RESPONSES OF COMMON BEAN (*PHASEOLUS VULGARIS* L.) CULTIVARS TO BEANFLIES (DIPTERA: AGROMYZIDAE)

BY

JOHN HURIA NDERITU

THESIS SUBMITTED IN FULFILMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (ZOOLOGY) IN THE UNIVERSITY OF DAR-ES- SALAAM

1988

DECLARATION BY CANDIDATE

I hereby declare that the work contained in this thesis is my original work and has not been submitted for a similar degree in any other university.

JOHN HURIA NDERITU

DECLARATION BY SUPERVISORS

This thesis has been approved for submission.

HKayumbo	K.N. Saxena
Professor H. Y. Kayumbo	Professor K. N. Saxena
1st internal supervisor	2nd internal supervisor

Dr J. M. Mueke
ICIPE supervisor

Chief academic officer

COPYRIGHT

ABSTRACT

The population patterns and behaviour of the immature stages and the adults of two species of *Ophiomyia*, namely *Ophiomyia spencerella* Greathead and *Ophiomyia phaseoli* Tryon on seven selected cultivars of common beans (*Phaseolus vulgaris* L.) were studied under field conditions with a view to determining the resistance/susceptibility of the cultivars to infestation of beanfly. The method adopted for evaluating resistance/susceptibility of the cultivars involved exposing growing bean plants to natural beanfly populations in the field and recording the number of leaf punctures, eggs, larvae, pupae/puparia, and percent infested plants, percent plant mortality and damage scores of representative sample for each cultivar. On the basis of levels of infestation and damage, Glp 1004 and Glp x-92 appeared to have some resistance while Glp 2, Glp 24, Glp 585, Glp x-1127(a) and Mexican 142 appeared to be susceptible. However, seasonal differences in the response of the cultivars to beanfly infestation tended to obscure this finding. The anomally in the results was attributed to differences in the size of the initial population of beanfly in the vicinity of the bean crop, being highest in the noncropping season of 1985 and lowest in long rains of 1985. In cases of high beanfly infestation all the bean cultivars, including those that had shown signs of resistance under moderate infestation, were severely damaged. Thus there were difficulties in having a

uniform beanfly infestation of sufficient level to which the cultivars were subjected during the growing period. However, natural populations of beanfly on beans planted in a single planting in the late part of the cropping season or the beginning of noncropping season was sufficient to cause observable damage symptoms, which could be reliably used as parameters for resistance. Successive plantings of bean cultivars in the middle part of cropping season could also produce a beanfly population sufficiently high for screening purposes.

Under moderate field infestation, determination of percent plant mortality due to *O. spencerella*, stem damage scores due to *O. phaseoli* and the number of pupae/puparia were more reliable indices of resistance/susceptibilty than the number of beanfly leaf punctures, eggs or larvae as parameters for resistance measurement.

ACKNOWLEDGEMENTS

I am most grateful to Professor H. Y. Kayumbo and Professor K. N. Saxena, University supervisors, and Professor J. M. Mueke, ICIPE supervisor for their encouragement and guidance in the course of the research work and their constructive critcisms and comments in the write up of the thesis. I am also grateful to Mr G. N. Kibata, D. K. Kipruto, J. K. Ruto, C. M. Macharia, Dr J. K. Wanjama, Mrs A.A. Okumali, Mrs M. S. Myendo and Mr. M. Latigo for their support, encouragement and assistance in various ways during the course of this study.

I am grateful to Mr. W. W. Wapakhala, Director of Research, Ministry of Agriculture, Kenya for permission to join African Regional Postgraduate Programme in Insect Science (ARPPIS) of ICIPE. I wish to thank Professor Thomas R. Odhiambo, Director, ICIPE for the opportunity in the ARPPIS programme. The study was carried out with generous funding from ARPPIS. I wish also to express sincere gratitude to Dr. M.E. Smalley, Academic Coordinator, ARPPIS for his valuable constant encouragement, guidance and assistance during the course of my study. He was a source of hope and determination when feelings of desparation and low morale occurred during the course of the study. I wish to express gratitude to all members of staff of ICIPE and NAL for their continued support and understanding while carrying out the research project.

I wish to express my most sincere thanks to my wife, Wangui; children: Wangari, Muthoni, Nderitu; other members of my family and friends who contributed constant encouragement and support throughout the course of this study.

TABLE OF CONTENTS pages

List of tables

List of figures

List of plates

CHAPTER 1

1. GENERAL INTRODUCTION

1:1 Production, distribution and utilisation of common beans

Common beans (Phaseolus vulgaris L) are pulse legumes adapted to humid and semi-humid regions of the world. They have a wide geographical distribution, growing in many parts of the tropics and temperate regions (Sinha, 1977). The estimated world hectarage in 1975 was 20.4 million tons (Anon,1975). The major world producers of common beans are South and Central America. Africa produces about 1.35 million tons annually (Londono et al, 1980). This is equivalent to 37% of Latin American production. East Africa produces 61% of the total bean production in Africa. The five East African countries:- Uganda, Rwanda, Kenya, Burundi and Tanzania have equal production of common beans. The combined production is 822,000 tons from 1,882,000 hectares. Common beans are the most widely grown legumes in Kenya. They are second to maize in importance as a food crop (Anon, 1978). The estimated area under beans in Kenya is 763,500 hectares with an estimated production of 161,000 tons. They are grown mainly in the medium area of Central and Eastern Provinces of Kenya where there is a bimodal rainfall of 700-900mm per year.

In tropical cropping systems common beans are cultivated either as monocrops or mixed crops, particularly with cereals. In Kenya 65% of beans are interplanted with other crops and 31% are grown as pure crop by small holder farmers (Schonherr and Mbugua, 1976). They are intercropped mainly with crops such as maize, sorghum and cassava. The methods of production and farming systems will probably change in Kenya, as production of beans for commercial purposes increases.

The principal uses of common beans are:- human food; livestock feed; erosion control and fertility maintenance. As human food, they are mainly consumed as dry seeds, fresh seeds, fresh pods and green leaves. Like other pulse legumes, common beans are a major sources of protein, energy, minerals, vitamins and roughage. They form an economical source of protein to the majority of the Kenya population, since animal proteins are too expensive.

1:2. Constraints on bean production in Kenya.

The major constraints to bean production in Kenya are diseases and insect pests. Other constraints include:- moisture deficits; high temperatures; inadequate or unbalanced plant nutrients; weeds and poor soil conditions.

Various diseases limit the production of beans in Kenya. The bean diseases of major importance are:-

(i) Fungal diseases - Anthracnose (<u>Colletotrichum lindemethianum</u>), Rust (<u>Uromyces appendiculatus</u>), Angular leaf spot (*Isariopsis griseola*).

(ii) Bacterial diseases - Halo blight (*Pseudomonas phaseolicola*), Common blight (*Xanthomonas phaseoli*), Fuscous blight (*Xanthomonas phaseoli* var. *fuscans*).

(iii) Virus diseases - Bean common mosaic virus (BCMV).

The diseases of moderate and minor importance are:-

(i) Fungal diseases - Ashy stem blight (*Macrophomina phaseoli*), *Fusarium* root rot (*Fusarium solani* f. *phaseoli*), Southern blight (*Sclerotium rolfsii*), Rhizoctonia root rot (*Rhizoctonia solani*), Powdery mildew (*Erysiphe polygoni*), Ascochyta leafspot (*Ascochyta boltshauseri*), *Phoma diversispora*, Scab (*Elsinoe phaseoli*), *Phythium* root rot (*Phythium* spp).

(ii) Bacterial diseases - Bacterial brown Spot (*Pseudomonas syringae*).

(iii) Nematodes- Root knot nematodes (*Meloidogyne javanica*, *M. incognita*).

Insect pests attack beans both in the field and in stores in Kenya. Several insects are of major economic importance because they cause considerable reduction and quality reduction in beans. The beanflies, *Ophiomyia* spp (Diptera: Agromyzidae) are by far the most important field pest of common beans. Bean aphid, *Aphis fabae* Scopoli (Homoptera: Aphididae) are serious pests of beans, especially in dry weather. They attack the foliage, tender stems and growing points of bean plants. They suck the plant sap from leaves and stems. Infested leaves are often cupped and later turn yellow, resulting to death of the plant. Besides the direct damage to bean plants, the bean aphid serves as a vector of the bean common mosaic virus disease. The African bollworm, *Helicoverpa Heliothis)* *armigera* Hb (Lepidoptera: Noctuidae) are sporadically serious pests attacking the flowers and pods of bean plants. Young larvae feed on flowers and young pods but the main damage is caused by old larvae burrowing into the green pods and eating the developing seeds. Bean bruchid, *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae) are the most destructive pests of stored beans. Infestation starts in the field and continues in the store if unchecked. Larva feed inside the seed and make tunnels almost to the surface leaving the seed coat to form a window at the end of the tunnel through which the adult emerges. Beans which are attacked by bruchids are not only unfit for human consumption but are also unsuitable for planting.

There are a number of pests, considered to be of moderate or lesser importance, but which could become a threat to bean production. The blue beetle, *Ootheca bennigseni* Weise (Coleoptera: Chrysomelidae) and green beetle, *Hallirhotius africana* (Coleoptera: Chrysomelidae) attack the leaves of bean plants mainly in the early stages of growth, sometimes leading to the death of the bean plants. The larvae live in the soil and can damage the root system. Pollen beetles, *Coryna apicicornis* Guern (Coleoptera: Meloidae) feed on the pollen and destroy the anthers. Blister bettle, *Mylabris* spp (Coleoptera: Meloidae) are common but minor pests of bean flowers. They feed on floral parts and destroy them. Bean thrips, *Taeniothrips* spp (Thysanoptera: Thripidae) attack flower buds and flowers of bean plants. The feeding injury is characterized by distortion, malformation and discoloration which leads to abortion of flowers. The Legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) attacks flowers, pods and seeds of bean plants. The early instars feed on flowers and later instars feed on pods. The presence of legume pod borer in the pod is characterized by frass around the entrance hole. Spring brown bugs, *Clavigralla*(*Acanthomia*)*horrida* Germ and *Clavigralla*(*Acanthomia*)*tomentosicollis* Stal (Hemiptera: Coreidae) suck sap from pods as they are formed, causing premature drying and shrivelling of pods. The seeds remain small or they may not develop at all. The Green stink bug, *Nezara viridula* (Hemiptera: Pentatomidae) attack pods, seeds and leaves. The feeding punctures cause necrosis resulting in deformation or pod shedding if the bean plants are attacked when very young.

1:3. Importance of Agromyzid beanflies

Agromyzid beanflies are pests of cowpeas, lima beans, soybeans, mungbeans, green grams and winged beans in many parts of the tropics and warm temperate regions. They have been identified as the most important field insect pests of beans in Africa (van Schoonhoven, 1980). The seriousness of these pests in Kenya varies from season to season and they are generally most severe during the dry conditions when up to 100% losses have been reported (Schonherr and Mbugua, 1976).

Beanflies infesting bean plants in East Africa are *Ophiomyia phaseoli* Tryon, *Ophiomyia spencerella* Greathead and *Ophiomyia centrosematis* (de Meiji). *O. spencerella* and *O. phaseoli* are usually found in a bean crop. Infestation of bean plants by beanflies begins as soon as they germinate. The damage is caused by the larvae feeding in the stem causing calloused growth around the injured base of the stem and leaf yellowing. The attacked seedlings may become severely stunted or die. Late infestation does not have serious effects on the plant.

Various control measures are recommended for beanflies in Kenya . These include:- pre-or post-planting application of various chemical pesticides; early planting; hilling up and elimination of host plants. A parasite complex reduces the beanfly infestation in a bean crop. Infestation of beanflies is less in a maize/bean intercrops than in monocrops. Bean cultivars resistant to beanflies, a potential means of controlling beanflies, are not available. Such bean cultivars would be most welcome to the small scale farmers, especially since most of them cannot afford to buy insecticides and other control measures are more difficult to implement.

1:4. Towards developing techniques for evaluating common bean cultivars for resistance to Agromyzid beanflies

The cheapest and most environmentally acceptable method of beanfly control is the use of resistant bean cultivars. In order to increase bean production in East Africa, research priorities have included breeding for resistance to beanflies. Developing commercial bean cultivars which possess high level of resistance to beanflies and which are also high yielding is the ultimate goal for future control of beanflies in East Africa.

The work of identifying sources of resistance to beanflies has been initiated recently in East Africa (Anon, 1986). Various reports in East Africa indicate the existence of resistance to beanflies in common bean cultivars, but no good source of resistance has been found. The resistance categories of the bean cultivars/lines identified in East Africa vary with season, year and degree of infestation. Therefore, a stable source of resistance in an available pool of resistant sources has not been identified. The screening techniques must identify stable sources of resistance to be used in the breeding programme.

In order to identify a stable source of resistance in the available pool of resistant sources, standard techniques for screening bean cultivars are very much required. The present study was directed at assessing the best evaluation techniques for identifying the sources of resistance to beanflies. Evaluation of plant material for resistance to insects requires an adequate number of insects for a uniform level of infestation. Therefore an attempt was made to answer the following questions:-

(a) Is natural infestation reliable or unreliable for the screening of common bean cultivars for resistance to beanflies?

(b) Can we obtain naturally the numbers and uniformity required for the screening of common bean cultivars?

(c) How can natural infestation be manipulated for the purpose of screening bean cultivars for resistance to beanflies?

The criteria for measuring resistance is generally based on the effect that the insect has on the plant and/or the effect that the plant has on the behaviour and the biology of the insect. The techniques for evaluating plant materials must be simple, efficient and accurate. Which are the best criteria for evaluating common bean cultivars for resistance to beanflies?. In order to answer the above questions the objectives of the study were the following:

1. To determine the relative rates of leaf puncturing and oviposition by beanflies in selected common bean cultivars (pp 91-136).

2. To investigate the pattern of larval feeding and development of beanflies in selected common bean cultivars (pp 91-136).
3. To assess the nature and effects of damage caused by beanflies in selected common bean cultivars (pp84; pp127-132).
4. To establish the population pattern of beanflies in different cropping seasons (pp 34-90).
5. To assess the relationship of time of planting to level of beanfly infestation and damage in selected common bean cultivars (pp 137-166).

The above information was used to categorize selected common bean cultivars into those susceptible, resistant or tolerant to Agromyzid beanflies. The information was also used to provide insights into methods of providing adequate levels of beanfly populations in the field and criteria for measuring resistance for future selective breeding of bean cultivars which are more fully resistant to agromyzid beanflies.

CHAPTER 2

2. LITERATURE REVIEW

2:1 Taxonomy of Agromyzid beanflies

In East Africa, Greathead (1968) studied the taxonomy of agromyzid beanflies mining the stems of bean plants and reported that it is a complex of three species. These are *Ophiomyia phaseoli* Tryon, *Ophiomyia spencerella* Greathead and *Ophiomyia centrosematis* (de Meiji). Earlier reports by Harris (1937), Wallace (1939) and Le Pelley (1959) considered *O. spencerella* and *O. phaseoli* as one species (*O. phaseoli*) for which they adopted beanfly as the common name, referring to *O phaseoli* before this study.

Spencer (1961; 1959; 1973; 1985) and Greathead (1968) described various taxonomic characters that can be used to distinguish *O. phaseoli*, *O. spencerella* and *O. centrosematis*. The adults of *O. phaseoli* can be distinguished from *O. centrosematis* by having elongate shining ocellar triangle reaching to or beyond the lower orbital setulae. The adults of *O. spencerella* and *O. phaseoli* are distinguished in the male by the form of aedeagus, and in the female by the shape of serrations of the ovipositor blade. The aedeagus of *O. spencerella* is broad and cylindrical with the vas deferens opening into a structure enclosed by the body of aedeagus and not on a projecting arm of the aedeagus as in *O. phaseoli*. The ovipositor valves of *O. spencerella* are blunt at the apex which is slightly concave and not tapering to a simple point as in O. phaseoli. The puparia of O. phaseoli are yellowish brown with black apices, those of O. centrosematis are yellow brown with no black apices, while those of O. spencerella are shining black. The mean number of openings in the posterior spiracles of unparasitized puparia of O. phaseoli are 8.4 + 1.2. and 9.9+ 1.2 of unparasitized puparia of O. spencerella. Greathead (1968) reported O. spencerella in East Africa, and the same species has also been detected in Nigeria (Spencer, 1973).

2:2 The biology of Agromyzid beanflies.

2:2:1 O. phaseoli

The biology of O. phaseoli has been reported by various researchers: Wallace (1939), Walker (1960), Swaine (1968) and Greathead (1968) in East Africa; Hassan (1947), Ali (1957), and Abul-Nasr and Assem (1968) in Egypt, Quesales (1918) in Phillipines; Ho (1967) in Malaysia; Burikam (1980) in Thailand, Jack (1913), Taylor (1958), Taylor (1980) in Zimbabwe; Caldwell (1945), Heley (1947) and Davis (1969) in Australia; Lall (1959), Agrawal and Pandey (1961), Pandey (1962), Singh and Beri (1971), Manohar and Balasubrammanian (1980) and Gupta and Singh (1984) in India and Kato(1961), Yasuda (1981), and Yasuda (1982) in Japan. Oviposition takes place either on the upper or lower surface of young leaves. After hatching the larva forms a short leafmine, and then enter the nearest vein which is followed into the petiole down the stem. The pupa remains beneath the epidermis and the adult emerges through a semi-transparent opening in the stem. The complete life cycle from egg laying to emergence of the adult fly varies from 3 weeks in warm weather to 12 weeks in cold weather. In the laboratory, development time from egg to adult was 27-31 days at a mean temperature of 21^{o}C (Greathead, 1968).

2:2:2. O. spencerella

Greathead (1968) described the biology of O. spencerella on common beans in East Africa. The bulk of oviposition occurs in the hypocotyle at ground level in the first two or three days after the first appearance of the plants above the ground level. A few eggs are also deposited in young stem tissues above the level of the cotyledons. Although the main attack is on young plants; eggs may be laid in old plants. The females, though they puncture the leaves in the same way as O. phaseoli, rarely oviposit in the leaves. The eggs resemble those of O. phaseoli and are laid in similar punctures. Larvae from eggs in the leaves follow the same life cycle as those of O. phaseoli. Those laid in the hypocotyle or stem mine downwards feeding extensively in the hypocotyle and taproot, and then move to ground level or above to the nearest healthy tissue to pupate. The larva pupates in the same position as that of O. phaseoli after preparing a window in the stem. In the laboratory, development time from egg to adult ranged from 28 to 35 days at a mean temperature of 21^0C (Greathead, 1968).

2:2:3. O. centrosematis

Spencer (1961), Lee (1976) and Greathead (1968) described the biology of O. centrosematis. Oviposition occurs in the stem and hypocotyle. The larvae mine the stems and pupate beneath the epidermis. The anterior spiracles of puparia pierce the dry epidermis and project from it. In the laboratory, the development time from egg to adult was 30 days at a mean temperature of 21^0C.

2:3 Population dynamics of agromyzid beanflies.

The seasonality of beanflies has been reported by Wallace (1941), Walker (1960), Swaine (1968), Greathead (1968), Okinda (1979), Mueke (1979a) and Kibata (1980) in East Africa; Lin et. al. (1977) and Talekar and Chen (1983) in Taiwan; Kwon et. al. (1981) in Korea, Morgan (1938) and Caldwell (1939) in Australia; Pandey (1962), Manohar and Balasubrammanian (1980b) and Kooner et. al. (1977) in India; and Abul-Nasr and Assem (1966) in Egypt. Beanflies occur throughout the year in most areas. They cause severe damage during the hotter months but are unimportant during the colder months. Plant stress resulting from beanflies attack is more pronounced in dry conditions than wet conditions. There is less beanflies infestation during cold weather because of the retarding effect of temperature on beanfly development. Lin *et*. *al*. (1977) reported that factors influencing population density of *O*. *phaseoli* are:- soil moisture; soil types; PH value; solar intensity and relative humidity. They also reported that soil temperature, wind velocity, precipitation, air temperature and evaporation of soil water are not related to the beanfly density. Manohar and Balasubrammanian (1980b) found no significant correlation between *O. phaseoli* incidence and temperature, rainfall or relative humidity.

2:4. Pest status and nature of damage of common beans by agromyzid beanflies.

Agromyzid beanflies, especially *O*. *phaseoli*, are widely distributed seedling pest in East and South Africa, Asia and Australia (Singh and van Emden, 1979). Heavy losses of common beans due to beanflies have been reported from:- Zimbabwe (Jack, 1913; Taylor, 1958); East Africa (Wallace, 1939, 1941; Swaine, 1968; Schonherr and Mbugua, 1976; Njuguna *et*. *al*. 1980; Omunyin *et*. *al*., 1984); Egypt (Hassan, 1947); Nigeria (Deeming and Njend et al, 1979); Australia (Davis, 1969); Asia (Wickramasinghe and Fernando, 1962; Ho, 1967, Sharma *et*. *al*.). Bean losses of up to 100% have been reported in some countries. Beanflies also infest a wide range of other leguminous plants (Le Pelley, 1959; Greathead, 1968; Kleinschmidt, 1970). In East Africa, they have been reported in cowpeas, green and black grams, garden peas, pigeon peas and soybeans.

The early reports of the occurrence and extent of damage of common beans by beanflies in East Africa are by Wallace (1939, 1941) and Le Pelley (1958). A Survey of pests in various cropping systems has shown beanflies to be major pests of beans in Kenya (Karel and Mueke 1978; Khaemba and Khamala, 1978; Khamala et al, 1979, Schonherr and Mbugua, 1976). The beanflies were found on all the farms where beans are grown. These workers indicated that beanfly infestation was serious and that some efforts should be made to prevent the damage caused by them as they reduced yields of beans more than any other bean pest.

The nature of beanfly damage on common beans has been discussed by Wallace (1939), Caldwell (1945), Hassan (1947), Taylor (1958), Greathead (1968) and Davis (1969). The damage by beanfly is mainly on the stems of the bean plants. The effect of larvae feeding on young plants is serious and frequently results in total destruction. In most cases there is a calloused growth around the injury to the stem which then cracks and turns brown. This is where the larvae have pupated. The plant becomes stunted and finally dies. The plants that do survive an attack produce pods, many of which are empty or contain small seeds.

2:5. Control of beanflies on common beans.

Various methods have been used to control beanflies on common beans in East Africa. Walker (1960), Swaine (1968), Pury (1968), Okinda (1979), Kibata (1980) and Matee and Karel (1983) have indicated various insecticides which can be used for controlling beanflies on common beans. These include Endosulphan for seed treatment, Carbofuran for furrow application or Dimethoate for foliar application. A number of these chemicals are not environmentally safe and have negative effects on parasites which are also important in the control of beanflies in East Africa.

Cultural control methods have been recommended by Bohlen (1973), Hill (1975) and de Lima (1976). Recommendations such as early planting to avoid peak infestation period; elimination of host plants; rotation with non-host crops; hilling or soil moulding to encourage adventitious root formation on the stem have been advocated.

The parasite complex associated with beanflies is widespread in East Africa and plays an important role in control of beanflies. While high levels of parasitism have been found on _O. phaseoli_, _O. spencerella_ is not effectively controlled (Greathead, 1968).

A long term control method is use of resistant or tolerant cultivars of beans. In this regard no beanfly resistant cultivar has yet been developed (Hober, 1978). Presently there is lot of interest in developing resistant bean cultivars and identifying the mechanisms of such resistance in commonly grown beans in East Africa (Anon, 1986)

2:6. Host plant resistance : Definition, types and mechanisms of resistance.

Painter (1951) defined resistance as 'the relative amount of heritable qualities possesed by the plant which influence the ultimate degree of damage by the insect in the field.' Beck (1965) defined resistance as 'the collective heritable characteristics by which a plant species, race, clone or individual may reduce the probability that an insect species, race, biotype, or individual can successfully utilize the plant as a suitable host.' Beck's definition excluded the plants ability to recover or repair losses after injury occurs (Hober, 1980). Resistance is thus the ability of a host plant to reduce infestation or damage, or both, by an insect. In practical agriculture, resistance represents the ability of a certain cultivar to produce a larger crop of good quality than other cultivars attacked by the same insect population.

The types of resistance that have been described (Painter, 1951; Hober, 1980; Wiseman, 1985) are immunity, high resistance, moderate resistance, low resistance and susceptibility. An immune cultivar is one which a specific insect will not damage or use under any known conditions. A highly resistant cultivar has qualities that result in small damage by a specific insect under a given set of conditions. A moderately resistant cultivar has intermediate resistance and is moderately injured or infested. Low resistant cultivars show more damage or infestation by insects than

2:6. Host plant resistance : Definition, types and mechanisms of resistance.

Painter (1951) defined resistance as 'the relative amount of heritable qualities possesed by the plant which influence the ultimate degree of damage by the insect in the field.' Beck (1965) defined resistance as 'the collective heritable characteristics by which a plant species, race, clone or individual may reduce the probability that an insect species, race, biotype, or individual can successfully utilize the plant as a suitable host.' Beck's definition excluded the plants ability to recover or repair losses after injury occurs (Hober, 1980). Resistance is thus the ability of a host plant to reduce infestation or damage, or both, by an insect. In practical agriculture, resistance represents the ability of a certain cultivar to produce a larger crop of good quality than other cultivars attacked by the same insect population.

