRT	4	2.65	0.66	1.03	0.4079
SYT*TRT	4	1.08	0.27	0.42	0.7937
ERROR	30	19.28	0.65		
CORRECTED					
TOTAL	39	23.00			
CV	24.66				

Appendix 8c. ANOVA table for adventitious root formation score in various cropping system (SYT) and fertilizer application (TRT) for September crops.

Source	DF	SS	MS	F-value	P value
SYT	1	7.67	7.67	9.51	0.0440
TRT	4	2.72	0.68	0.84	0.5083
SYT*TRT	4	2.86	0.72	0.89	0.4834
ERROR	30	24.18	0.81		
CORRECTED					
TOTAL	39	37.42			
CV	37.13				

Appendix 9a. ANOVA table for the first internode length in different cropping system (SYT) and fertilizer application (TRT) for April 1996 crops.

Sources	DF	SS	MS	F-value	P-value
SYT	1	0.24	0.24.	4.65	0.0391
TRT	4	0.09	0.02	0.46	0.7662
SYT*TRT	4	0.09	0.02	0.44	0.7813
ERROR	30	1.53	0.05		
CORRECTED					
TOTAL	39	1.95			
CV	13.03				

Appendix 9b. ANOVA table for first internode length distances in different cropping system (SYT) and fertilizer application(TRT) for June crops.

Source	DF	SS	MS	F-value	P-value
SYT	1	0.0002	0.0002	0.01	0.9374
TRT	4	0.16	0.04	1.54	0.2163
SYT*TRT	4	0.03	0.008	0.32	0.8646
ERROR	30	0.77	0.025		
CORRECTED					
TOTAL	39	0.96			
CV	11.98				

Appendix 9c. ANOVA table for first internode length distances in different cropping system (SYT) and fertilizer application(TRT) for September crops.

Source	DF	SS	MSS	F-value	P value
SYT	1	0.22	0.22	0.40	0.5341
TRT	4	0.56	0.14	2.51	0.0624
SYT*TRT	4	0.16	0.04	0.72	0.5[illegible]16
ERROR	30	0.67	0.06		
CORRECTED					
TOTAL	39	2.42			
CV	12.60				

Appendix 10a. ANOVA for the effect of cropping system(SYT) and fertilizer application (TRT) on beanfly plant mortality in April 1996 crops.

Sources	DF	SS	MSS	F-value	P-value
SYT	1	22.66	22.65	7.99	0.0083
TRT	4	11.69	2.92	1.00	0.4074
SYT*TRT	4	11.43	4.36	1.54	0.2166
ERROR	30	85.01	2.83		
CORRECTED					
TOTAL	39	136.78			
CV	32.38				

Appendix 10b. ANOVA for mortality due to beanfly attack in various cropping system (SYT) and fertilizer application (TRT) for June planted crops.

Sources	DF	SS	MSS	F-value	P-value
SYT	1	48.84	48.84	5.64	0.0241
TRT	4	18.67	4.67	0.54	0.7080
SYT*TRT	4	37.62	9.41	1.09	0.3808
ERROR	30	259.68	8.66		
CORRECTED					
TOTAL	39	364.81			
CV	52.40				

Appendix 10c. ANOVA table for mortality due to beanfly attack in various cropping system (SYT) and fertilizer application (TRT) for September 1996 crops.

Source	DF	SS	MSS	F-value	P value
SYT	1	0.99	0.99	1.27	0.2685
TRT	4	5.38	1.34	1.72	0.1711
SYT*TRT	4	1.77	0.44	0.57	0.3808
ERROR	30	23.42	0.78		
CORRECTED					
TOTAL	39	31.56			
CV	15.43				

Appendix 11a ANOVA table on yields of beans under different cropping system(SYT) and fertilizer application(TRT) on yields of beans April,1996 crop.

Sources	DF	SS	MS	F-value	P-value
SYT	1	12452.55	12452.55.	12.55	0.0014
TRT	4	2587.11	646.78	0.65	0.6302
SYT*TRT	4	28770.65	378.50	0.38	0.8199
ERROR	29	28770.65	922.09		
CORRECTED					
TOTAL	38	45324.71			
CV	44.95				

Appendix 11b. ANOVA for yields in various cropping system (SYT) and fertilizer application (TRT) for June planted crops.

Sources	DF	SS	MSS	F-value	P-value
SYT	1	17251.56	17251.56	43.87	0.0001
TRT	4	3231.89	807.97	2.05	0.1119
SYT*TRT	4	1365.89	341.47	0.87	0.4943
ERROR	30	11797.40	393.28		
CORRECTED TOTAL	39	33647.75			
CV	27.85%				

Appendix 11c. ANOVA table for yields in various cropping system (SYT) and fertilizer application (TRT) for September 1996 crop.

Source	DF	SS	MSS	F-value	P value
SYT	1	85008.40	85008.40	149.86	0.0001
TRT	4	2320.39	508.09	1.02	0.4116
SYT*TRT	4	861.49	215.37	0.35	0.8213
ERROR	30	11798.40	393.28		
CORRECTED TOTAL	39	17017.50			
CV	27.85%				