The types of resistance that have been described (Painter, 1951; Hober, 1980; Wiseman, 1985) are immunity, high resistance, moderate resistance, low resistance and susceptibility. An immune cultivar is one which a specific insect will not damage or use under any known conditions. A highly resistant cultivar has qualities that result in small damage by a specific insect under a given set of conditions. A moderately resistant cultivar has intermediate resistance and is moderately injured or infested. Low resistant cultivars show more damage or infestation by insects than the average for the crop plant considered. A susceptible cultivar shows considerably more than average damage by an insect.

Painter (1951) grouped mechanism of resistance into non-preference/preference, antibiosis and tolerance. Non-preference refers to a plant character or characters which affects the insects' behavioral responses towards the plant for oviposition, food, shelter or for a combination of these three. Preference denotes susceptibility on the part of the plant and therefore is no longer used as an expression of the resistance mechanism (Painter, 1968). Kogan and Ortman (1978) proposed the term antixenosis to replace non-preference. This new term lacks credibility because the behavioral responses for shelter of the insect were omitted (Wiseman, 1985). Antibiosis refers to the adverse effects on the insects' mortality, size and life history duration that results from feeding on a resistant cultivar. The effects measured may be in the form of death of the early instars, small size or low weight, abnormal longevity, low food reserves, lower fecundity, death in the prepupal stage and abnormal behaviour. Antibiosis may be conferred by physical factors such as hard woody stems, tissue thickness and arrangement of trichomes, or by biochemical factors such as the presence of toxins or imbalances in some essential nutritional materials in resistant plants. Tolerance refers to the ability of the host plant to grow or reproduce or to repair injury while supporting a population approximately equal to that damaging a susceptible cultivar. Tolerance is of great biological significance and practical value since it does not exert a selection pressure on pest populations whist the other two mechanisms of resistance do. It has been suggested that tolerance as a mechanism of resistance was more subject to environmental variation than antibiosis and non-preference/preference (Hober, 1972).

The bases of resistance are biochemical and morphological factors in plants (Norris and Kogan, 1980). Biochemical factors affect the chemically mediated behavioral and metabolic processes of the insect, while morphological factors affect the mechanisms of host selection, feeding, ingestion, digestion, mating and oviposition. The behavioural bases of plant resistance to insects are orientation, feeding, metabolism of ingested food, development of the larvae, egg-production in the adult and oviposition (Saxena, 1969). These behavioural responses are involved in determing the establishment of an insect on a plant (Saxena, 1985).

Resistant/tolerant cultivars provide an ideal method of controlling insects. Resistance has several advantages over other methods of pest control. It does not harm beneficial insects and can be compatible with biological, chemical, cultural and other control methods (Hober, 1972). Resistant Cultivars may also augment the effectiveness of natural enemies of pests and thus delay economic damage levels in crops.

2:7. Resistance of pulse legumes (excluding common beans) to agromyzid beanflies

The search for sources of beanfly resistance in pulse legumes has been investigated with some success. Quesales (1918) reported lima beans (*Phaseolus lunatus L*) resistant to the beanfly, *O. phaseoli*. Fernando (1941) screened 93 cowpea (*Vigna unguiculata*) cultivars and revealed that one cultivar was resistant to *O. phaseoli*. Lall (1959) compared seven cowpea cultivars for resistance to *O. phaseoli* and found one which was resistant. Balboa (1972) compared five Mungo (*Phaseolus aureus*) cultivars and found that two were resistant. Singh and Mishra (1977) evaluated 12 Garden pea (*Pisum* sativum) cultivars for resistance to *O. phaseoli* and found two which were resistant. Chiang and Talekar (1980) screened soybean (*Glycine max L*) and Mungbean (*Vigna unguiculata* L) accessions for resistance to *O. phaseoli*, *O. centrosematis* and *Melanagromyza sojae* (Zehntner). They reported 4 highly resistant soybean and three moderately resistant mungbean accessions to all the three species.

The bases of resistance of agromyzid beanflies in some pulse legumes has been elucidated or suggested. Fernando (1941) revealed that the resistant cowpea cultivar he found during screening was of short maturity. Balboa (1972) suggested that the thickness of the pubescence and toughness of the stem of resistant mungo cultivars seemed to be the main contributory factor in rendering them resistant. The thickness of pubescence of the resistant cultivar made them unsuitable for beanfly oviposition. Singh and Mishra (1977) reported that the late and mid-duration Garden pea cultivars with harder and thinner stems are more resistant than early cultivars which are more succulent and thicker stemmed. Lin and Mitchell (1981) studied the biophysical and biochemical factors of host selection of O. phaseoli. The degree of preference of the beanfly was correlated with the amount of attractant, and the amount of antifeedant and pubescence. Leaf weight; colour area; moisture content; antifeedant; thickness and attractant were directly related to preference by the beanfly. Morphological; anatomical; physiological and biochemical factors are involved in soybean resistance (Chiang and Norris, 1982; 1983a, b, c; 1984; 1985). They have identified the following resistance parameters: (i) trichome density and length on the abaxial leaf surface (2) leaf size (3) stem diameter (4) rate of secondary growth (5) rate of sclerenchyma differentiation, involving completion of secondary cell wall and lignification (6) Production of polyphenols (including tannins) in the stem contents.

2:8. Resistance of common beans to agromyzid beanflies.

Although some reports on bean resistance to various insects are available, very little work has so far been done on bean resistance to the beanflies (Hober, 1978). Caldwell (1945) in Australia reported that long beans possess a considerable degree of resistance to beanfly compared to french beans. Ali (1957) in Egypt evaluated three bean cultivars and found them highly susceptible to beanfly attack. Abul-Nasr and Assem (1966) in Egypt showed that there were significant differences in the mean number of larvae and pupae in four bean cultivars. Mueke (1979b) in Kenya screened 17 bean cultivars for beanfly resistance and found some which had low numbers of beanfly larvae and pupae. Talekar (1980) in Taiwan screened 369 bean accessions and found one highly resistant and seven moderately resistant accessions. Rwamugira and Karel (1983), Karel (1984), Msangi and Karel (1984), Maerere and Karel (1984), and Mushebezy and Karel (1985) in Tanzania have screened many bean cultivars for beanflies resistance. The resistance of cultivars they have screened varies with the area, seasons, years and degree of infestation. They have not identified stable source of resistance among the available pool of resistant cultivars which could be used in a breeding programme. Bean cultivars which have a stable source of resistance have not been identified in the Regional Beanfly Resistance Nursery in Southern and Eastern African region (Allen, personal communication).

There is very little work done on the basis of resistance of common beans to beanflies. Caldwell (1945) reported that the climbing tendrils in long beans enabled them to withstand very severe infestation. Greathead (1968) reported that most of the locally adapted cultivars in Uganda were resistant to the beanflies due to their ability to produce adventitious roots and thickened hypocotyle. Rogers (1979) quantified varietal differences to O. phaseoli in terms of non preference and antibiosis. He found that the number of viable eggs laid per plant showed significant correlations with leaf hair density, stem diameter and internode length, with low viable egg counts being associated with high leaf hair density, thin stems and long internodes. He found no significant differences in the developmental period of larvae and pupae or in the size of adults emerging from the cultivars he studied. Msangi and Karel (1984) found negative correlation between the ovipuncture counts and leaf hairiness, indicating that high leaf hairiness was associated with low ovipunture counts. Mushebezy and Karel (1985) reported that trichome density on the abaxial surface of leaf, leaf area and stem diameter are related to resistance of common bean cultivars to beanflies as bean plants with high trichome density on abaxial surface of leaves, small leaf area and narrow stems are likely to experience less beanfly attack.

2:9. Techniques for evaluating pulse legumes for resistance to beanflies.

In order to effectively screen plant genotypes for resistance, there must be a sufficient number of insects for a uniform and controlled level of infestation (Guthrie, 1975; Davis, 1985). Natural field population are adequate during most seasons to locally adapted cultivars in Uganda were resistant to the beanflies due to their ability to produce adventitious roots and thickened hypocotyle. Rogers (1979) quantified varietal differences to O. phaseoli in terms of non preference and antibiosis. He found that the number of viable eggs laid per plant showed significant correlations with leaf hair density, stem diameter and internode length, with low viable egg counts being associated with high leaf hair density, thin stems and long internodes. He found no significant differences in the developmental period of larvae and pupae or in the size of adults emerging from the cultivars he studied. Msangi and Karel (1984) found negative correlation between the ovipuncture counts and leaf hairiness, indicating that high leaf hairiness was associated with low ovipunture counts. Mushebezy and Karel (1985) reported that trichome density on the abaxial surface of leaf, leaf area and stem diameter are related to resistance of common bean cultivars to beanflies as bean plants with high trichome density on abaxial surface of leaves, small leaf area and narrow stems are likely to experience less beanfly attack.

2:9. Techniques for evaluating pulse legumes for resistance to beanflies.

In order to effectively screen plant genotypes for resistance, there must be a sufficient number of insects for a uniform and controlled level of infestation (Guthrie, 1975; Davis, 1985). Natural field population are adequate during most seasons to infest plants for evaluation for resistance. However, in many cases such field insect populations cannot be relied upon, because too few. or too many occur and their distribution is not uniform for screening.

There are a number of ways in which the effectiveness of natural populations have been manipulated to increase probability of having uniform and sufficiently high pest population at the desired growth stage for screening. For example, Starks (1970) while working on sorghum resistance to shootfly, found that natural population of the shootfly could be increased by late planting of sorghum. Other workers, for example Tees (1980) recommended multiple planting of the same test material to increase midge population in sorghum. As will be explained later (pp27-33) late planting and multiple plantings were adopted in the present study to increase the field population of beanflies so that resistance of bean cultivars could be evaluated. Chiang and Talekar (1980) screened soybean and mungbean materials during the fall season when the population was relatively high. They also maintained damaging beanfly population by planting in every two weeks beanfly-susceptible mungbean, snapbean and mungbean as source blocks. Talekar and Chen (1983) determined appropriate time for screening of soybean and mungbean cultivars resistant to beanflies. They reported that O. phaseoli, O. centrosematis and M. sojae occur throughout the year but they cause severe damage only during the fall season. Agromyzid beanflies infestation has been reported to be severe during the relatively dry period after the rainy season and infestation was lower during relatively cool periods (Morgan, 1938; Swaine, 1968; Lee, 1976; Kwon et. al., 1980).

Many techniques are used to locate sources of resistance to insects. The technique for evaluating plant material must be simple, efficient and accurate (Guthrie, 1975). Techniques for measuring resistance are based on the effect that the insect has on the plant and/or the effect that the plant has on the behaviour and biology of the insect. Dahms (1972) discussed many criteria for evaluating resistance. Saxena (1985) mentioned that differences in the resistance of cultivars to an insect are reflected in the magnitude of its population established on them and the resulting damage. Fernando (1941), Lall (1959) and Balboa (1972) evaluated resistance by the proportion of plants infested by beanfly. Abul-Nasr and Assem (1966) assessed resistance in common beans by grading the degree of infestation to light, medium and severe, and by the number of larvae and pupae per plant. Walker (1971) reported that rating the degree of damage in common beans is more accurate than assessing the percentage of plants attacked or number of larvae and pupae as a method of evaluating loss of the beans. Singh and Mishra (1977) calculated the percentage of infested plants, number of larvae and pupae to evaluate resistance in Garden peas. Chiang and Talekar (1980) recorded the number of beanfly larvae and puparia in each plant and the number of plants with damage. Since there was a significant positive correlation between insect numbers and percent damaged plants, they later used only the mean number of insects as the criterion for resistance. Talekar (1980) also used the number of beanfly larvae and pupae per plant as a criterion for resistance of common bean accessions. Gangrade and Kogan (1980) mentioned that dissection of soybean seedlings gives excellent, absolute beanfly population estimates but it is not applicable in screening of resistant cultivars since the method is destructive. They also mentioned that the symptoms of beanfly infestation would be perfectly adequate for resistance evaluation programmes since plants surviving a heavy infestation probably have some resistance provided that they are not merely escapees. The number of ovipunctures in plant leaves; larval and pupal counts; stem damage; percentage plants infested; plant vigor rating; and stem damage rating have been used as screening techniques for assessment of resistance of common beans to beanflies in East Africa (Mueke, 1979b, Karel, 1984; Msangi and Karel, 1984; Maerere and Karel, (1984); Mushebezy and Karel, 1985). The above screening techniques have been adopted in the present study with a view to identifying resistance parameters which are simple, reliable and efficient.

CHAPTER 3

3. GENERAL MATERIALS AND METHODS

3:1 Area of study

Field experiments were conducted at the National Agricultural Laboratories and Kabete Campus Field Station, Nairobi. These areas are at an altitude of about 1700m. The typical soil at both locations is well drained, very deep, dark reddish brown to dark red friable clay (humic Nitosol). The characteristics of the climate are alternating dry and wet seasons and the absence of large seasonal changes in temperature. The precipitation pattern is bimodal with one long rain season from mid-March to May and a short rain season from mid-October to December. The period from June to October is cool, rather cloudy and almost dry, while the warmest time of the year is from mid-December to mid-March. The mean air temperature is 18^{O}C and mean soil temperature is 22^{O}C. The ecological zone is dry sub-humid to semi-humid.

3.2 Field experiments

Seven common bean cultivars viz:- Glp 2 (Rose Coco); Glp 24 (Canadian Wonder); Glp x 92 (Mwitemania); Glp x -1127(a) (New Mwezi Moja); Glp 585 (Red Harricot) and Mexican

142 were used in the field experiments. Except for Mexican 142, all the other bean cultivars are commercially grown in Kenya. The characteristics of these bean cultivars are indicated in Table 1. They were grown in small plots with an inter-row spacing of 50 cm and within-row spacing of 10 cm. Sowing was done at the rate of one seed per hole. DAP fertilizer was applied at planting time at a rate equivalent to 200 kg/ha. Weeding was done 2 to 3 times per season. No insecticide or fungicide was used in the experimental plots.

Plants sampled from the plots were put in polythene bags. Tally counters were used in counting the punctures. Dissecting microscopes were used to observe eggs in the leaf and stem punctures. Needles were used to search for eggs in the punctures. Stems were dissected with a scalpel in search of larvae and pupae.

Field experiments to evaluate bean cultivars in single plnating at different seasons were conducted as shown in Table 2. Date of emergence and sampling of bean plants for studies on population patterns of beanflies is as for experiment to evaluate bean cultivars. During the short rains of 1984 there was high rainfall in October and November and low rainfall in December and January. The bean crop was irrigated during the month of December and January. There was high rainfall in April and May, but low rainfall in June and July during the long rains of 1985. The rains were adequate and therefore the bean crop was not irrigated. The bean crop was irrigated throughout the growing period during off-season of 1985.

Table 1. Varietal characteristics of the bean cultivars (Anon, 1983)

	Glp 2.	Glp24	Glp1004	Glpx-92	Glp x-1127(a)	Glp 585	Mexican 142
1. plant characteristcs							
a Growth type	determinate	indeterminate	determinate	indeterminate	determinate	indeterminate	indeterminate
b Flower colour	white	white	white	white	white	white	white
c leaf characters	dark green with golden shine	light green	dark green	green	dark green	green	—
d. Days to 50% flowering	42	46	39	42	43	45	—
e. Days to maturity	90	95	85	99	85	88	—
f. pod length(cm)	13	11	14	8	12		—
g. seeds per pod	5	4	5	4	5	5	—
2. Seed characteristics and quality:							
a. Seed appearance	large red flecks on cream	purple	light brown speckled purple	brown flecks on cream	dark brown, speckled purple	red	white
a. 100 seed weight (g)	52	34	44	40	41	31	—
c. crude protein (%)	25.04	23.5	21.39	22.13	—	—	—
d. crude oils (%)	1.17	1.4	1.25	1.33			
f. cooking time	fast	fast	fast	fast	fast	fast	fast
g. palatability	good	good	very good	good	fair	good	good
3. Disease reaction:	Tolerant to blight, bean common mosaic virus, anthracnose, angular leaf spot, rust and Halo blight	Resistant to angular spot but susceptible to bean common mosaic virus. Tolerant to anthracnose, halo blight and rust.	Tolerant to rust and bean common mosaic virus and anthracnose. susceptible to halo blight and angular leaf spot	Resistant to Halo blight, susceptible to bean common mosaic virus and rust. Tolerant to angular leaf spot and anthracnose	Tolerant to halo blight, angular leaf spot and rust Resistant to bean common mosaic virus and and anthracnose	Tolerant to angular leaf spot, rust. anthracnose and halo blight. Resistant to bean common mosaic virus	—
4. Area suitability	high rainfall areas but is also suited for the medium rainfall areas during long rains	medium rainfall areas	low rainfall areas but can do well in medium rainfall areas during short rains	medium rainfall areas	medium rainfall areas	high rainfall areas but may also be grown in medium rainfall areas	

— Characters not known.

Table 2. Field evaluation of bean cultivars and population patterns of beanflies at single planting at different seasons.

Seasons	Site	Date of emergence	Date of 1st sampling
1. Short rains season, 1984 (October-January)	NAL	23rd october, 1884	9th November, 1984
	Kabete	8th November, 1984	16th November, 1984
2. Long rains season, 1985 (April-July)	NAL	1st April, 1985	11th April.1985
	Kabete	29th March, 1985	9th April, 1985
3. Off-season, 1985 (July-October)	NAL	11th July, 1985	16th July, 1985
	Kabete	2nd July, 1985	9th July, 1985
4. Short rains season, 1985 (November-February)	NAL	16th November, 1985	23rd November, 1985

During the short rains of 1985 there was enough rainfall in October and November but the crop was irrigated during the month of December and January because the rainfall was insufficient.

The experiments on evaluation of common bean cultivars in successive plantings were carried out as shown in Table 3. For all planting dates in all seasons the beans emerged one week after sowing. Sampling of bean plants of each planting date was done one week after emergence. During the short rains of 1985 the beans sown on 21st November and 28th November were irrigated throughout their growing period because there was very little rainfall. During the long rains of 1986 there was high rainfall in April and May but light rainfall in June and July. The rains were sufficient for the growth of the bean plants. During off-season of 1986, the bean plants were irrigated throughout the growing period because there was very little rainfall. During the short rains of 1986 there was heavy rainfall in November and early December but little rainfall in January and February. The bean plants were irrigated once per week in those months when there was little rainfall.

The same sevem bean cultivars used in the above experiments were evaluated for resistance to beanflies when they were at three different growth stages. They were grown in 45 cm deep x 27 cm diameter plastic pots in the greenhouse.

Table 3. Field evaluation of bean cultivars in four planting dates at different seasons at NAL, Nairobi.

	Dates of planting			
Seasons	1st Planting	2nd planting	3rd planting	4th planting
1. Short rains seasons, 1985 (October-January)	14th November, 1985	21st November, 1985	28th November,1985	5th December,1985
2. Long rains seasons, 1986 (April-July)	30th March, 1986	7th April, 1986	14th April, 1986	21st April, 1986
3. Off-season, 1986 (June-September)	24th June, 1986	1st July, 1986	8th July, 1986	15th July, 1986
4. Short rains season, 1986 (November-January)	3rd November, 1986	10th November, 1986	17th November,1986	24th November, 1986

Humic Nitosol soil, which was put in the pots for growing these bean plants was collected from the field at NAL. The potted plants were removed to the field for five days and placed in the vicinity of growing beans where natural beanfly population was known to be present. The materials used during the sampling and collection of data were polythene bags, tally counters, table lamps, dissecting microscopes, dissecting needles and scapel.

3:3 General description of statistical analysis of data.

Analysis of variance (ANOVA) statistical tests were used to determine whether there were significant differences in the response of the bean cultivars to attack by two species of beanfly as indicated by the number of beanfly leaf punctures, eggs, larvae, puparia, percent bean plants damaged and percent plants infested. The data for all the sampling dates in a season were pooled before being analysed. Standard procedures were followed to compute various correlation coefficients. In all cases tests for significance were at least $p < 0.05$. Duncan's multiple range test was used to rank the means.

CHAPTER 4

4. POPULATION PATTERNS OF BEANFLIES IN CROPPING AND NONCROPPING SEASONS.

4:1. INTRODUCTION

Implementation of control measures requires accurate information on beanfly populations. A uniform beanfly infestation of a sufficient level is necessary for reliable varietal resistance screening (Talekar, 1980). Beanflies are present in the bean growing areas in Kenya throughout the year and infestation levels may vary from season to season (Okinda, 1979; Kibata, 1980). In the studies being reported in this chapter investigations on levels of beanfly infestation in single plantings and at different planting dates at different seasons was assessed. The study aimed at determining the appropriate time when natural populations would be sufficiently high and uniform for screening of bean cultivars for resistance to beanflies.

4:2. MATERIALS AND METHODS

4:2:1 Beanfly infestation on common beans in the field.

Glp 2 (Rose Coco) beans were grown in plots of 21.5m.x5m., with an inter-row spacing of 50cm and within-row spacing of 10cm. The bean seedlings were left to natural beanfly infestation. Sampling started 7 days after emergence of the seedlings and continued at weekly intervals during the growing period of the crop. From the 44 rows per plot, one plant was randomly sampled per each row and the 44 sampled plants per plot were placed in polythene bags and taken to the laboratory. The number of beanfly punctures, eggs, larvae and puparia in the bean plants were counted. The number of dead plants due to beanfly attack were recorded. The experiments were done during the short rains of 1984 (October- January); Long rains of 1985 (April- July); off-season of 1985 (July- October) and short rains of 1985 (October - January) at the National Agricultural Laboratories, Nairobi and the Kabete Campus Field Station, Nairobi.

4:2.1 Effect of date of sowing on beanfly infestation of the the bean crop.

Glp 2 (Rose Coco) bean seeds were sown in plots of 9.5m.x5m. with an inter-row spacing of 50cm. and within-row spacing of 10cm. There were four successive sowings of bean plants in four plots. The first sowing of beans was immediately after the start of the rains. Then subsequent sowing times were at weekly intervals. The bean seedlings were left to natural beanfly infestation. Sampling started 7 days after emergence of the seedlings of each sowing time and continued at weekly intervals during the growing period of the crop. From the twenty rows per plot, one plant was randomly sampled per each row and the 20 sampled plants were placed in polythene bags and taken to the laboratory. The number of beanfly punctures, eggs, larvae and the puparia in the plants were counted. The number of plants dead due to beanflies were recorded. The experiments were done during the short rains of 1985 (October - January); long rains of 1986 (April - July) and short rains of 1986 (October - January) at the National Agricultural Laboratories, Nairobi.

4.1 RESULTS

4.3.1 Seasonal fluctuation of beanfly leaf punctures, eggs, larvae and puparia in bean plants.

The beanflies punctured the leaves of bean plants at the base and edges of the lamina (Plate 1). The base of the lamina was the preferred site for puncturing. Leaf puncturing occurred immediately after plant emergence and continued throughout the season (Fig.1). The number of punctures were accurately counted within the first four weeks. After this time the older punctures dried and coalesced so that it became difficult to count them accurately. During off-season of 1985

Plate 1. Beanfly leaf punctures on base and edges of the leaf x 0.8.

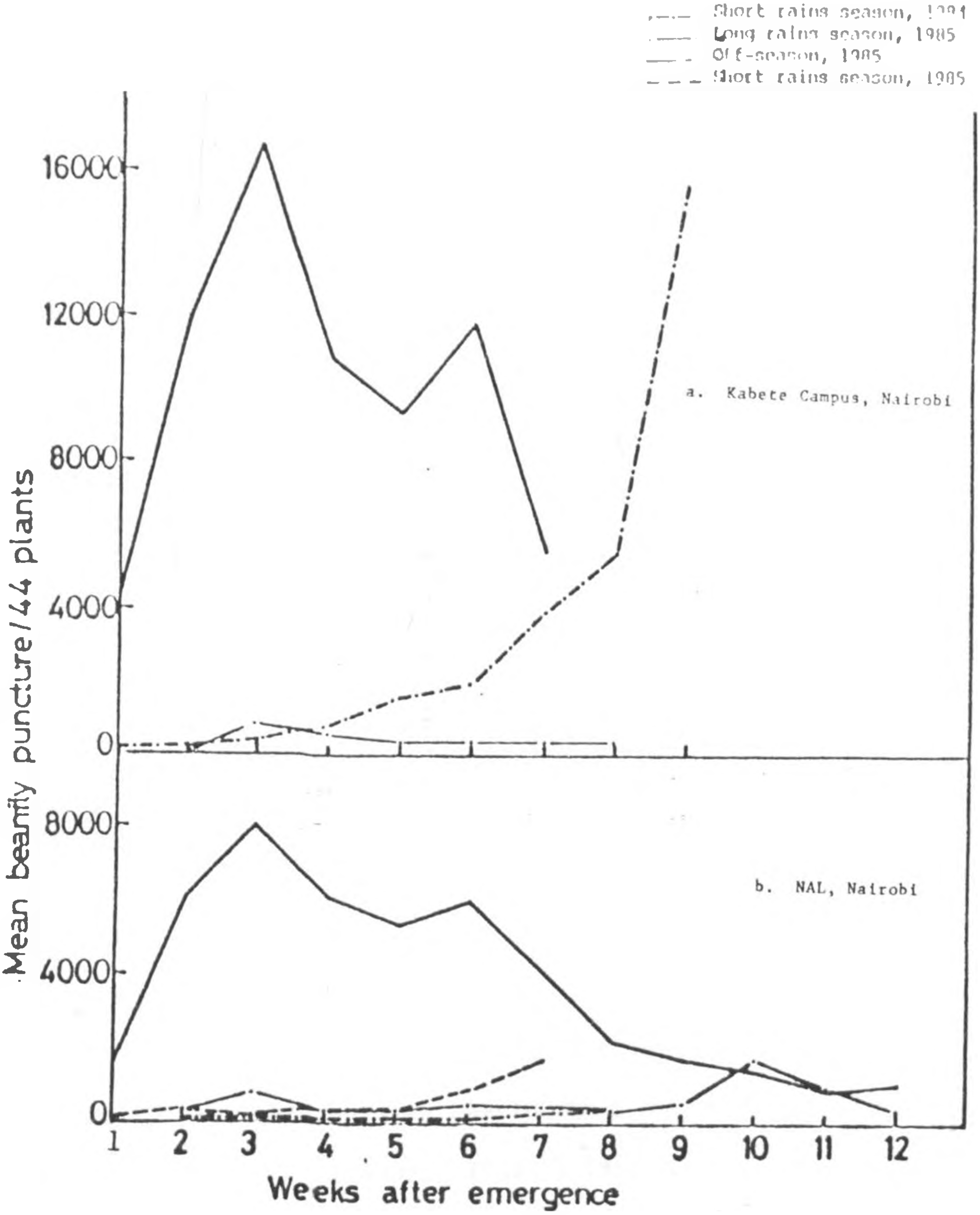

Figure 1. Population fluctuation of beanfly punctures in the leaves of bean plants.

leaf puncturing was very high during the early stage of growth of plants at the two sites. Beanfly leaf punctures fluctuated slightly during the short rains of 1984; long rains of 1985 and short rains of 1985 at the two sites. However, during the late part of the short rains of 1984 there was a high build up of beanfly leaf punctures in the bean plants at National Agricultural Laboratories, Nairobi. Immediately after emergence all the bean plants grown during off-season of 1985 at the two sites were punctured (Fig 2). More bean plants had beanfly leaf punctures during the early part of the long rains of 1985 than during the early part of short rains of 1985. However, this pattern reversed towards the late part of the seasons.

Beanflies laid eggs in only a few of the leaf punctures. The eggs were ovoid, white and were inserted singly in the punctures (Plate 2). They were mainly found in the leaf punctures located at the base of the leaf lamina (Plate 3). Eggs were deposited in the leaves of plants immediately after emergence and oviposition continued throughout the season (Fig 3). During the off-season of 1985, oviposition was higher at the seedling stage than mature stages of the plants. There were peak numbers of eggs in the leaves 2 weeks after plant emergence. During the short rains of 1984 and 1985 the number of eggs laid in the leaf punctures was low immediatey after plant emergence but increased towards the later part of the

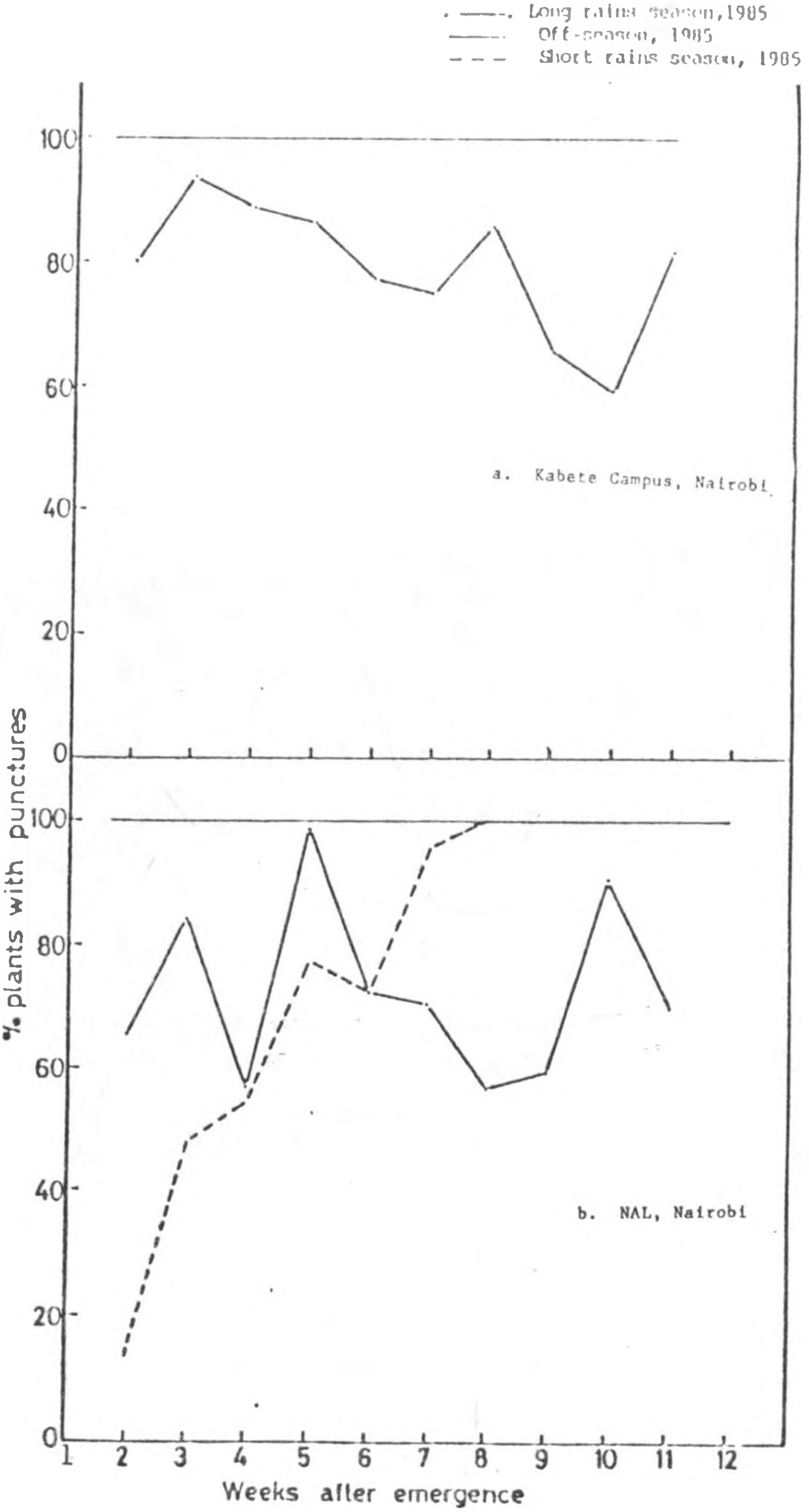

Figure 2. Infestation of the leaves of bean plants with beanfly punctures.

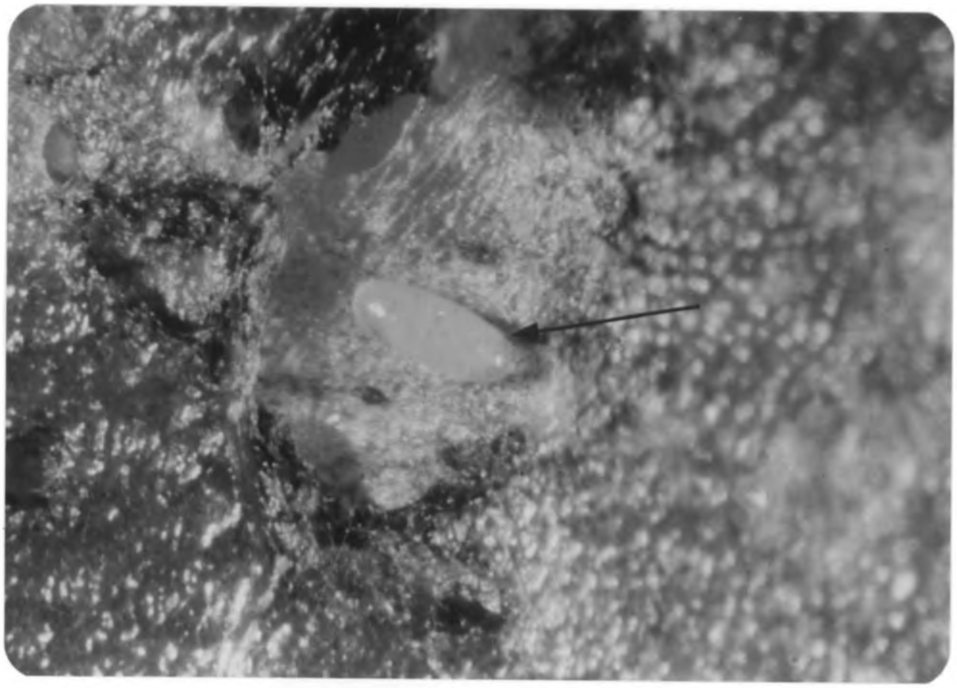

Plate 2. The ovoid, white beanfly egg in the leaf x 7.

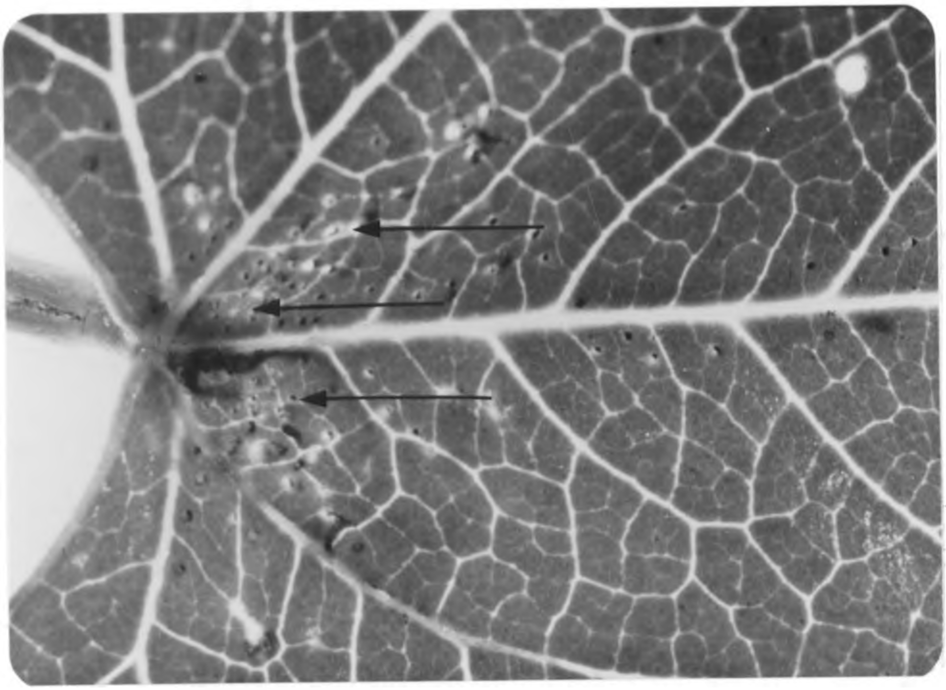

Plate 3. Beafly egg and punctures at the base of the leaf x 3.5.

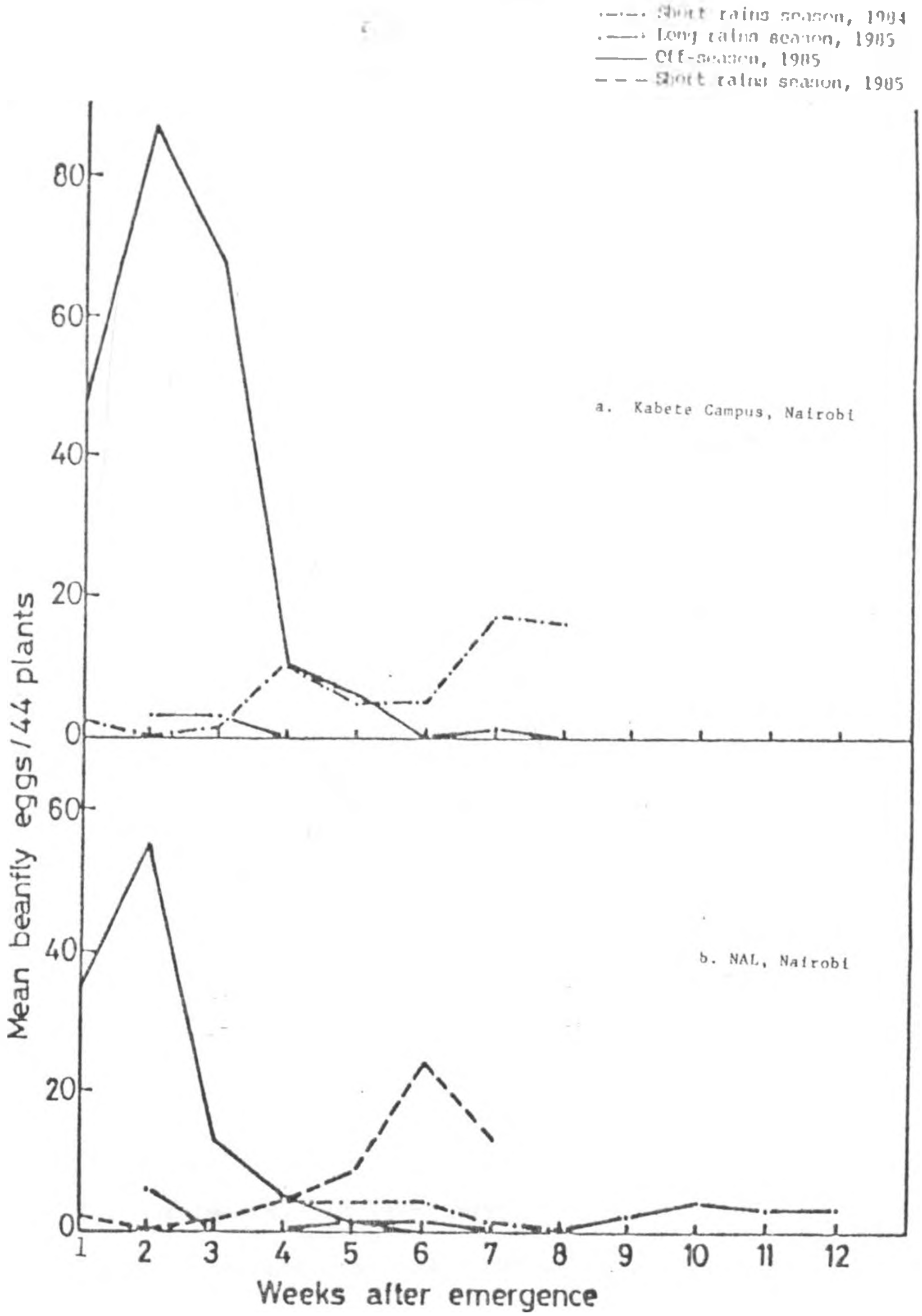

Figure 3. Population fluctuation of beanfly eggs in leaves of bean plants.

seasons. During the long rains of 1985, ovipositon was low throughout the season. More plants had beanfly eggs on the leaves during the off-season of 1985 than during short rains and long rains of 1985 (Fig. 4). There were more bean plants with eggs in the leaves during the short rains than during the long rains of 1985. More plants had eggs early in the season than later in the season. During the short rains and long rains of 1985 more plants had eggs in the leaves in the late than in the early part of the season.

During the off-season of 1985 beanflies laid eggs in the stems of young bean seedlings. No eggs were observed in the stems of young seedlings during the long rains or short rains of 1985. Beanflies punctured the stems of young bean seedlings above and below the ground level and laid the eggs in these punctures (Plate 4). Most eggs were laid in the part of the stem below the ground level (Plate 5). During the off-season of 1985 oviposition in the stems mainly occurred during the two weeks after emergence of the bean plants (Fig 5). There were more eggs in the stems than in the leaves within the 1st week after plant emergence. In later weeks the number of eggs in the leaves exceeded those in the stems of the plants. The number of bean plants with eggs in the stems were greater during the first week than in subsequent weeks after plant emergence (Fig. 6). There was a drastic decrease in the number of plants with eggs in the stems on later growth stages. There

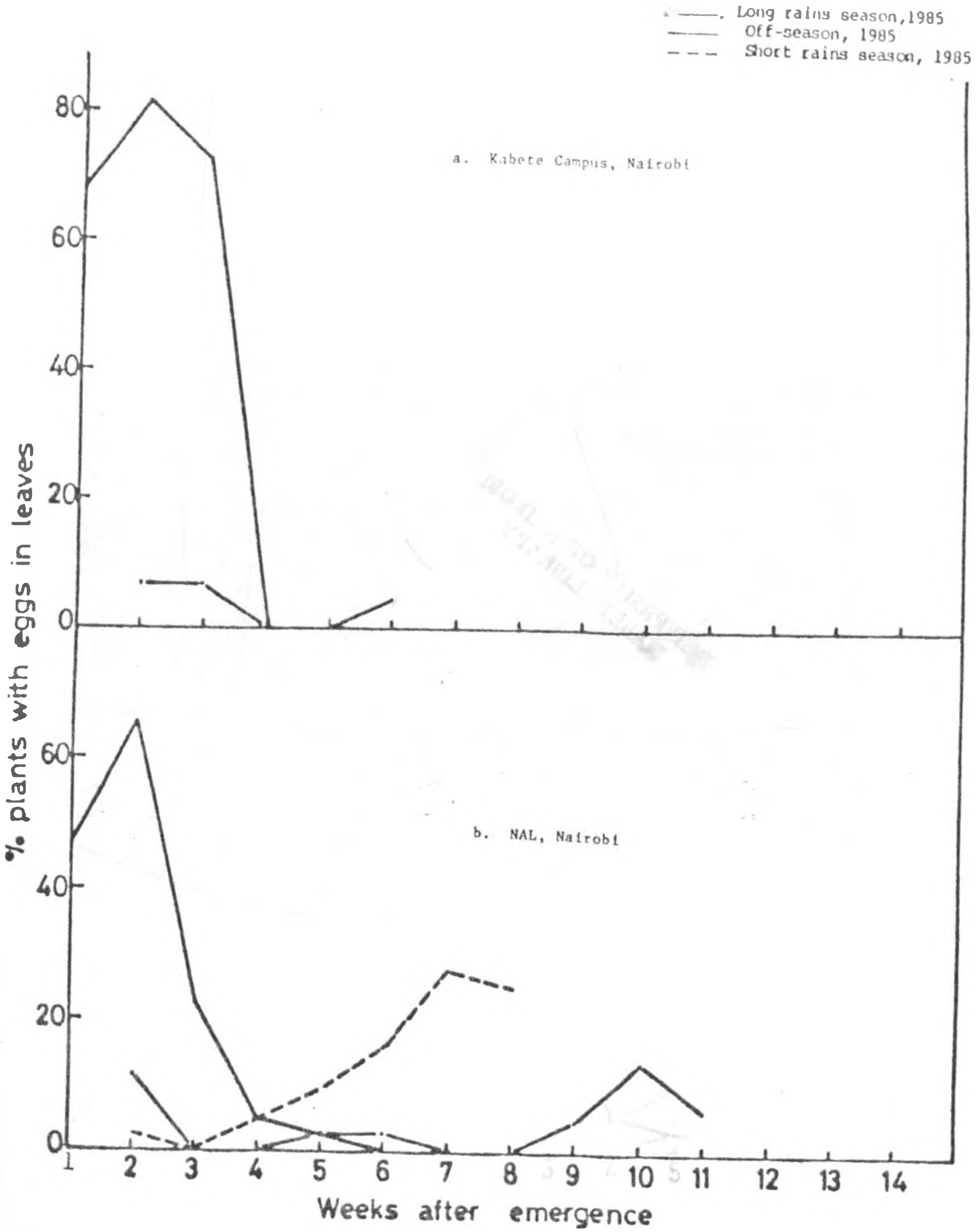

Figure 4. Infestation of leaves of bean plants with beanfly eggs.

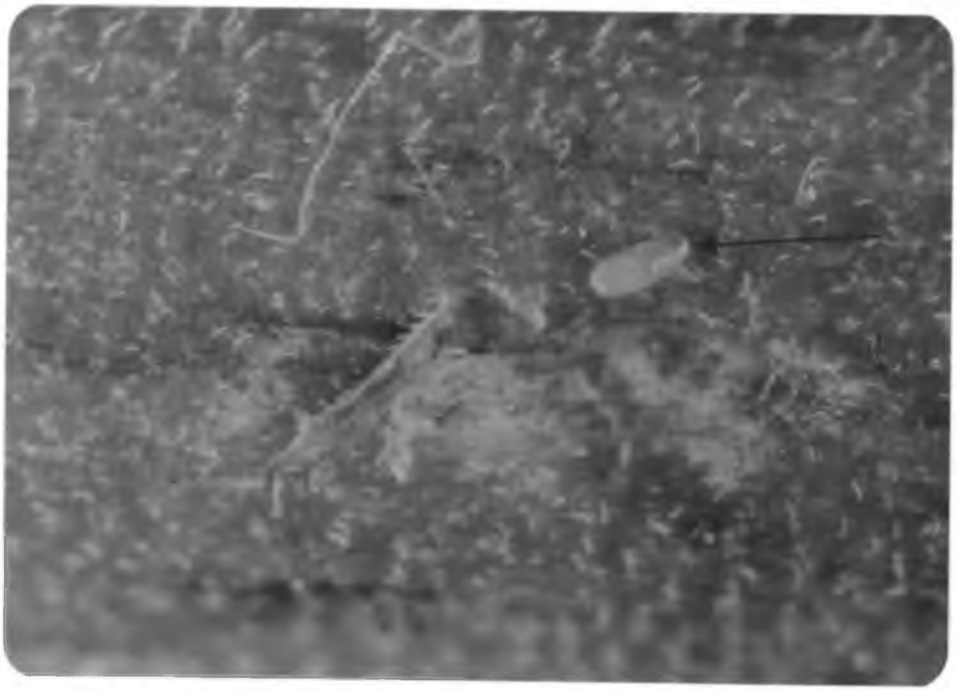

Plate 4. Beanfly egg in the stem of bean seedling x 3.

Plate 5. Bean seedling stems with brown stripes of punctures x1.5.

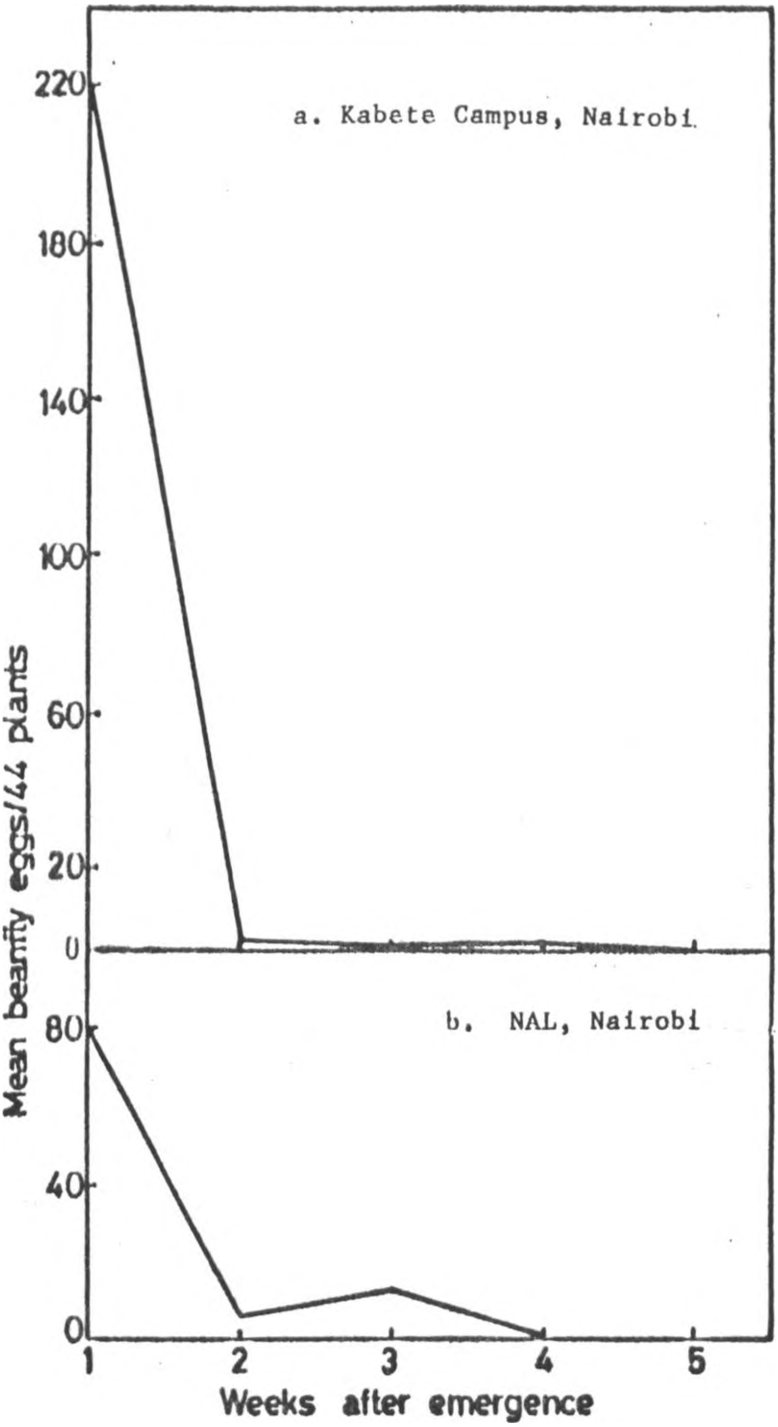

Figure 5. Population fluctuation of beanfly eggs in stems of bean plants grown during off-season of 1985.

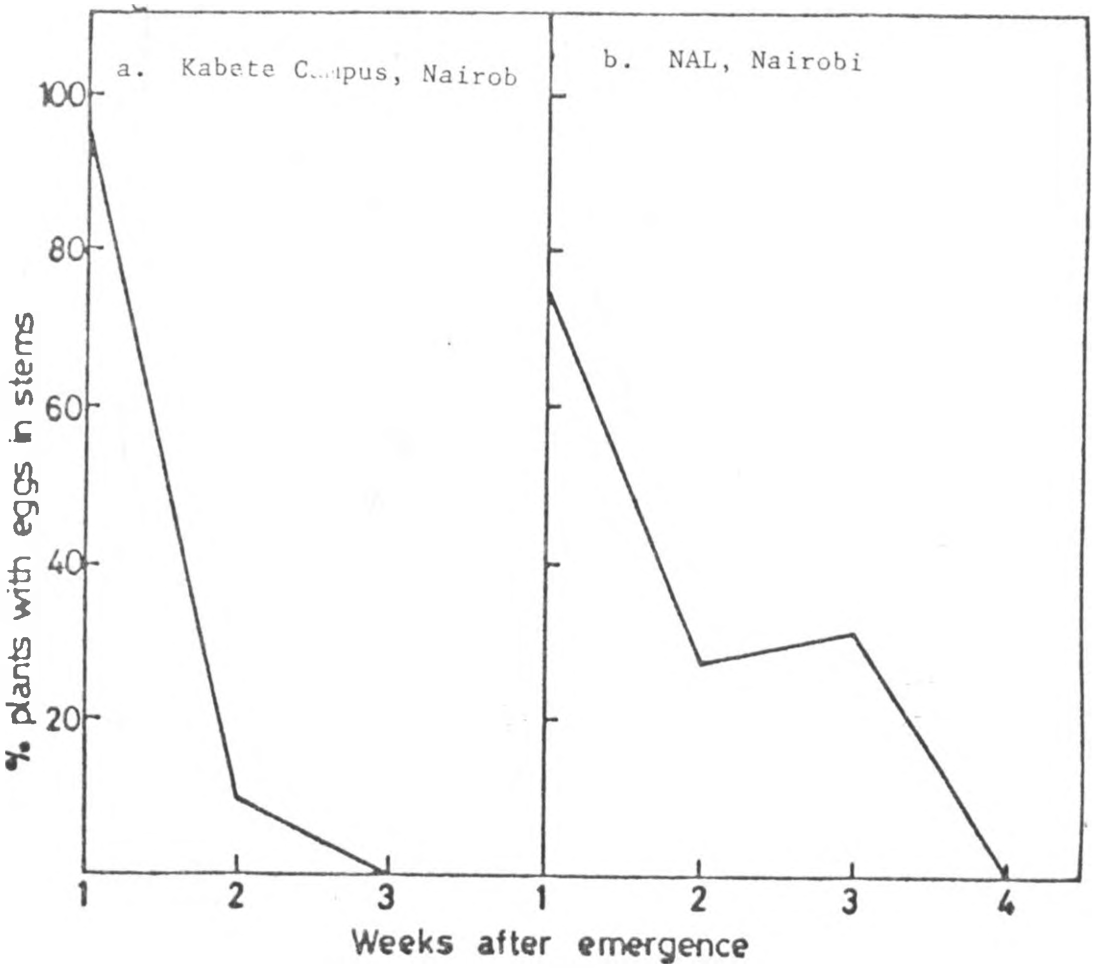

Figure 6. Infestation of the stems of bean plants with beanfly eggs during off-season of 1985.

were more bean plants with eggs in the stems than in the leaves immediately after plant emergence.

Eggs in the leaf punctures hatched as 1st instar larvae (Plate 6). Most larvae in the leaves were observed when they were in the leaf punctures before they moved into the leaf veins. Those few larvae which were observed along the leaf veins were orientated towards the base of the leaf lamina (Plate 7). The larvae moved fast along the leaf veins into the petiole. During the short rains of 1984 and 1985, and the long rains of 1985 there were very low numbers of beanfly larvae in the leaves in the early part of the seasons at the two sites (Fig 7). There was a build up of larvae in the leaves as the seasons advanced. During the off-season of 1985 larvae in the leaves reached a peak immediately after plant emergence but three weeks after there was very low population. In each season there was at least one peak of larvae in the leaves during the growth of the bean crop. During the short rains and long rains of 1985 the number of plants with larvae in the leaves was less in the early part than in the later part of the seasons (Fig. 8). The increase in the number of plants with larvae in the leaves during the short rains of 1985 was faster and greater than the increase in the number of bean plants with larvae in the leaves during the long rains of 1985.

The larvae in the leaves fed along the petioles until

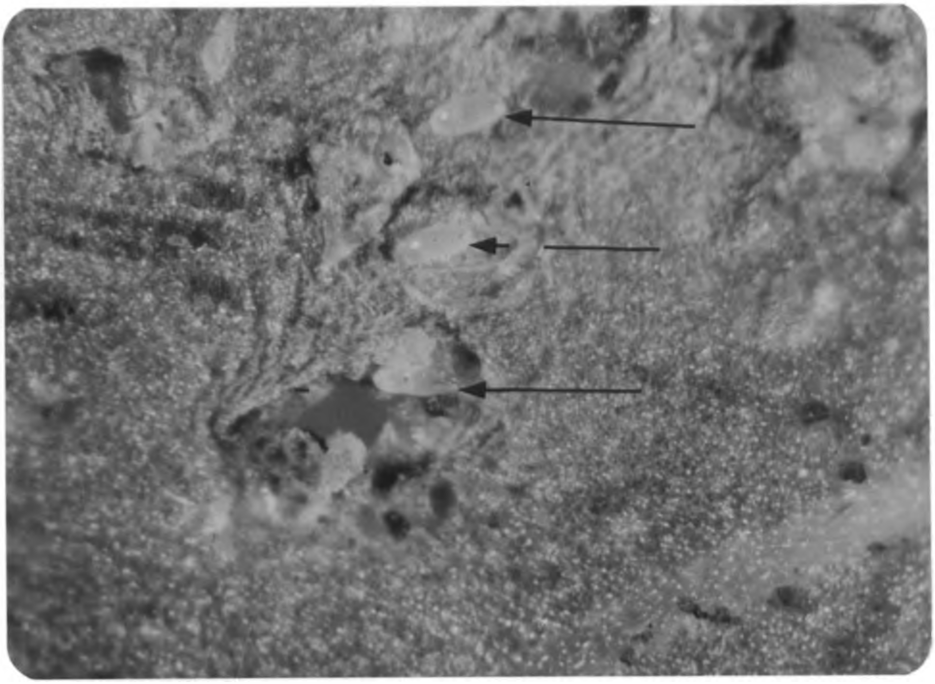

Plate 6. Dissected leaf punctures with 1st instar larvae identified with dark brown cephalopharygeal skeleton x 1.5.

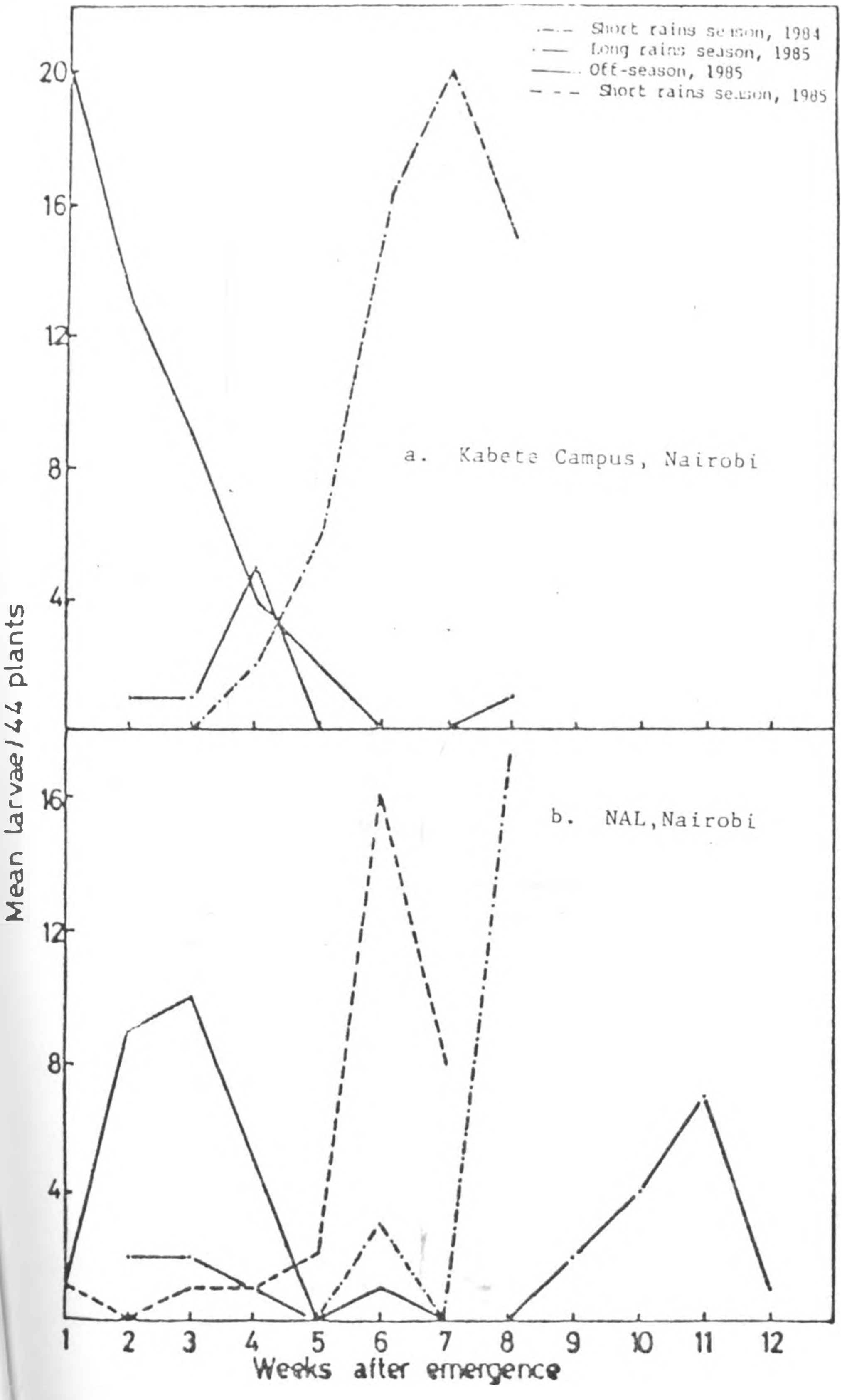

Figure 7. Population fluctuation of beanfly larvae in leaves of bean plants.

Plate 7. Orientation of 1st instar larva in the leafmine x3.0

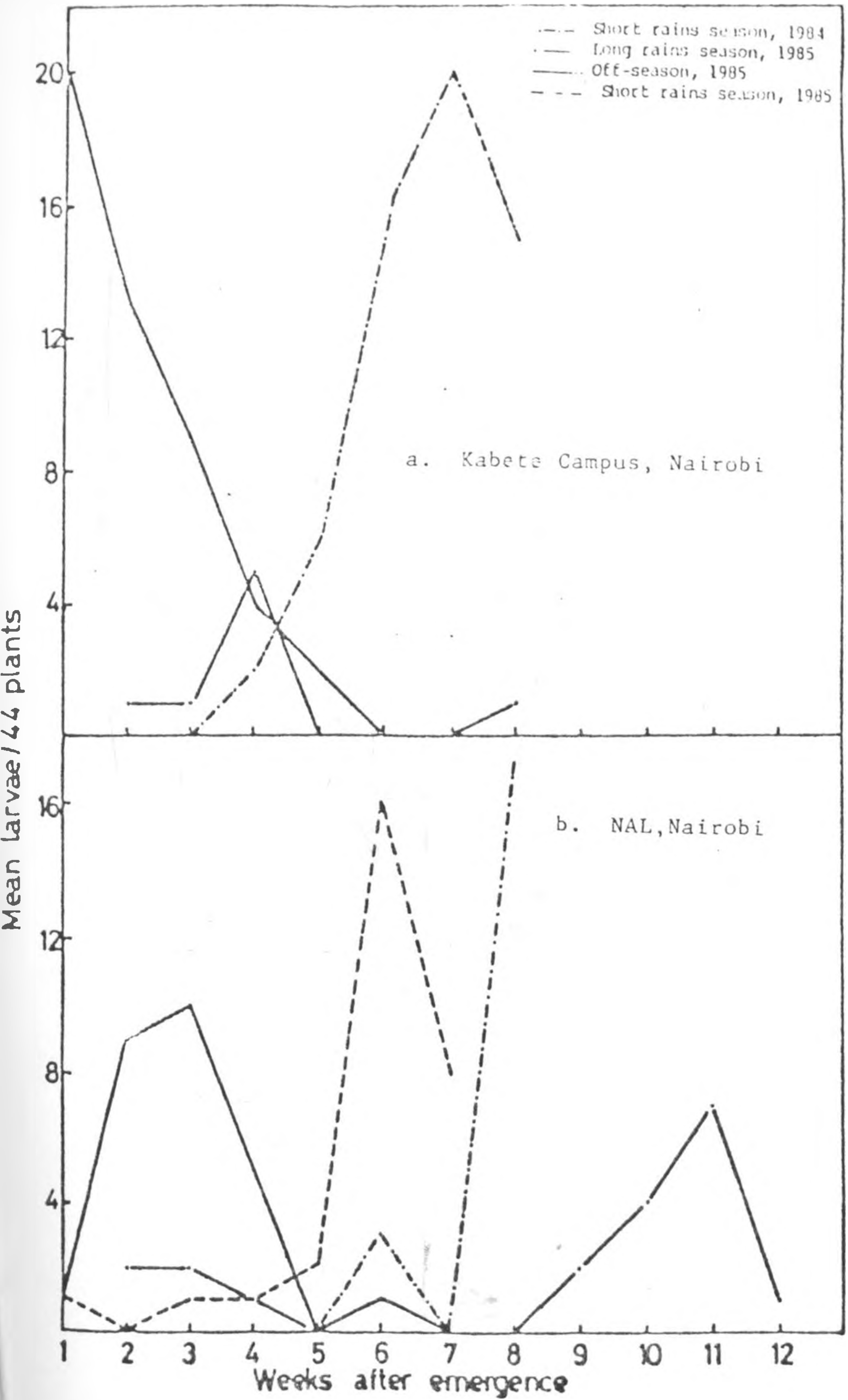

Figure 7. Population fluctuation of beanfly larvae in leaves of bean plants.

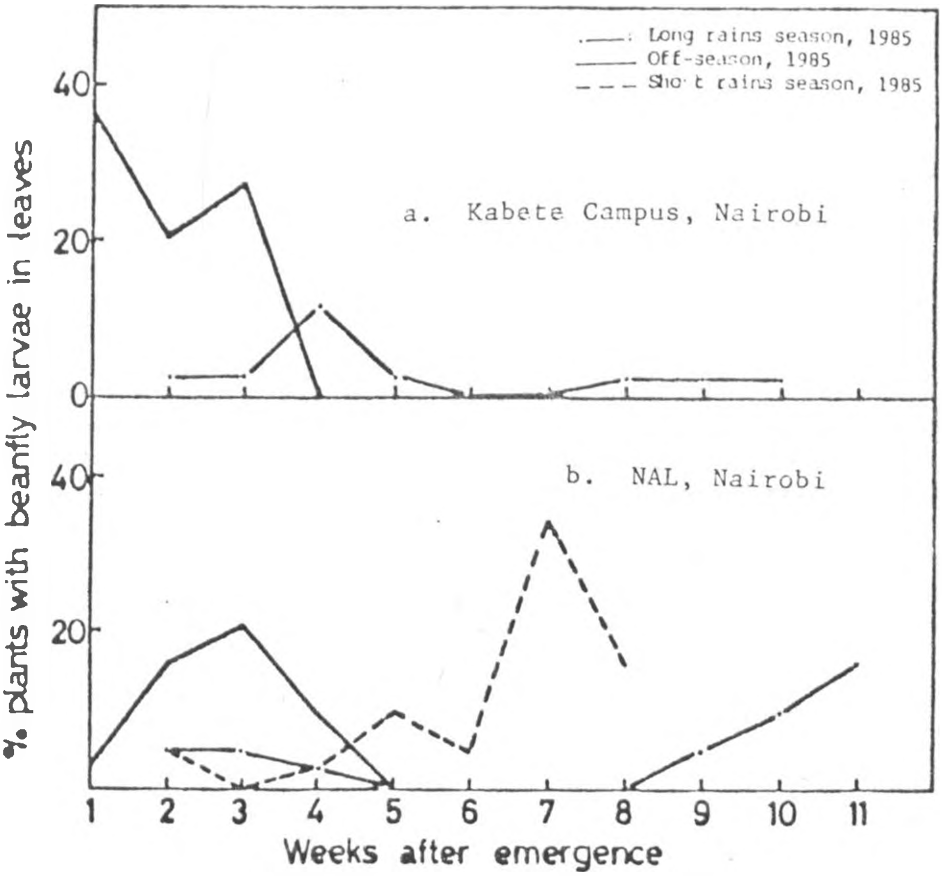

Figure 8. Beanfly larvae infestation in leaves of bean plants.

they reached in the stems. They were found tunelling the stems (Plate 8). The larvae in the stems occurred below and above ground level. They mined as far as the base of the stems of bean plants (Plate 9). No larvae were found in the roots. During the short rains of 1984 and 1985 and the long rains of 1985 the beanfly larvae were found in the stems of bean plants from the third week after plant emergence (Fig 9). In the early stages of growth of the crop the numbers of larvae in the stems was higher during the long rains of 1985 than during the short rains of 1984 or 1985. However, there were lower numbers of larvae in the bean plants in the later stages of growth of the crop during the long rains of 1985 than during the short rains of 1984 or 1985. During the off-season of 1985, the larvae were observed in the stems from the 1st week of plant emergence. Larval population increased rapidly reaching a peak 3rd-4th week after plant emergence during the season. Larvae in the stems fluctuated at lower levels later in the growing period of this season. There were more bean plants with beanfly larvae in the stems in the early stages of growth during the off-season of 1985 than during the long rains or short rains of 1985 (Fig 10). While there was an increase of plants with larvae in the stems as the season advanced during the short rains and long rains of 1985, there was a decrease in the number of plants with larvae in the stems during the off-season of 1985.

Larvae pupated at the base of the stems in young bean

Plate 8. Bean stems with brown stripes of mines x 0.7.

Plate 9. Third instar larva at the base of damaged stem x 3.

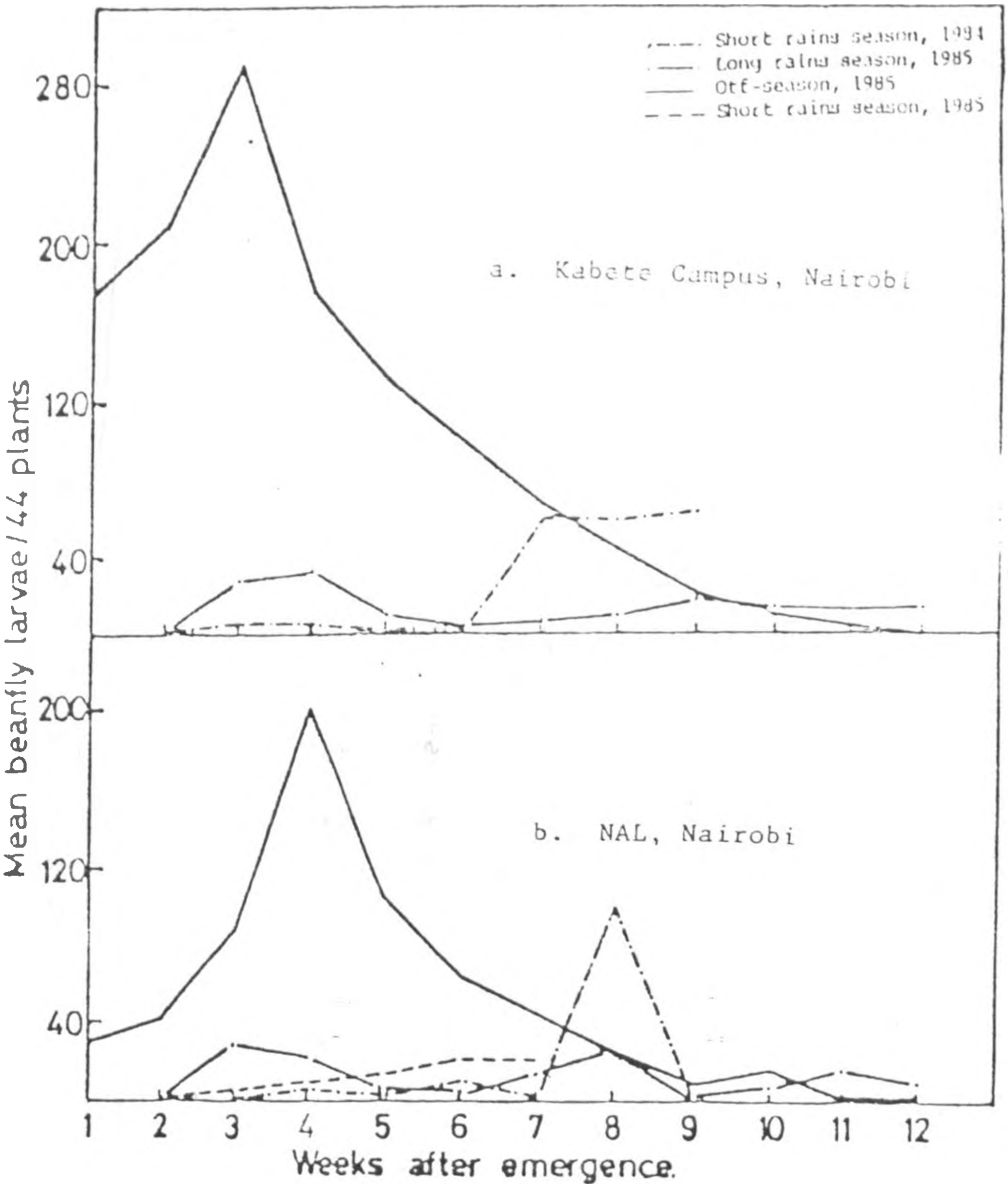

Figure 9. Population fluctuation of beanfly larvae in stems of bean plants.

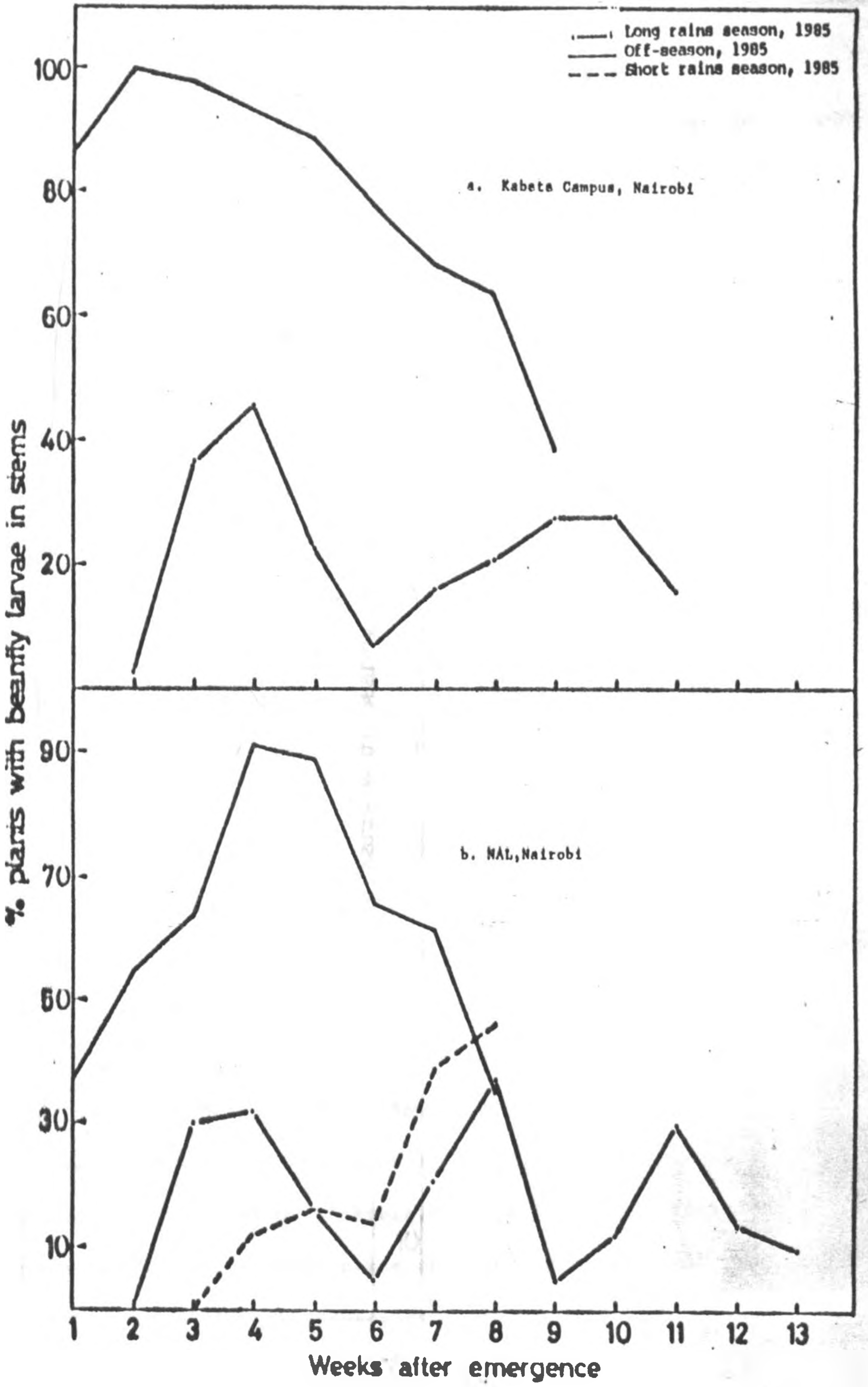

Figure 10. Beanfly larvae infestation in stems of bean plants.

plants and at the nodes on the stems in older bean plants (plates 10 and 11). O. phaseoli and O. spencerella were the species of beanflies infesting plants in the field. The puparia of O. spencerella were shining black (Plate 12) while those of O. phaseoli had black apices and intermediate segments yellow-brown (Plate 13). The population patterns of the two species of beanflies were shown by the incidence of the pupal stage in the bean plants (Fig. 11). O. spencerella puparia were found on plants three weeks while O. phaseoli puparia were found four weeks after plant emergence. During the short rains of 1984 and 1985 the puparia population of both species built up to the same level at the late stage of growth of the crop at both sites. During the off-season and long rains of 1985 the numbers of O. spencerella was higher than the numbers of O. phaseoli puparia. The peak numbers of O. spencerella puparia during the two seasons occurred during the 5th week after plant emergence. The number of O. spencerella puparia in the plants were about the same as the number of O. phaseoli during the short rains of 1984 and 1985. The seasons differed in terms of the numbers of O. spencerella puparia in the plants and were ranked as follows:- off-season of 1985 > short rains of 1984 > long rains of 1985 > short rains of 1985. The seasons also differed in the number of O. phaseoli puparia in the plants and were ranked as follows:- short rains of 1984 > off-season of 1985 > short rains of 1985 > long rains of 1985. During the plants and at the nodes on the stems in older bean plants (plates 10 and 11). *O. phaseoli* and *O. spencerella* were the species of beanflies infesting plants in the field. The puparia of *O. spencerella* were shining black (Plate 12) while those of *O. phaseoli* had black apices and intermediate segments yellow-brown (Plate 13). The population patterns of the two species of beanflies were shown by the incidence of the pupal stage in the bean plants (Fig. 11). *O. spencerella* puparia were found on plants three weeks while *O. phaseoli* puparia were found four weeks after plant emergence. During the short rains of 1984 and 1985 the puparia population of both species built up to the same level at the late stage of growth of the crop at both sites. During the off-season and long rains of 1985 the numbers of *O. spencerella* was higher than the numbers of *O. phaseoli* puparia. The peak numbers of *O. spencerella* puparia during the two seasons occurred during the 5th week after plant emergence. The number of *O. spencerella* puparia in the plants were about the same as the number of *O. phaseoli* during the short rains of 1984 and 1985. The seasons differed in terms of the numbers of *O. spencerella* puparia in the plants and were ranked as follows:- off-season of 1985 > short rains of 1984 > long rains of 1985 > short rains of 1985. The seasons also differed in the number of *O. phaseoli* puparia in the plants and were ranked as follows:- short rains of 1984 > off-season of 1985 > short rains of 1985 > long rains of 1985. During the

Plate 10. Damaged base of the stem with O. spencerella puparium x1.

Plate 11. Damaged stem nodes and leaf petioles caused by *O. Phaseoli* puparia x 0.5.

Plate 12. O. spencerella puparium x 3.5.

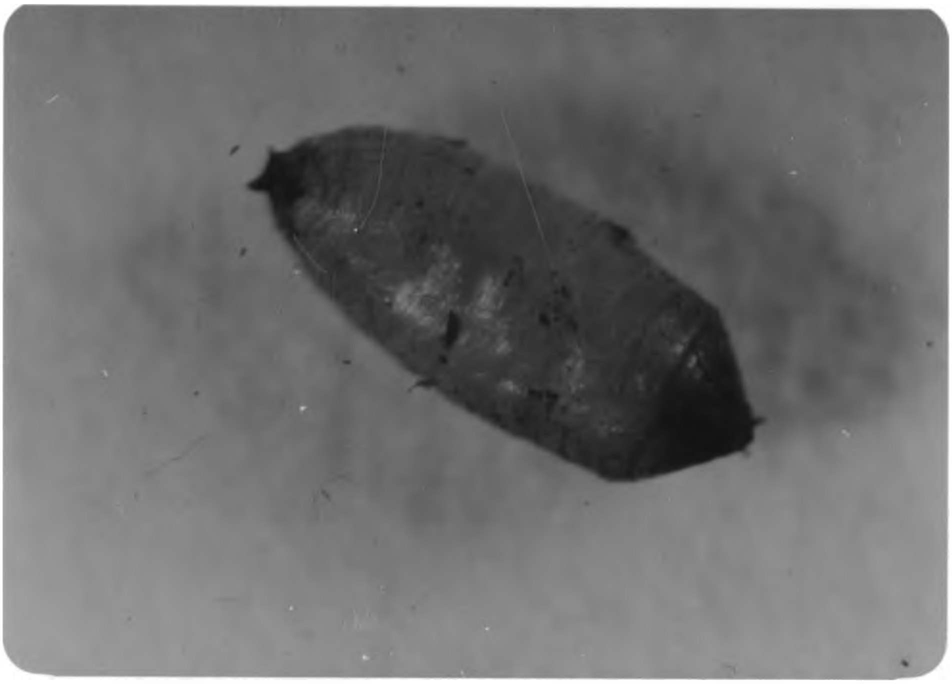

Plate 13. O. *phaseoli* puparium x 3.5.

a. Kabete Campus, Nairobi

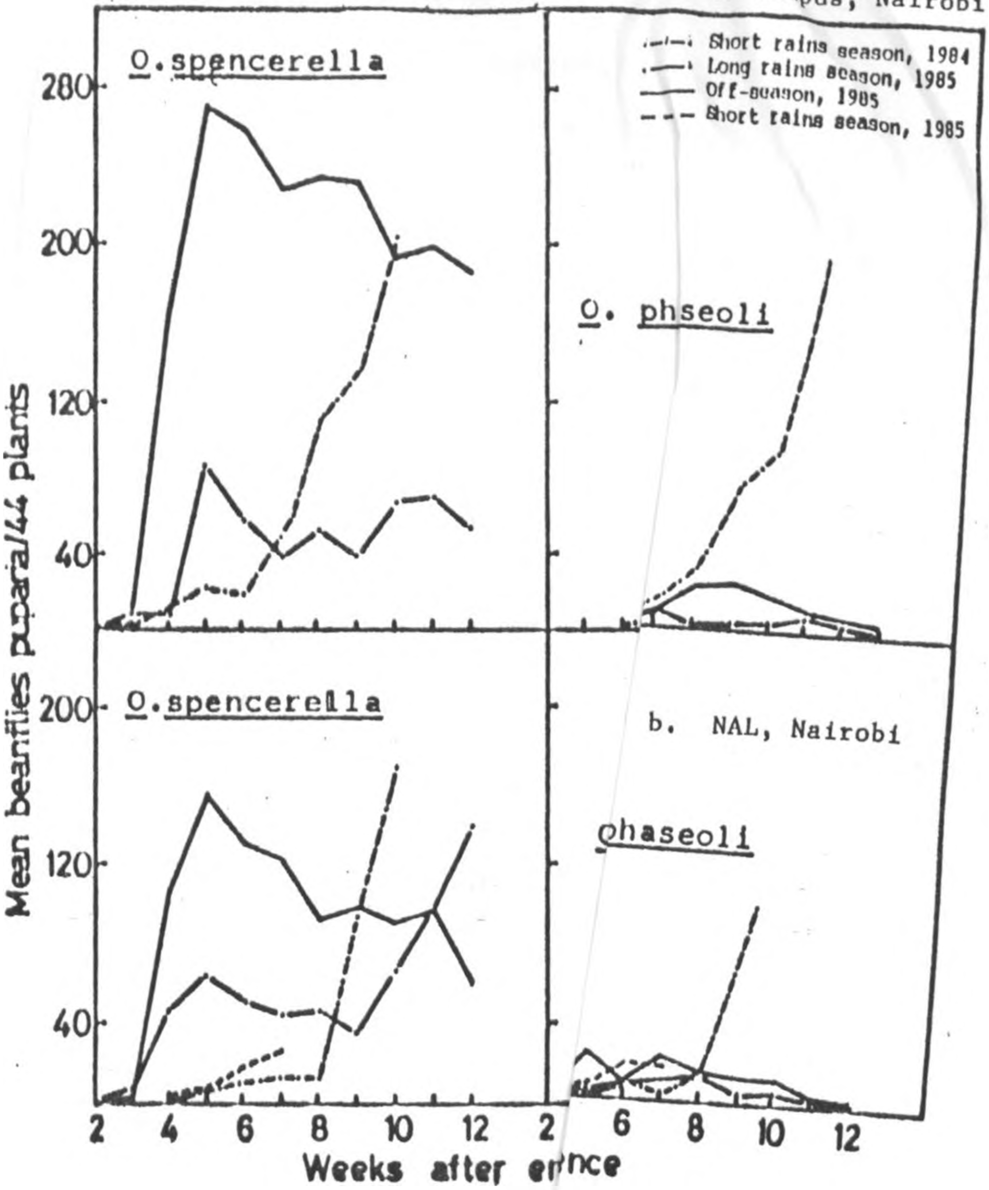

Figure 11. Population flu on of beanfly puparia in bean plants.

off-season and long rains of 1985 more plants were infested with O. spencerella than with O. phaseoli puparia (Fig. 12). During the short rains of 1985 more plants were infested with O. phaseoli than with O. spencerella puparia.

The beanfly infestation during the short rains of 1984; long rains and short rains of 1985 was not of a sufficient level to cause the death of the bean plants. However, during the off-season of 1985 the population of O. spencerella was high enough to cause such severe damage to the plants resulting in the death of the seedlings. Typical symptoms appeared as calloused growth around the injury where the larvae had pupated (Plate 14). Many plants withered (Plate 15) while those which appeared to withstand damage appeared stunted with yellowing of leaves (Plate 16). During this season 53.2% of bean plants at Kabete Campus Field station, Nairobi and 42.6% of bean plants at NAL, Nairobi died due mainly to O. spencerella. Death of the beans was first observed in the fourth week after plant emergence (Fig. 13) and most died five weeks after plant emergence. Those that did not die by the 10th week continued to grow until the end of the season. Those plants that escaped or had little attack grew vigorously and had high yields because of less plant population and more nutrient availability.

4:3:2. Effect of planting dates on beanfly infestation levels.

The number of leaf punctures and percent plants with

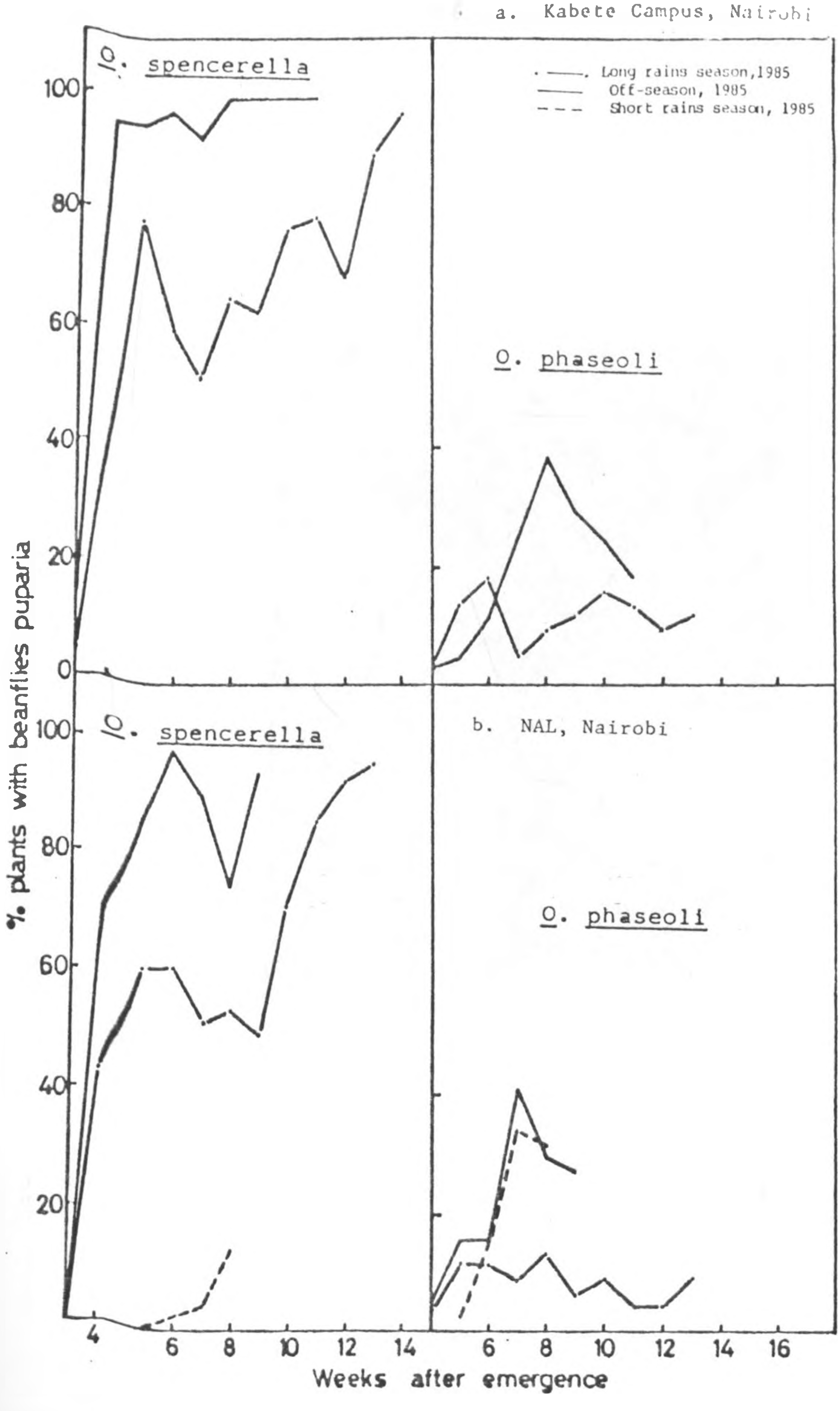

Figure [illegible]. Infestation of bean plants with beanfly puparia.

Plate 14. Calloused growth on the base of the stem x 0.1.

Plate 15. Withering bean plant x 0.5.

Plate 16. Bean plant with stunted and yellow leaves x 0.5.

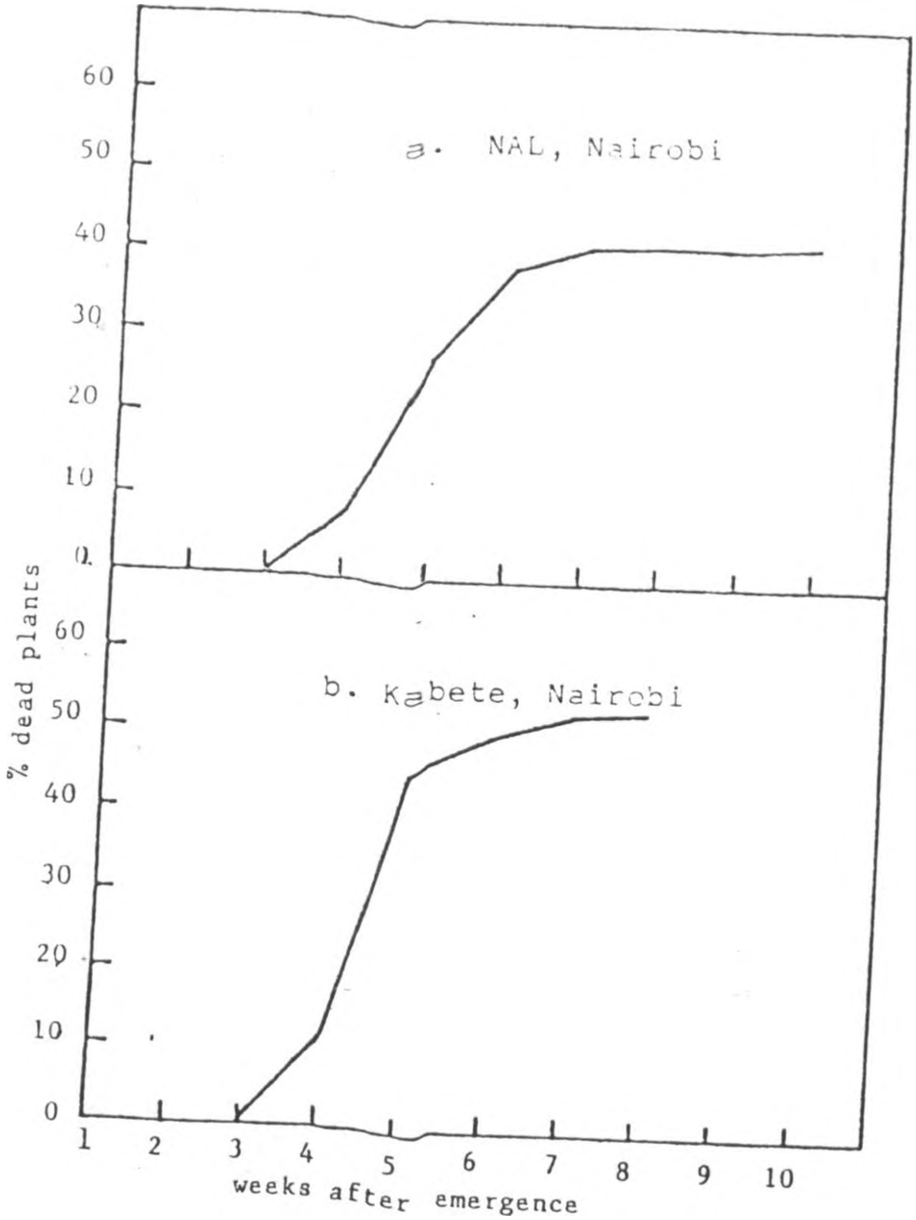

Figure 13. Cumulative mean percent dead plants caused by beanflies in a bean crop during the Off-season of 1985

leaf punctures were more in late planted than early planted bean plants in all the seasons (Figs. 14 and 15). There was a build up of beanfly leaf punctures and high percent of plants with punctures as the seasons advanced. The build up of leaf punctures was highest during the short rains of 1985 and lowest during the short rains of 1986. There were more bean plants with leaf punctures during the short rains of 1985 than the short rains or long rains of 1986. There were more bean plants with leaf punctures during the long rains than during the short rains of 1986.

The number of beanfly eggs in the leaves and percent plants with eggs increased as the seasons progressed (Figs 16 and 17). In late growth stages bean plants had lower eggs for all the four planting dates during the short rains of 1986 than during the short rains of 1985 or long rains of 1986. In all the three seasons, the number of eggs in leaves and percent infested plants with eggs were more in late planted than in early planted bean plants. Similarly, the number of larvae in the leaves and percent plants infested with larvae increased for all the four planting dates as seasons advanced (Figs 18 and 19). There were more larvae in the leaves and more infested plants with larvae in late planted than in early planted bean crop.

There were more larvae in stems and more infested plants with larvae in all the four planting dates during the short

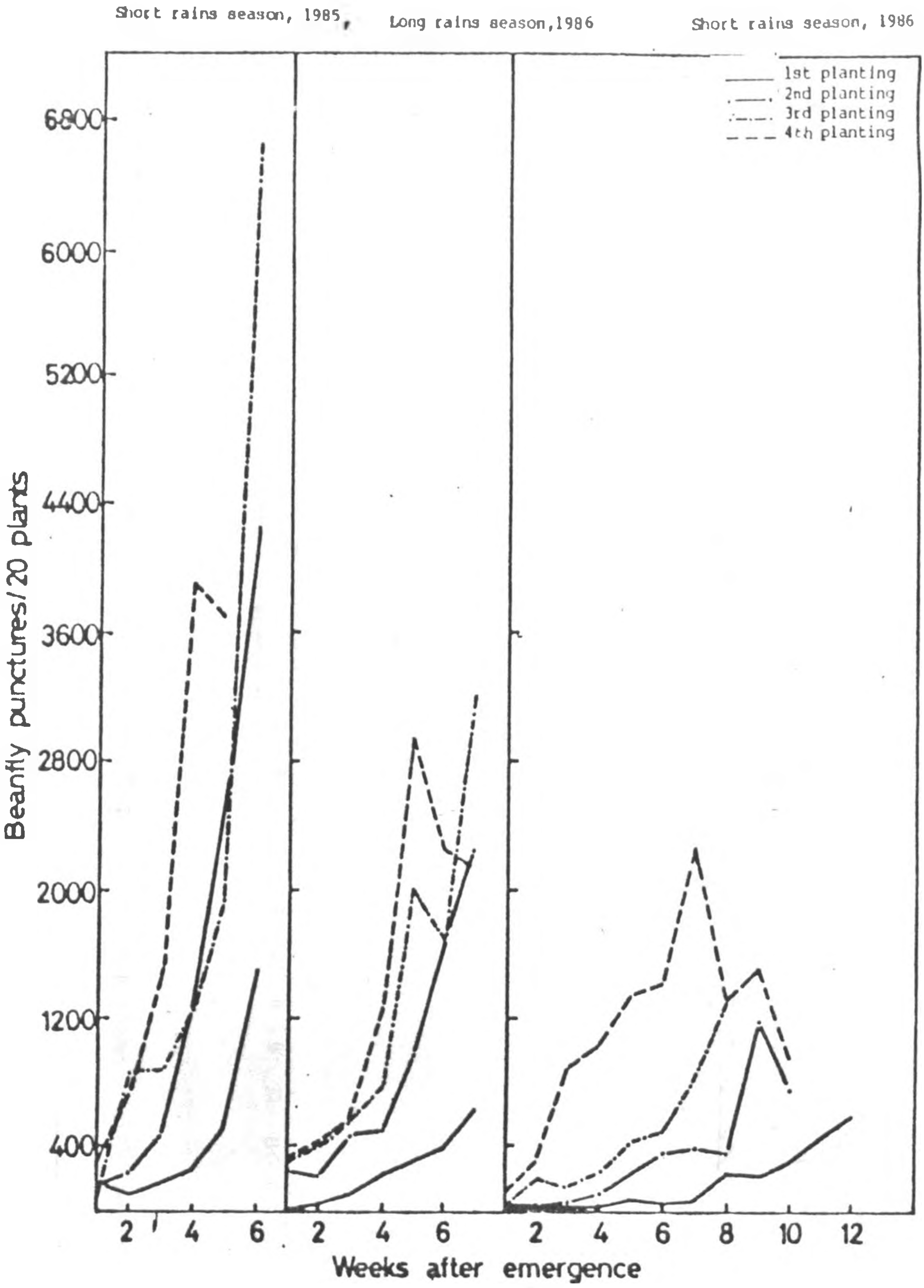

Figure 14. Population fluctuation of beanfly leaf punctures in bean plants grown at different dates in a season.

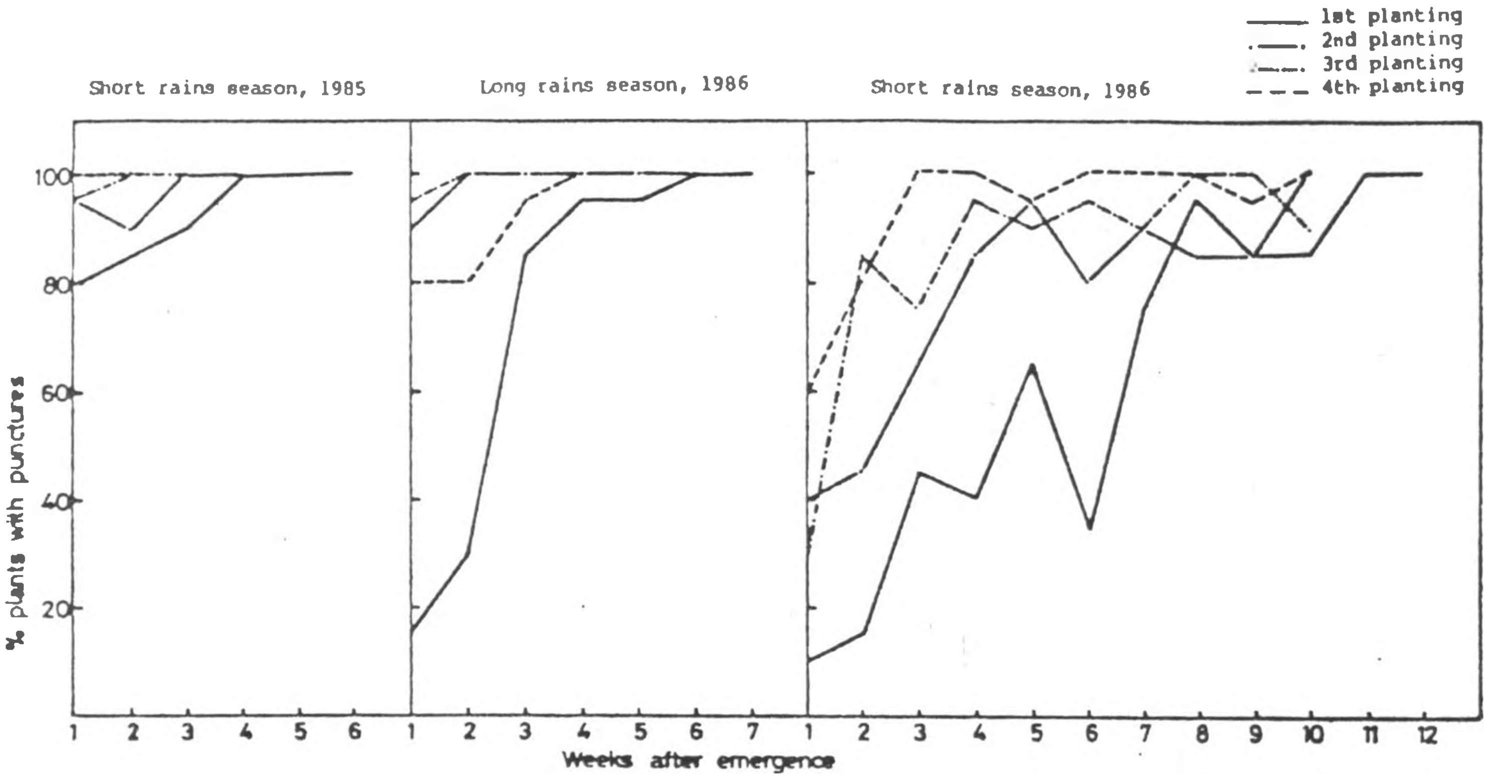

Figure 15. Infestation of bean plants, grown at different dates in a season, with beanfly leaf punctures.

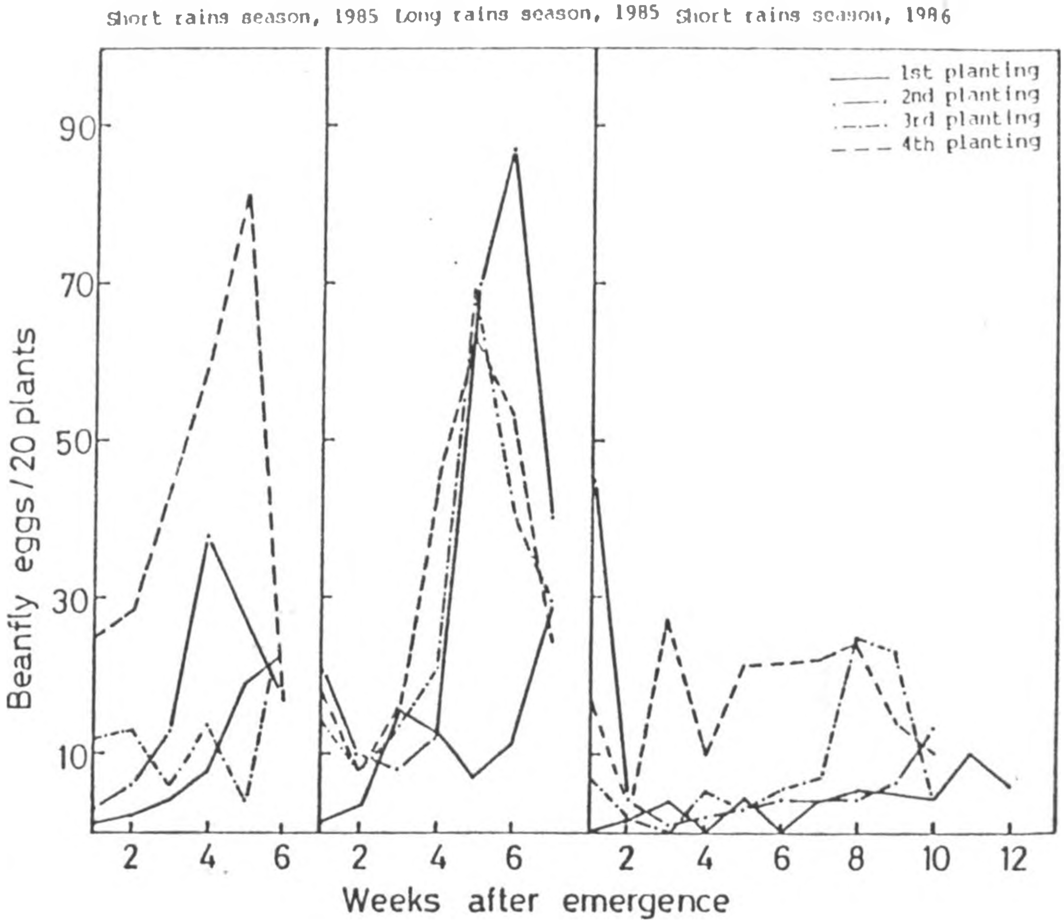

Figure 16. Population fluctuation of beanfly eggs in leaves of bean plants grown at different dates in a season.

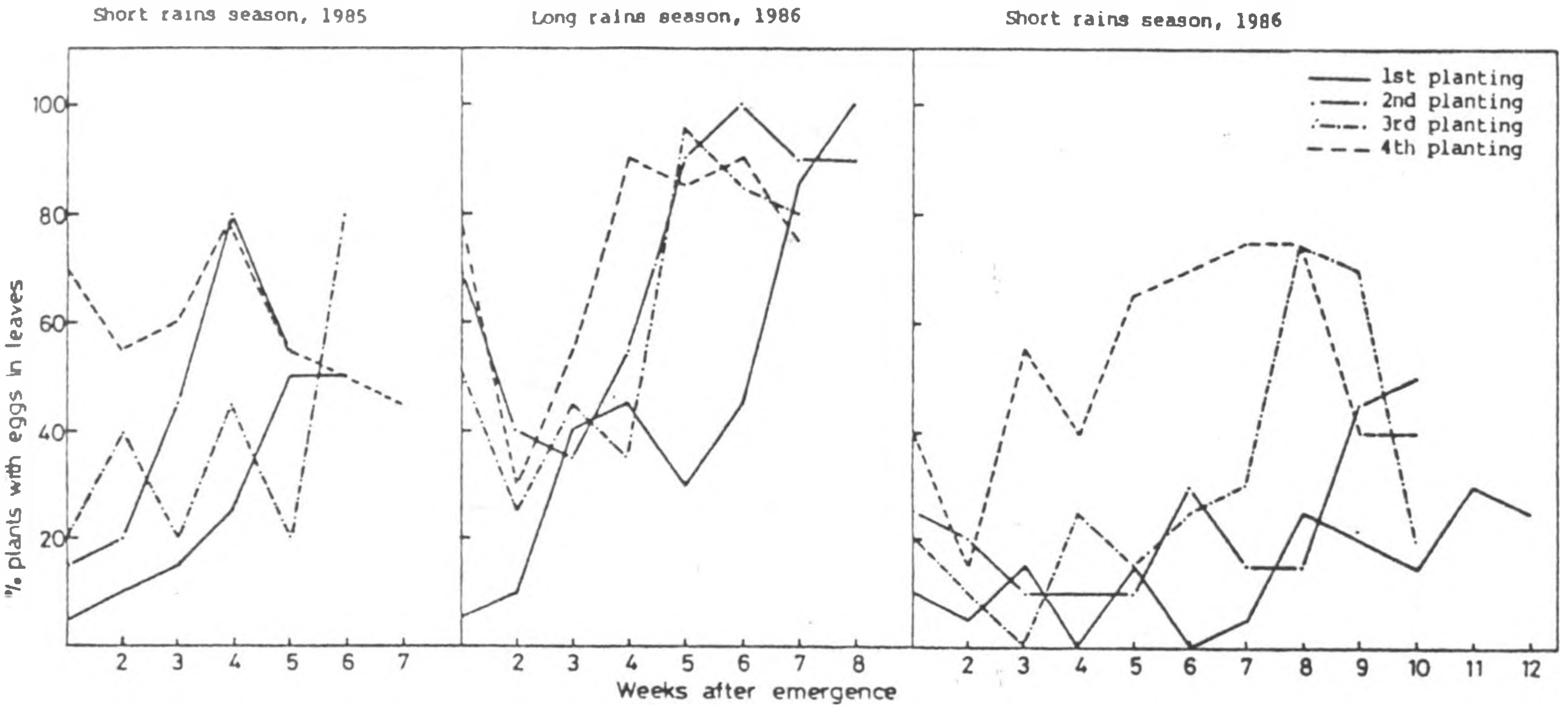

Figure 17. Infestation of bean plants, grown at different dates in a season, with beanfly eggs.

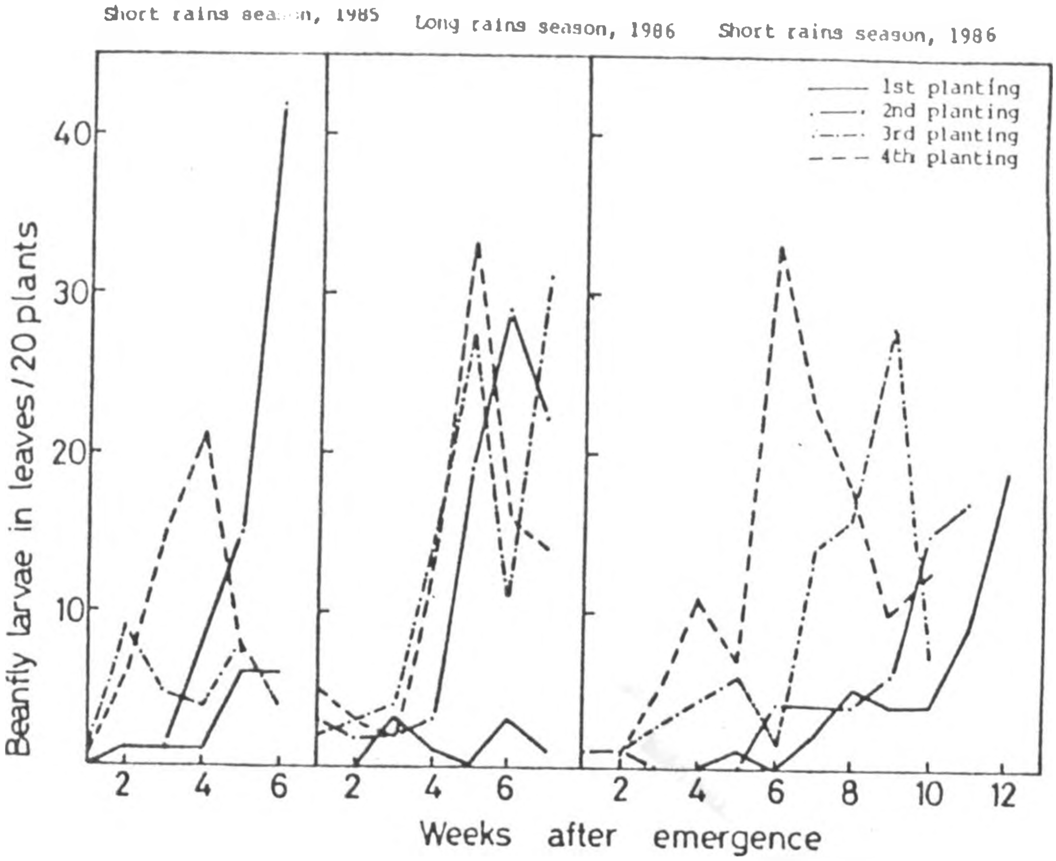

Figure 18. Population fluctuation of beanfly larvae in leaves of bean plants grown at different dates in a season.

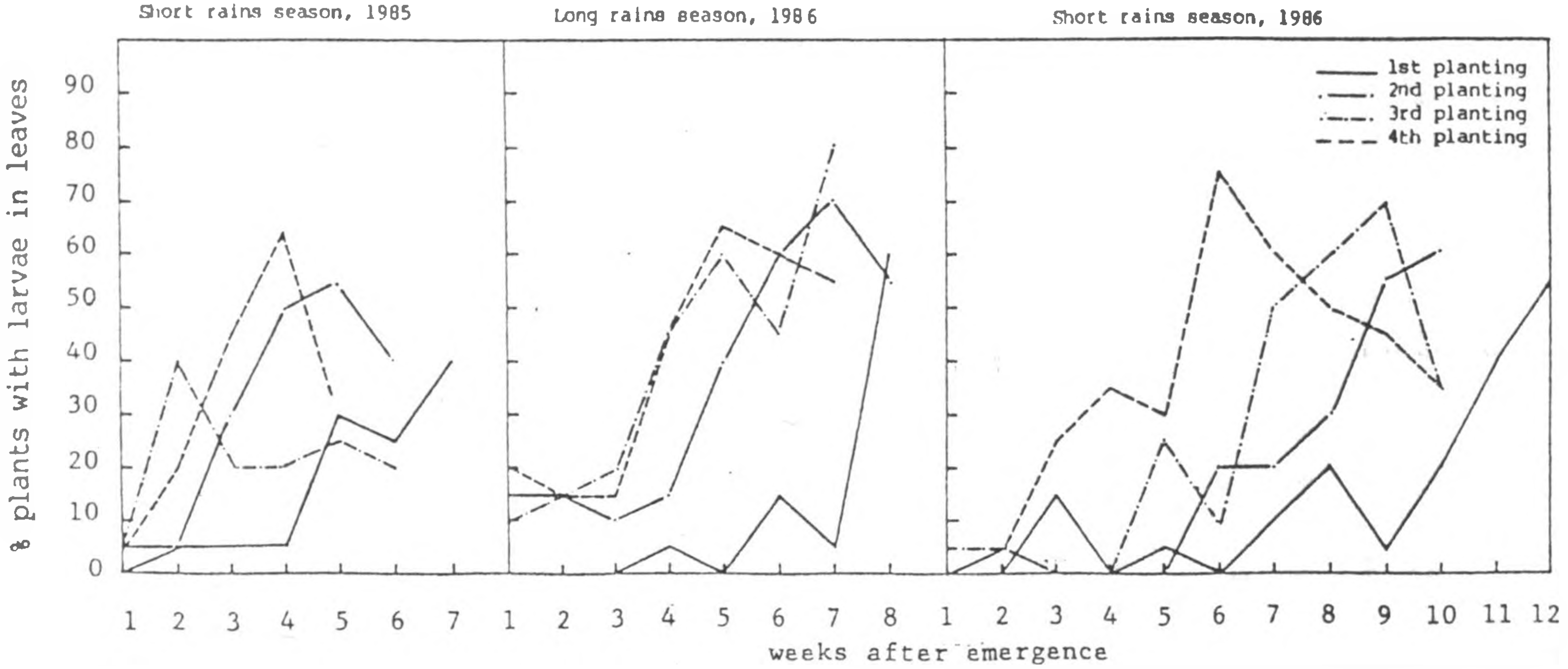

Figure 19. Infestation of leaves of bean plants, grown at different dates in a season, with beanfly larvae.

rains of 1985 than during the long rains or short rains of 1986 (Figs. 20 and 21). There was a rapid increase of larvae in stems and plants infested with larvae during the short rains of 1985. During the short rains of 1985 and 1986. there were more larvae and more infested plants with larvae in late than in early planted crop. However, during the long rains of 1986 the number of larvae and percent infested plants with larvae in the second and third planting dates were more than in the first and fourth planting dates.

In all the seasons, the puparia and percent plants with puparia increased in later growth stages (Figs. 22 and 23). During the short rains of 1985, the number of *O. phaseoli* puparia were more than the number of *O. spencerella* puparia; while during the short rains of 1986, *O. spencerella* puparia were more than *O. phaseoli* puparia in the bean plants. During the long rains of 1986, the number of *O. phaseoli* and *O. spencerella* puparia were equally low in the bean plants. The number of puparia and percent plants infested with puparia for four planting dates were more during the short rains of 1985 and 1986 than during the long rains of 1986. During the short rains of 1985 and 1986, the number of puparia and percent plants infested with puparia were more in the late planted than in the early planted bean crop. During the long rains of 1986 there were only small differences in early planted and late planted bean crop in the number of puparia and percent plants infested with puparia.

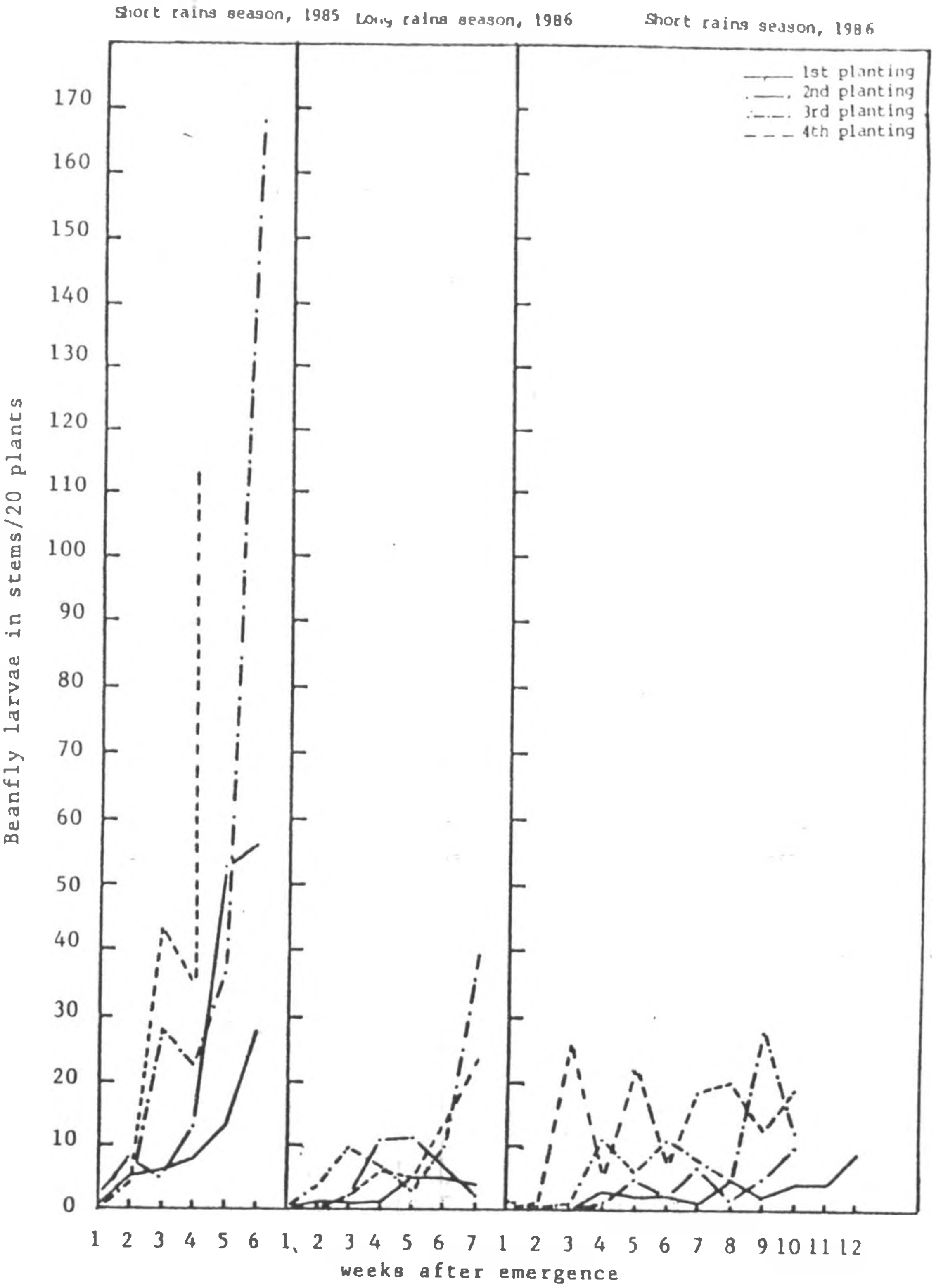

Figure 20. Population fluctuation of beanfly larvae in stems of bean plants grown at different dates in a season.

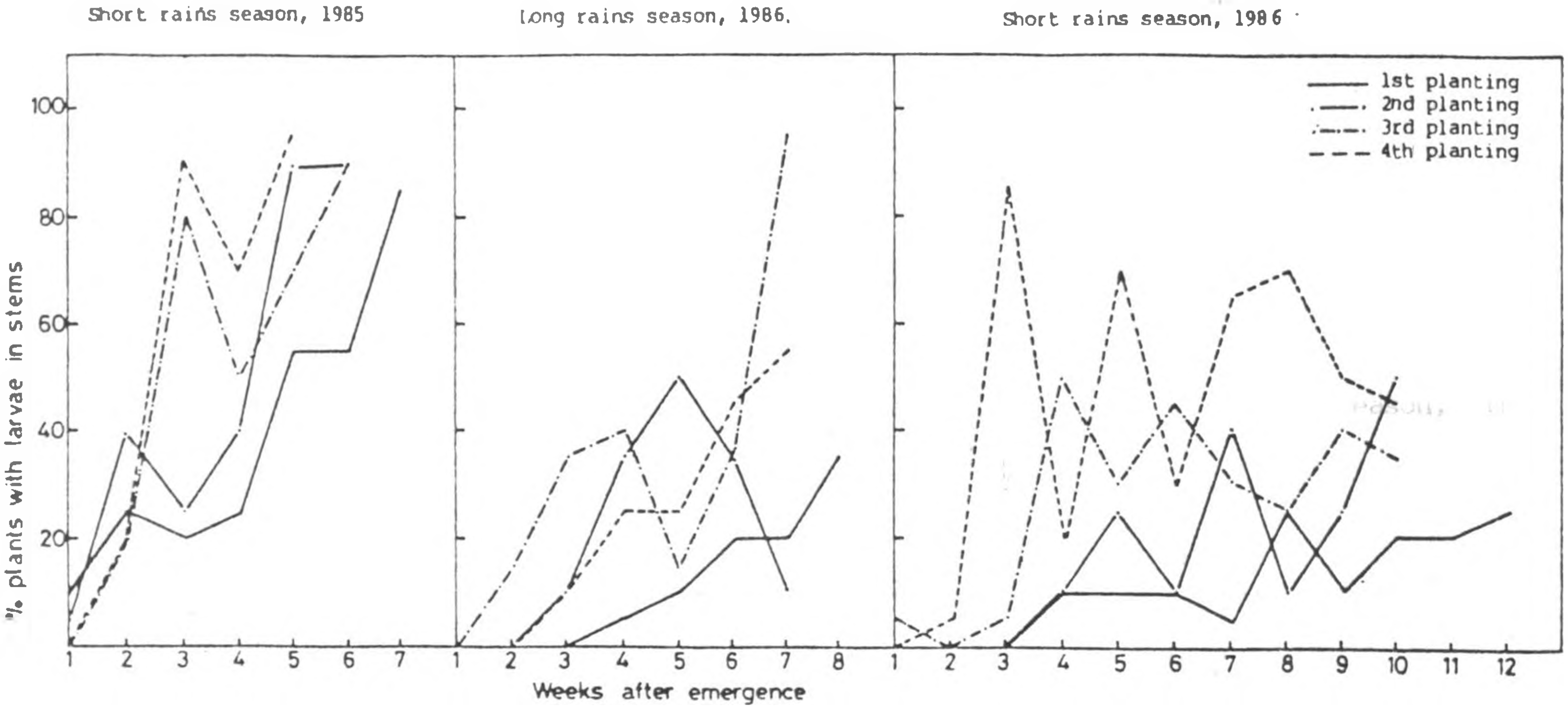

Figure 21. Infestation of stems of bean plants, grown at different dates in a season, with beanfly larvae.

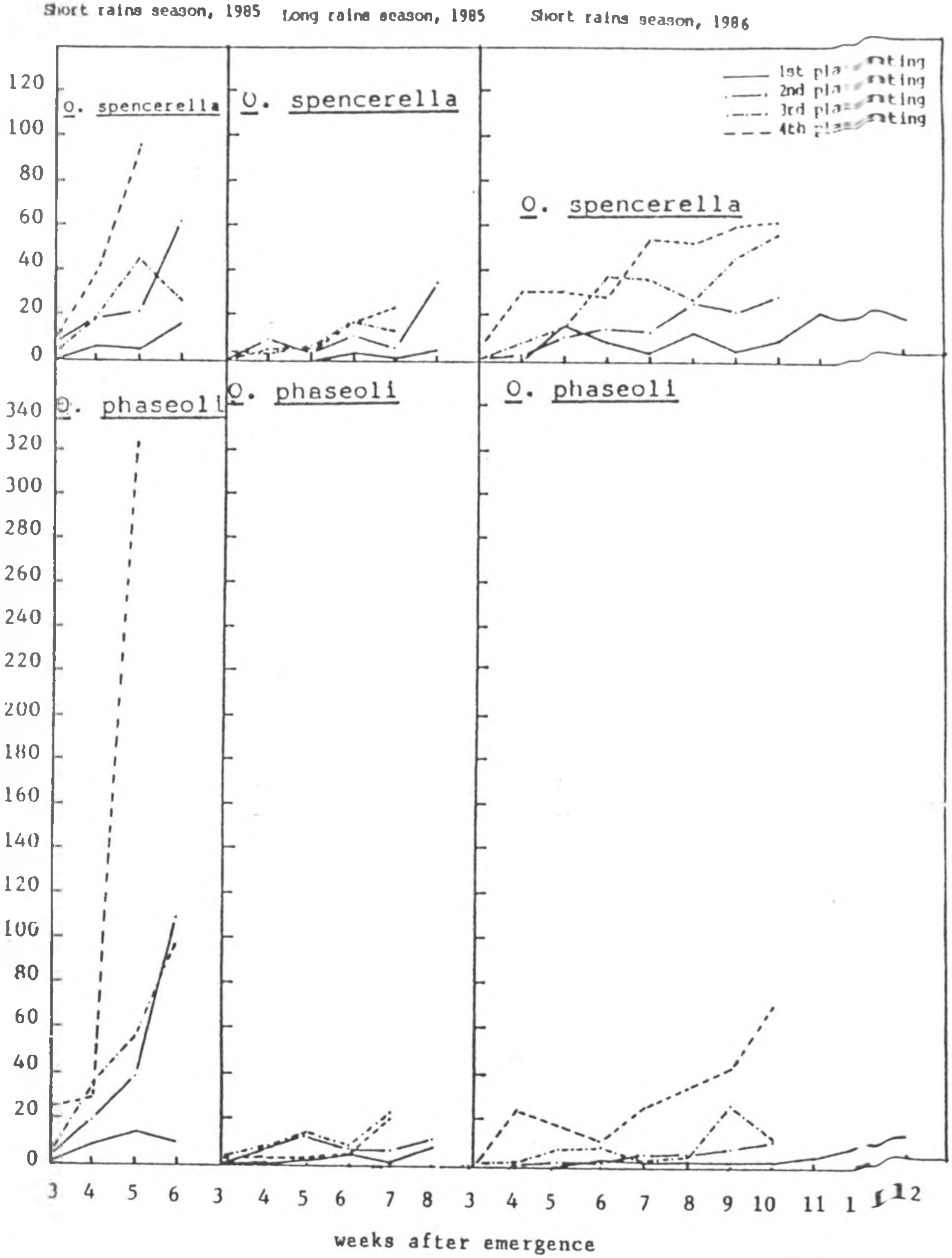

Figure 22. Population fluctuation of beanfly puparia in bean plants grown at different dates in a season.

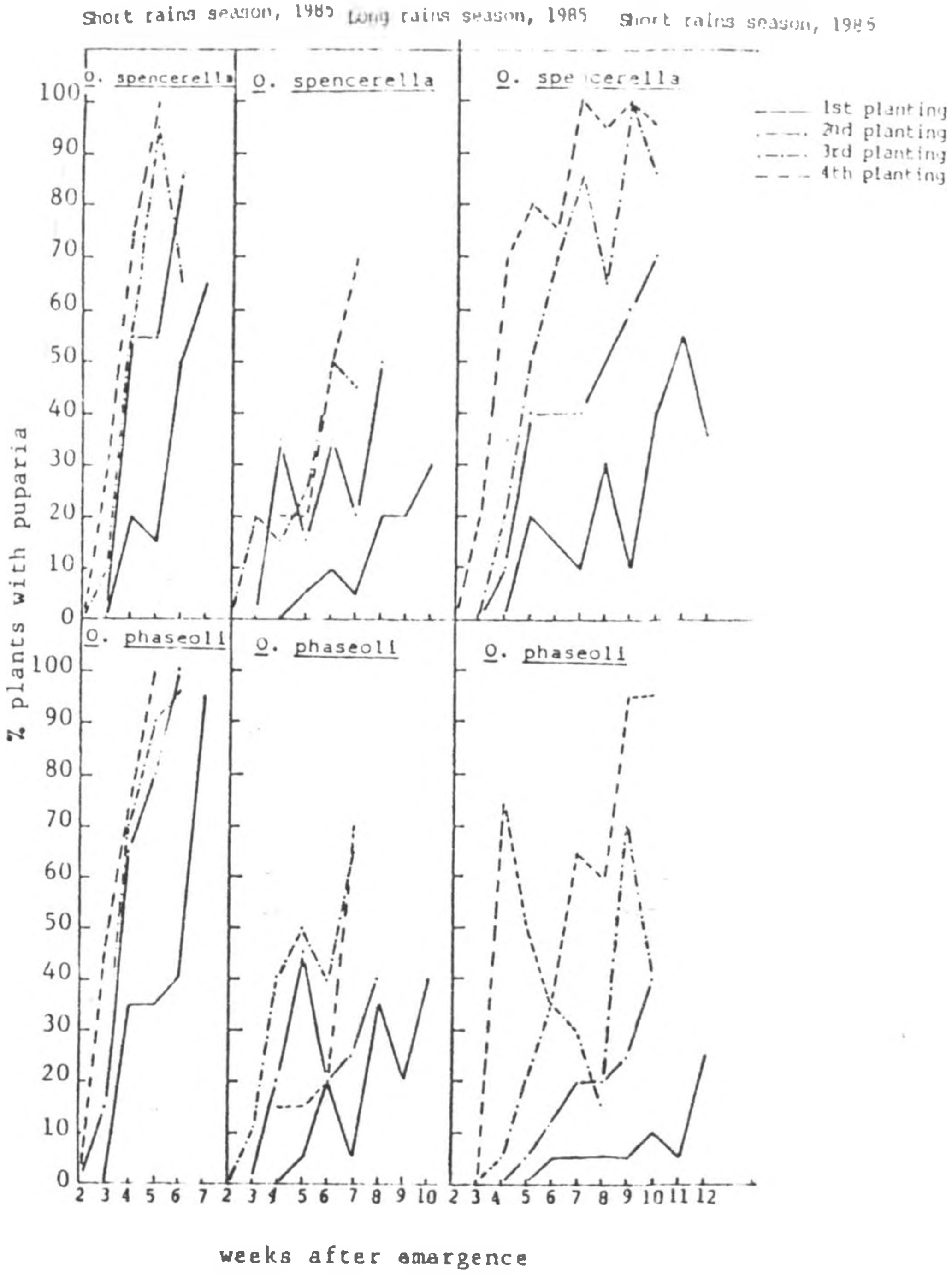

Figure 23. Infestation of bean plants, grown at different dates in a season, with beanfly puparia.

Beanfly infestation in the bean crops of the four planting dates during the cropping seasons were not high enough to cause the death of the bean plants. The attack neverthless had debilitating effect on the bean plants resulting in low pod production and poor seed formation (plate 17) in the late planted crops in the short rains of 1985 and 1986. These debilitating effects were especially true if the attack of *O. phaseoli* occurred late in the season on plants which had grown for over four weeks.

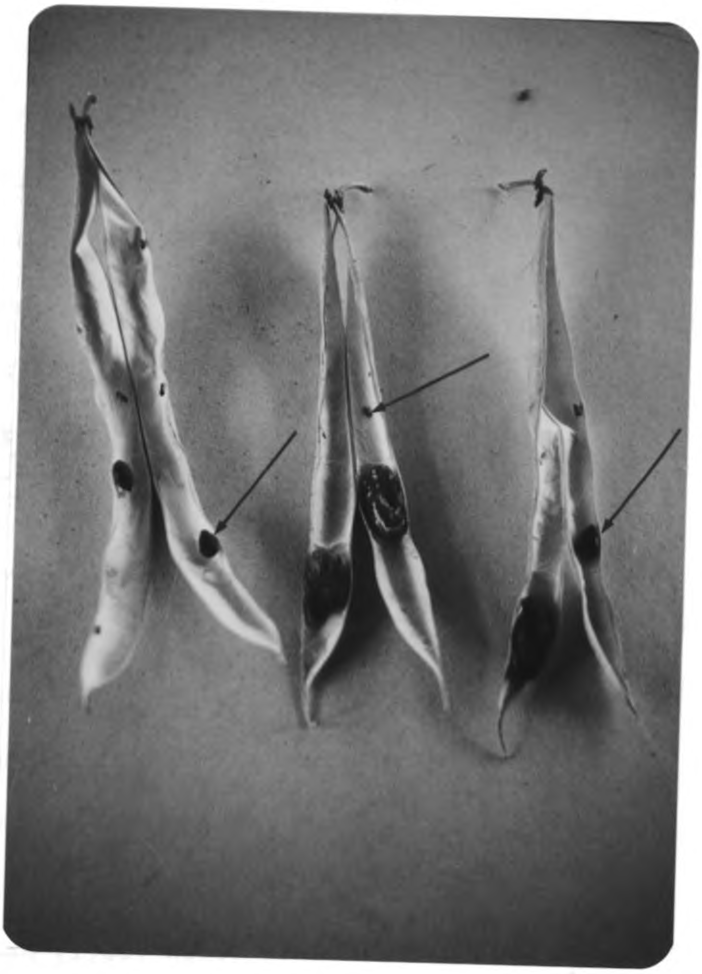

Plate 17. Pods with poor seed formation x 0.8.

4:4. DISCUSSION

Initial adult beanfly population was probably the main factor that influenced the number of leaf punctures on bean plants. Leaf punctures gave a good estimate of the onset of beanfly infestation confirming the findings of Okinda (1979) and Kibata (1980) who assessed infestation by using leaf punctures. But beanfly leaf punctures may overestimate the degree of infestation because not all punctures are used for oviposition. Leaf puncturing continued throughout the season. The rate of puncturing varied from season to season. Accurate estimate of leaf punctures was possible within the first four weeks of beanfly attack when punctures had not dried and coalesced.

Wallace (1939) and Swaine (1969) in Tanzania stated that beanflies laid eggs only in leaf punctures. Walker (1960) in East Africa stated that beanflies laid eggs only in the lower parts of the stems above the surface of the ground. This work showed that beanflies laid eggs in both the leaves and stems of bean plants. Greathead (1968) noted that oviposition in both the stems and leaves was an indication of infestation of bean plants by at least two species of beanflies. He recorded that *O. spencerella* mainly oviposited in the hypocotyle while *O. phaseoli* oviposited in the leaves of the bean plants. The present findings indicate that *O. spencerella* normally oviposited in the leaves, like *O. phaseoli*, but unlike

O. phaseoli, *O. spencerella* also oviposited in the stems of young bean seedlings when rainfall was low and the number of ovipositing adults was very high. Thus *O. spencerella* oviposited in the part of stem above and below the ground when more oviposition sites were in great demand. In some cases there were more eggs in the stems than in the leaves of bean plants, indicating that *O. spencerella* laid more eggs than *O. phaseoli*. Oviposition in the stems of bean plants, mainly concentrated in the seedling stage, was more detrimental than oviposition in the leaves because there was no lag period in attacking the susceptible parts of the bean plants (ie base of stems of bean plants after the eggs hatch). No eggs were found in the stems of bean plants when rainfall was high, although oviposition occurred in the leaves. During the normal rainfall patterns *O. phaseoli* and *O. spencerella* oviposited in the leaves of bean plants throughout the growth of the bean plant.

Larvae which were observed in the leaves were mainly the 1st instars. The larvae in the punctures formed short leaf mines but soon entered a vein and moved to the stem via the petiole. Larvae in the leaf mines and leaf veins were rarely observed. Both 1st instar larvae in the leaves are therefore not a good parameter for estimating the level of beanfly infestation. Second and third instar larvae in the stems were easier to count after dissecting the stems on account of their size. The number of larvae in the stems of bean plants is a good estimate of the absolute population of beanflies in the field. Okinda (1979) counted larvae in the stems of bean plants to estimate the degree of infestation. Larvae of different species of beanfly are not easily differentiated because of their close morphological similarity.

The colour of the puparia can be used to identify the species of beanflies infesting the plants in the field. Walker (1960) in East Africa mentioned that O. phaseoli puparia were dark brown to black while Swaine (1969) observed that they were at first brown but later turned black. Greathead (1968) described puparia of O. phaseoli as yellowish brown with black apices while those of O. spencerella as shining black. Previously these two species in East Africa had been considered as one, namely O. phaseoli. In the present work O. phaseoli and O. spencerella were the species infesting the bean plants in the field. O. centrosematis which had been found in bean plants in Kenya by Greathead (1968) was not found in the bean plants in this study. This observation is in agreement with that of Okinda (1979) and Spencer (1985) who also identified only two species in the bean crop. The presence and number of puparia can be very useful for population and resistance studies because they may be accurately counted and easily identified to species level. The pupae were observed in the bean plants from 3rd- 4th week after plant emergece, the numbers increasing to a certain level as the season progressed. O. spencerella puparia were observed earlier than those of O. phaseoli. This could indicate that O. spencerella initiates attack of bean plants, and therefore oviposits earlier or develops faster than O. phaseoli.

The amount of damage due to beanflies therefore depends upon the species, population intensity, intensity of attack, duration of noncropping period which reduces beanfly population and the weather. However, each species could reach high population levels and do serious damage in any season depending on the initial infestation of the bean plants and the prevailing environmental conditions. Infestation in the beans planted at the onset of the long rains or short rains was not of sufficient level to cause serious debilitating effects or death of the bean plants. The generalization made by Wallace (1941), Swaine (1969), Okinda (1979) and Kibata (1980) in East Africa that beanflies cause serious losses during the short rains season can only be true when there is very little rain at beginning of the season and that a short noncropping season prior to the short rains allowing high initial beanfly infestation. Otherwise the initial O. spencerella attack may not be high enough to cause death of the bean plants and the subsequent O. phaseoli infestation may not be high enough to cause reductions in yield. Death of bean seedlings due to O. spencerella was observed when beans were sown just before the harvest of the previous crop, a period which was outside the rainfall pattern of the area and no closed season. It did not matter whether the bean plants received a lot of water through irrigation during the growing period. In this situation, initial attack by O. spencerella was high enough to cause the death of the bean seedlings. Those beans which recovered from O. spencerella attack grew vigorously probably because of less competition for space and nutrients in the ground. Infestation by

O. phaseoli increased mainly later in the seasons. The nature of attack of O. phaseoli in old plants led to poor pod and seed formation.

In each season the level of leaf punctures; eggs; larvae; puparia and percent infested plants were greater in late planted than early planted crops. This finding is in agreement with that of Wallace (1941) and Okinda (1979) who found that early planted beans were less infested with beanflies than late planted ones. Damaging populations were not attained by planting the bean materials on a weekly basis for four weeks after the commencement of rains in a cropping season. However, such populations were obtained from the middle or late part of the cropping seasons.

CHAPTER 5

5. EVALUATION OF BEAN CULTIVARS FOR RESISTANCE/SUSCEPTIBILITY TO BEANFLIES IN SINGLE PLANTINGS AT DIFFERENT SEASONS

5.1. INTRODUCTION.

Agromyzid beanflies cause heavy losses to beans in many tropical and temperate regions. They are the major pests of beans in Kenya and other East African countries. Current control measures involve seed treatment or foliar sprays using insecticides. However, the cheapest and most environmentally acceptable control measure would be the use of resistant cultivars. There are no bean cultivars which have been bred for resistance to beanflies. Studies have been done in Tanzania (Karel, 1984; Maerere and Karel, 1984; Msangi and Karel, 1984; Mushebezy and Karel, 1985; Taiwan (Talekar, 1980) and Australia (Rogers, 1979) to evaluate cultivars for resistance to beanflies. These have indicated that some bean materials were resistant to beanflies. Little attempt has been made in Kenya to evaluate the local bean cultivars for resistance to beanflies (Mueke, 1979b).

In the present study local improved bean cultivars were evaluated for resistance to beanflies. The indices of resistance were:- number of leaf punctures; eggs; larvae; puparia; percent infested plants and percent dead plants. The study was done in different seasons to determine the performance of the bean cultivars under different weather and different population pressures in the field.

5:2.MATERIALS AND METHODS.

Seven common bean cultivars namely, Glp 2, Glp 24, Glp x- 92, Glp x-1127(a), Glp 585, Glp 1004 and Mexican 142 were used in the experiments. They were grown in small plots in complete randomized block design at the National Agricultural Laboratories, Nairobi and Kabete Campus Field station, Nairobi. Plot sizes were 5m.x 5m., with an inter-row spacing of 50cm. and within-row spacing of 10cm. A path of one metre was left between plots and between blocks. Each bean cultivar was replicated four times over the plots.

The bean seedlings were subjected to natural agromyzid beaflies infestation. Sampling was done at weekly intervals during the growing period of the crop. From the 11 rows per plot, one plant was randomly sampled per each row. The eleven sampled plants per plot were placed in polythene bags and taken to the laboratory. The number of punctures in the leaves were counted. Punctures and leaf mines were dissected and the eggs and 1st instar larvae in the punctures and 1st instar larvae in leaf mines were counted. The stems of plants were also dissected and the eggs, larvae and puparia were counted. The number of dead plants due to beanfly attack per each plot was recorded. The yield from 22 bean plants per plot were also recorded. The experiments were repeated for four seasons:- the short rains of 1984 (November - February); Long rains of 1985 (March - June); off-season of 1985 (July - October) and the short rains of 1985 (November - February).

5:3.RESULTS.

There were significant differences among the bean cultivars in leaf punctures during three seasons at Kabete Campus, Nairobi (Figs. 24, 25, and 26). Number of punctures in the bean cultivars were significantly different during the short rains of 1984 (Fig. 24) and statistically similar in other seasons at NAL, Nairobi (Figs. 25, 26 and 27). While Mexican 142 and Glp x-92 showed the highest seasonal mean number of punctures, other bean cultivars showed no consistent differences amongst them during the short rains of 1984 and 1985. In other seasons there was no bean cultivar which could be identified consistently with high or low numbers of leaf punctures. Among the bean cultivars the percentage plants with leaf punctures varied from significant to no significant differences in the three seasons at the two localities (Table 4). The cultivars could not be consistently ranked in terms of percentage plants with leaf punctures.

In most seasons there were no signifant differences among the cultivars in seasonal number of eggs in the leaves at the two sites (Figs. 28, 29, 30 and 31) and the cultivars could not be consistently ranked. In most seasons at the two sites there were no significant differences among the bean cultivars in percentage bean plants with eggs in the leaves (Table 5) and the bean cultivars were not consistently ranked. Beanfly eggs were found in the stems of young bean seedlings only during off-season of 1985 at both localities (Fig.32) Although the mean seasonal number of eggs in

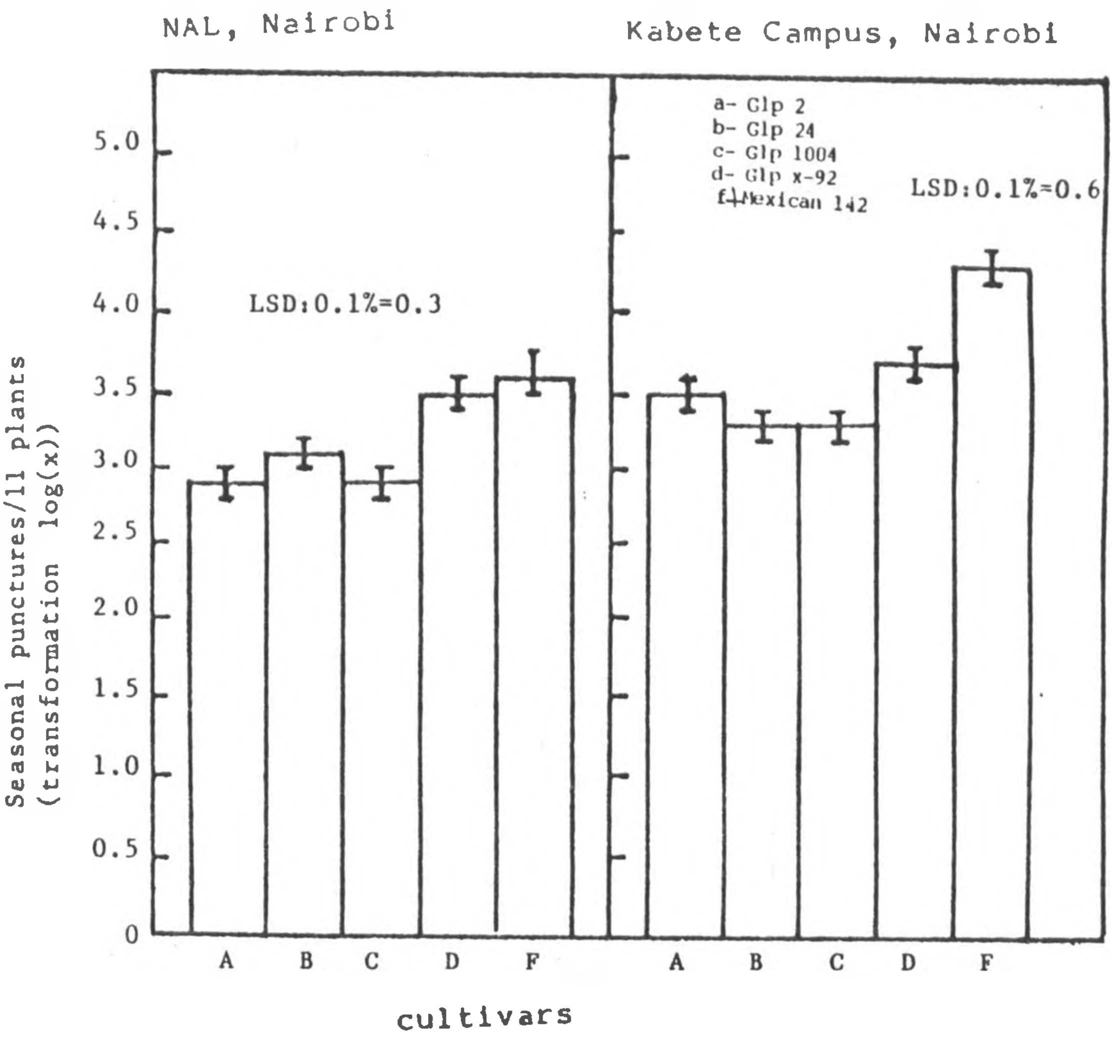

Figure 24. Beanfly punctures in leaves of bean cultivars grown during short rains of 1984 at two sites.

grown during long rains of 1985 at two sites.

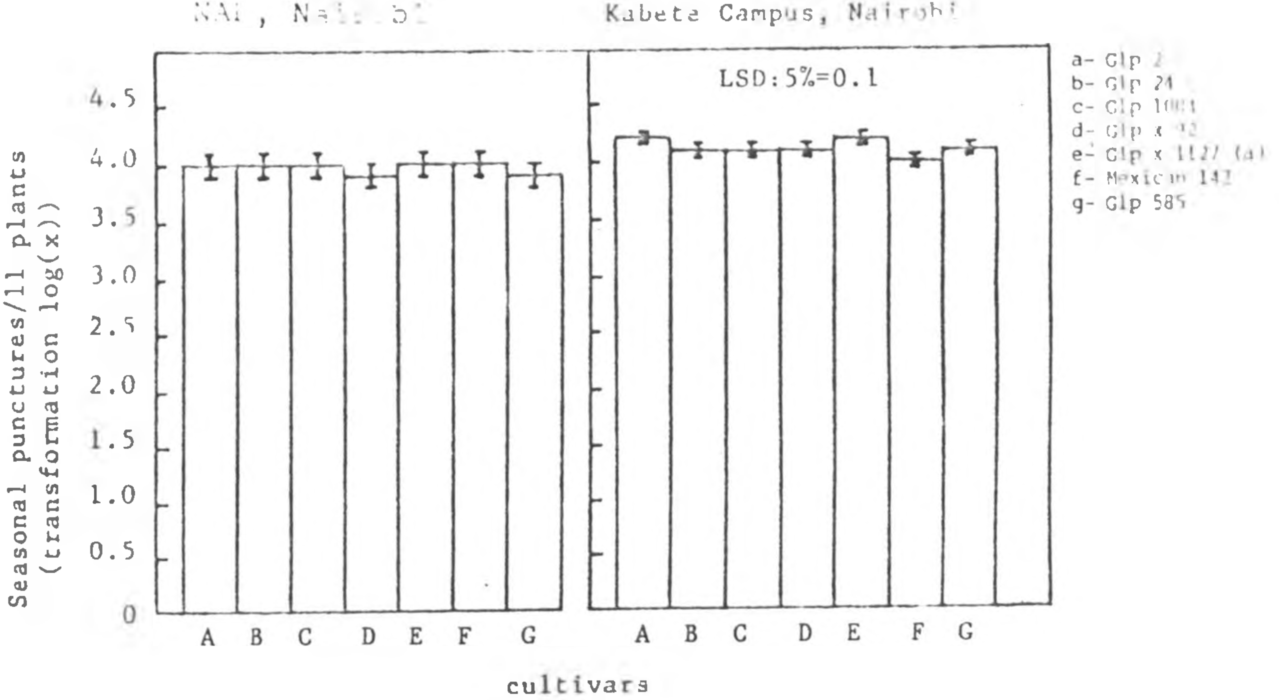

Figure 26. Beanfly punctures in leaves of bean cultivars grown during off-season of 1985 at two sites.

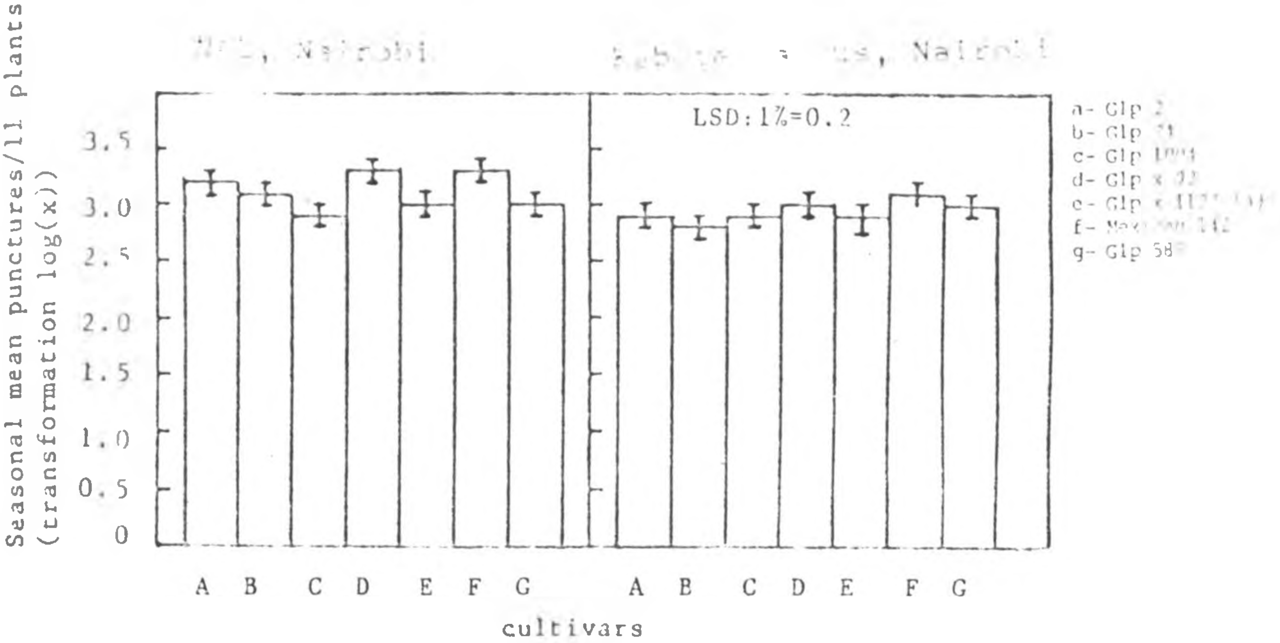

Figure 5. Beanfly punctures in leaves of bean cultivars

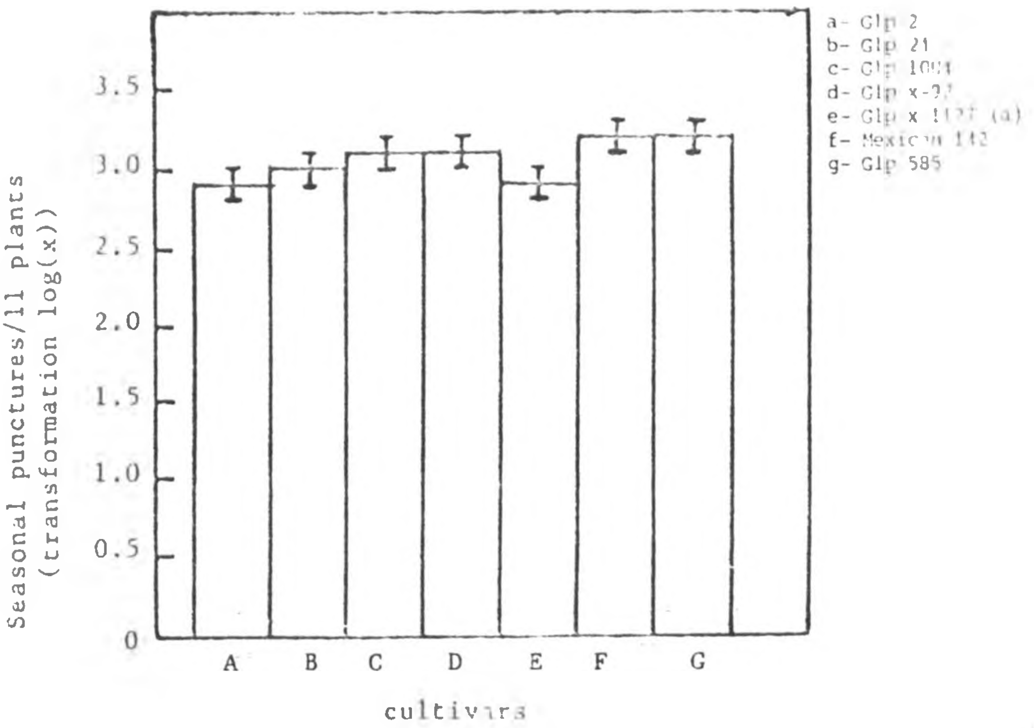

Figure 27. Beanfly punctures in leaves of bean cultivars grown during short rains of 1985 at NAL, Nairobi

Table 4. Percentage bean plants with beanfly leaf punctures during the long and short rains of 1985 and off-season of 1985 at two sites.

	long rains of 1985		off-season of 1985		short rains of 1985
Cultivars	NA1	Kabete	NA1	Kabete	NA1
Glp 2	57.4b	60b	100	100	54.5bc
Glp 24	56.6b	58.4b	100	100	60.4b
Glp 1004	58.6ab	54.8b	100	100	59.6ab
Glp x-92	62.1ab	58.3b	100	100	55.0abc
Glp x-1127(a)	57.1b	60.6b	100	100	57.0abc
Mexican 142	68.2a	73.7a	100	100	52.4c
Glp 585	60.4ab	61.3b	100	100	56.9abc
Statistical analysis:					
F value	2.001	5.19**			2.778**
C V (%)	9.6	8.6			6.0
S E	2.9	2.6			1.7
lsd 5%:		7.8			5.1
1%:		10.7			

Statistical analysis is on transformed values Arcsin $\sqrt{X}$

Means in each column followed by the same letter are not significantly different 5% based on Duncan's Multiple range test.

** $P< 0.01$

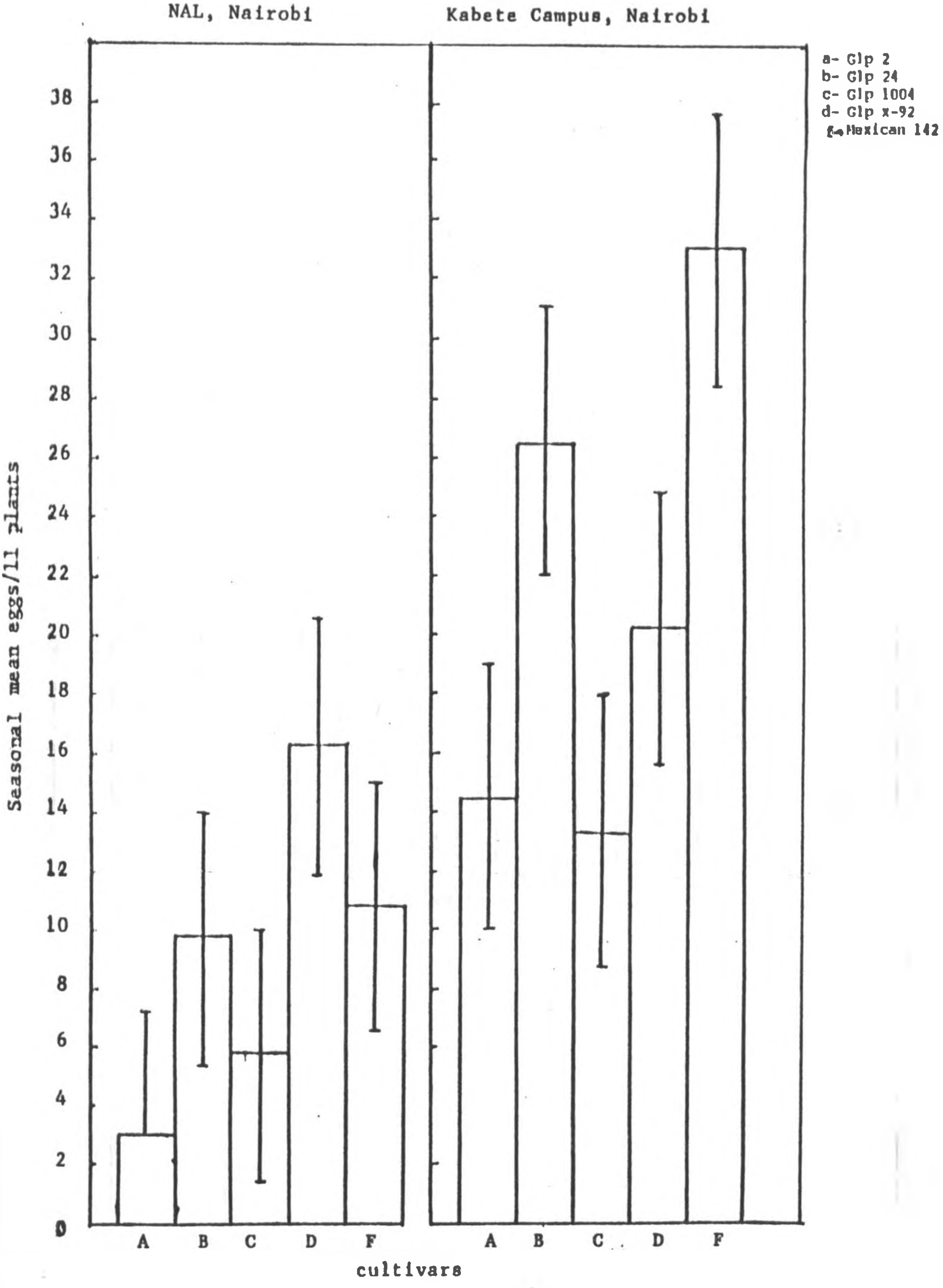

Figure 28. Beanfly oviposition in leaves of bean cultivars grown during short rains of 1984 at two sites.

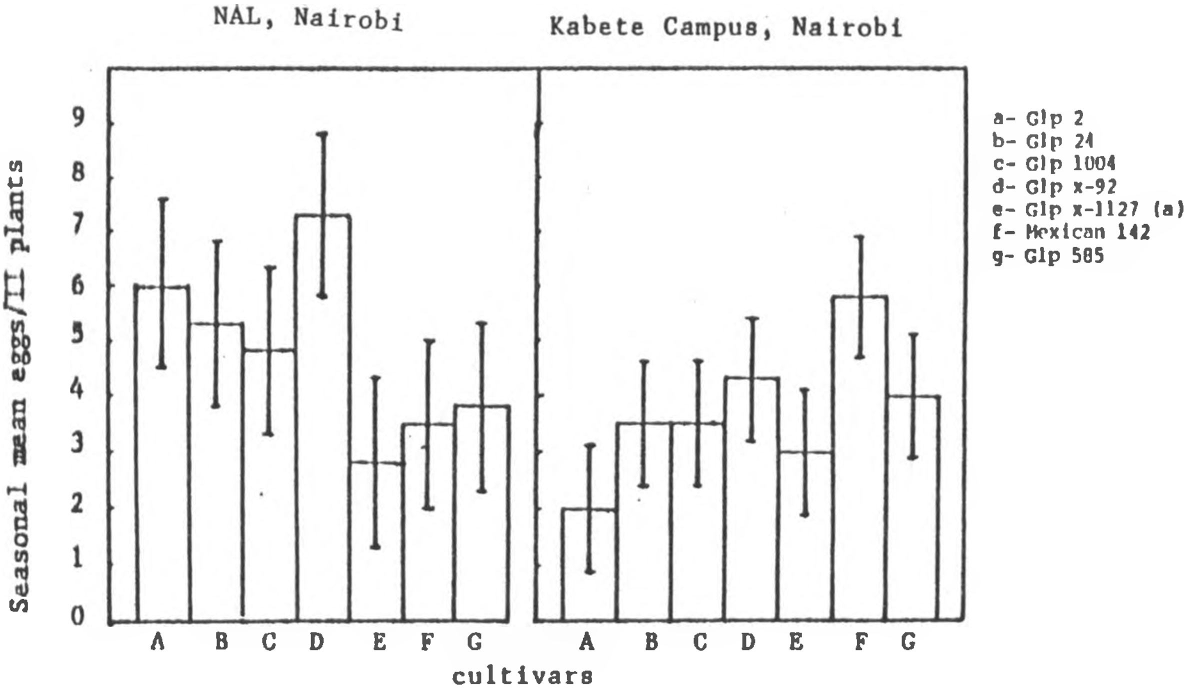

Figure 29. Beanfly oviposition in leaves of bean cultivars grown during long rains of 1985 at two sites

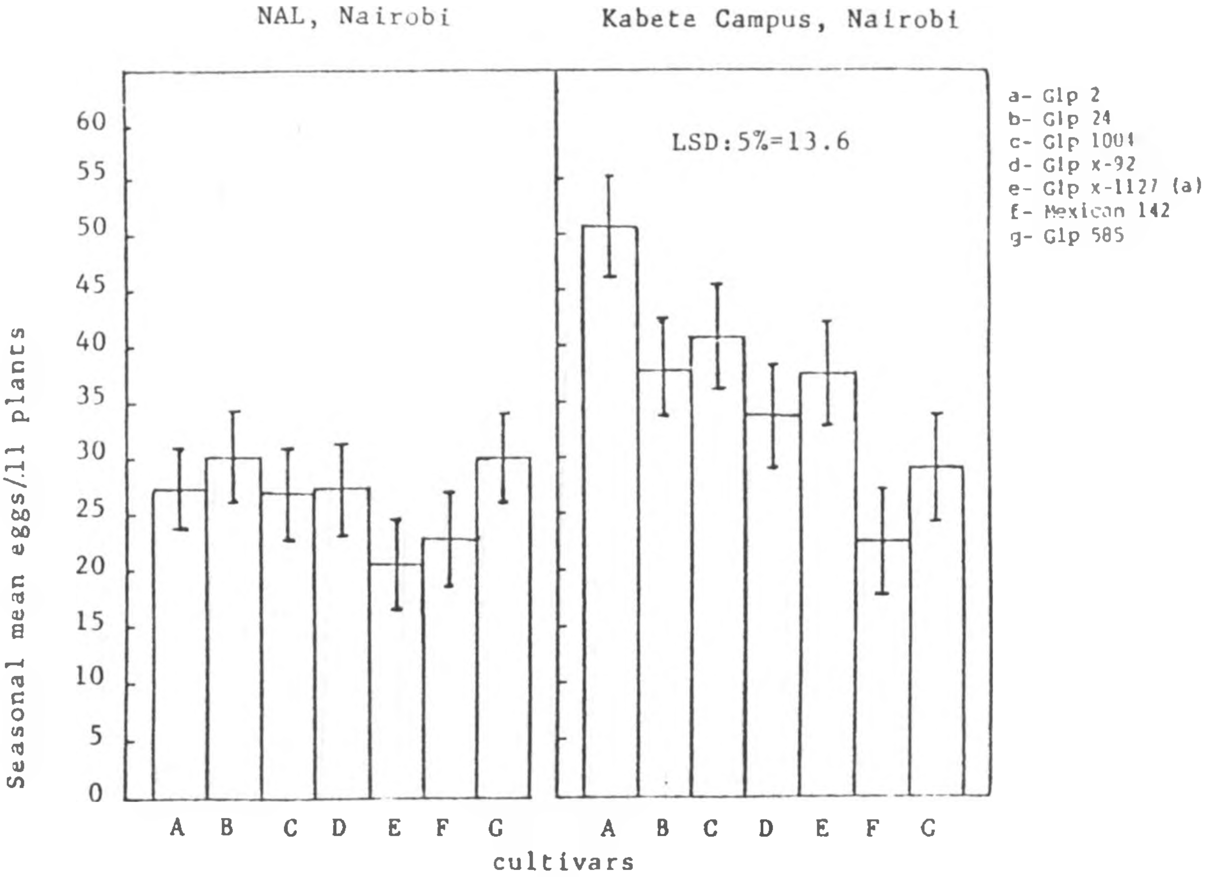

Figure 30. Beanfly oviposition in leaves of bean cultivars grown during off-season of 1985 at two sites.

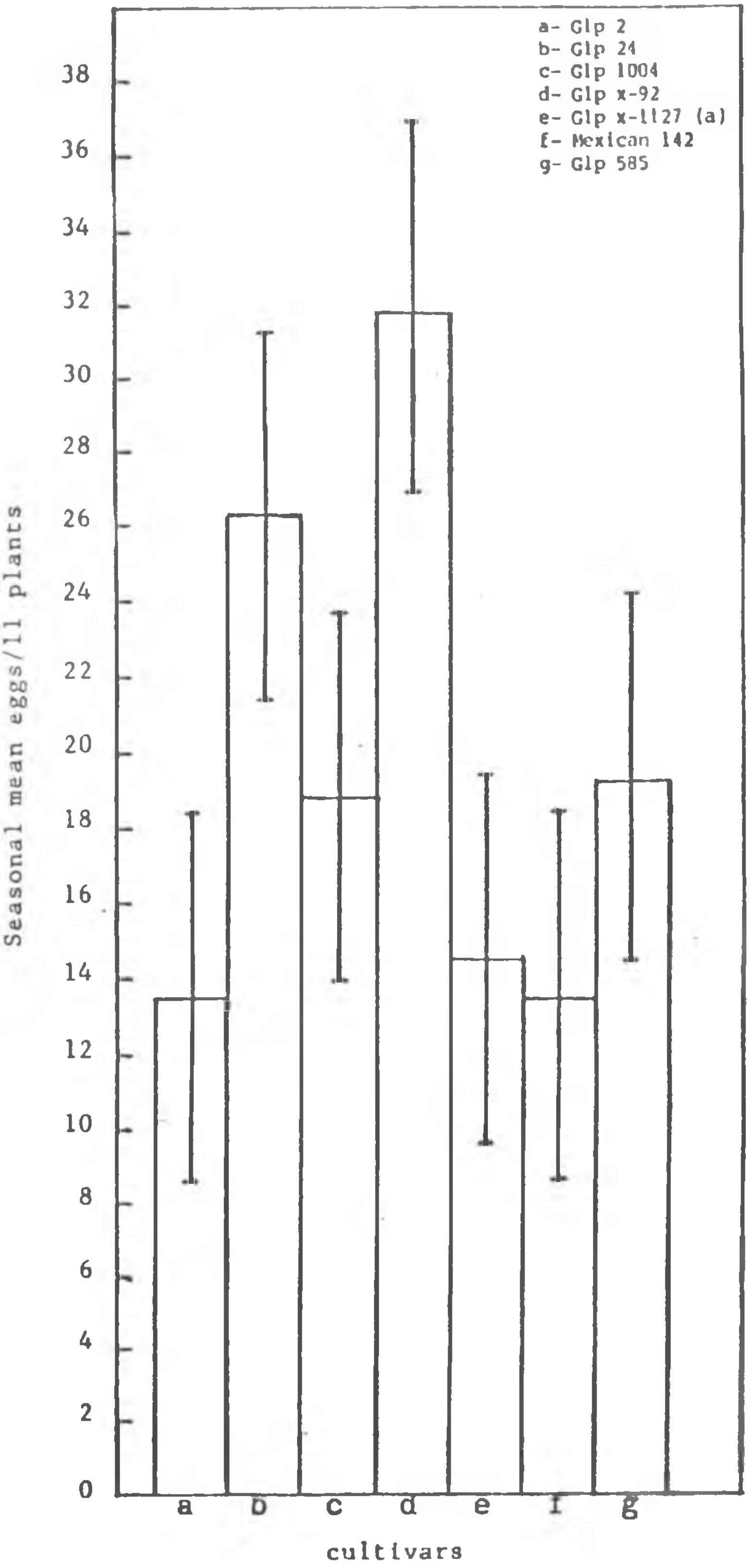

Figure 31. Beanfly oviposition in leaves of bean cultivars grown during short rains of 1985 at NAL, Nairobi.

Table 5. Percentage bean plants with beanfly eggs in the leaves during the long rains, off-season and short rains of 1985 at two sites.

	long rains of 1985		off-season of 1985		short rains of 1985
Cultivars	NA1	Kabete	NA1	Kabete	NA1
Glp 2	11.5a	6.2a	36.2ab	39.8a	19.9a
Glp 24	11.4a	8.1a	39.0a	34.6ab	26.4a
Glp 1004	9.5a	8.0a	39.0a	37.1ab	22.3a
Glp x-92	11.0a	8.5a	39.4a	34.6ab	25.3a
Glpx-1127(a)	8.6a	10.1a	29.9b	36.2ab	24.0a
Mexican 142	8.6a	11.4a	34.3ab	27.5c	21.5a
Glp 585	10.5a	10.1a	37.1ab	33.1b	23.9a
Statistical analysis:					
F value	0.739	1.001	1.562	5.249**	1.16
C V (%)	28.5	38.9	15.0	9.6	17.8
S E	1.4	1.7	2.7	1.7	2.1
LSD: 5%				5.0	
1%				6.8	

Statistical analysis is on transformed values Arcsin $\sqrt{X}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

$^{**}P < 0.01$

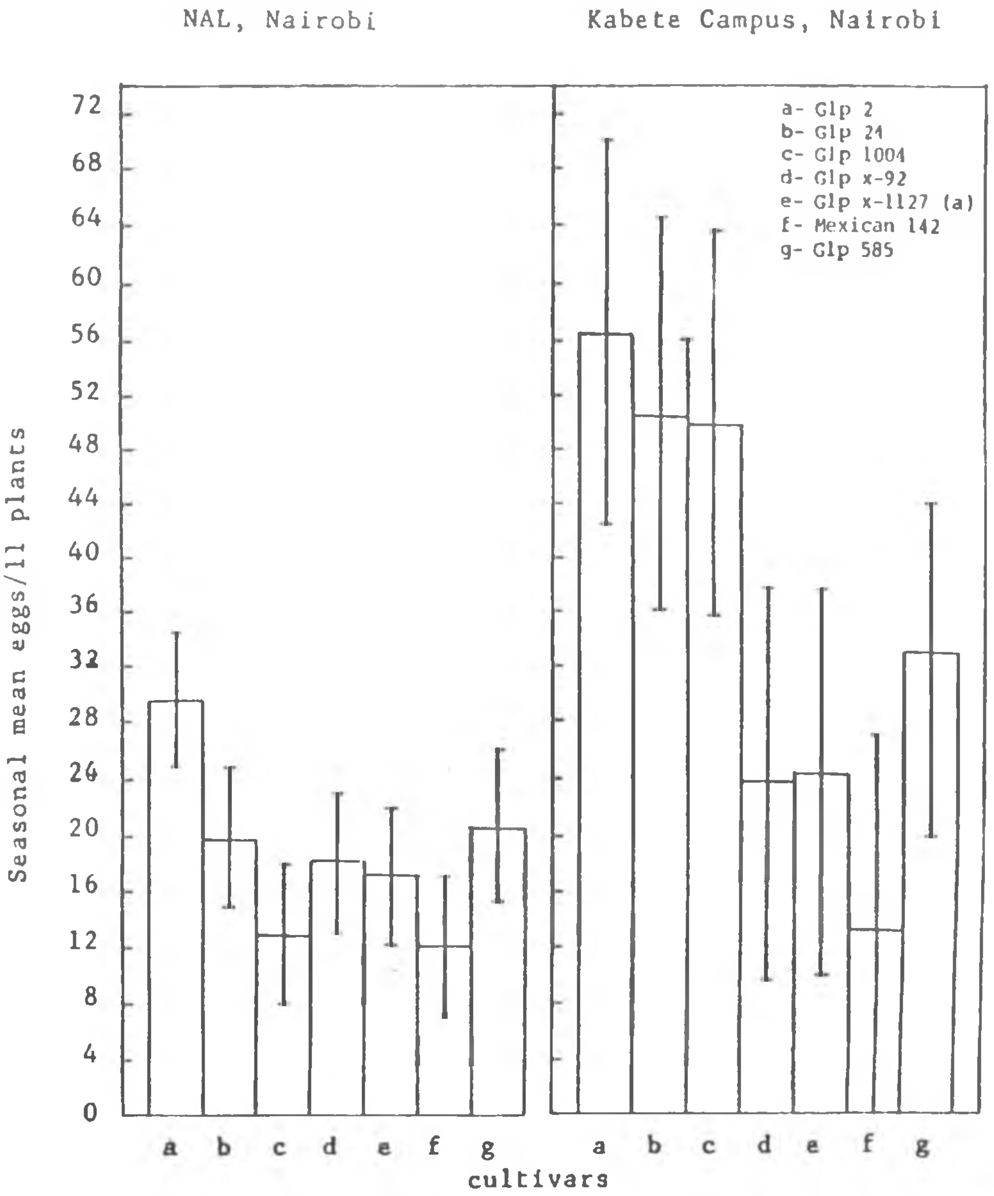

Figure 32. Beanfly ovipostion in stems of bean cultivars grown during off-season of 1985 at two sites.

the stems of bean cultivars were statistically identical, numerically Glp 2 had the highest while Mexican 142 had the lowest number of eggs. There were more eggs in the stems than in the leaves in all the cultivars during this season. There were significant differences among the bean cultivars in percentage plants with eggs in stems at Kabete Campus, Nairobi (Table 6) with Glp 2 having the highest while Mexican 142 the lowest infested plants.

The seasonal mean number of larvae in the leaves of bean cultivars were statistically different during the short rains of 1984 (Fig. 33) but these differences were not observed at both sites (Figs. 34, 35 and 36). Using the number of larvae in the leaves, the ranking of any single cultivar was not consistent from season to season at the two sites. There were no significant differences among cultivars in the number of plants infested with larvae in the leaves during the three seasons at the two sites (Table 7).

The seasonal mean number of larvae in the stems of bean cultivars were significantly different during the long rains of 1985 at the two sites (Fig. 37) and during the off-season of 1985 at Kabete Campus, Nairobi (Fig.38). They were statistically similar during the other seasons at the two sites (Figs. 39 and 40). In all these seasons when statistical differences in the number of larvae in stems of bean cultivars were shown, Glp 2 had consistently high while Mexican 142 had consistently low numbers of larvae. There were significant differences among the bean cultivars in percentage

Table 6. Percentage bean plants with beanfly eggs in the stems during off-season of 1985 at two sites.

Cultivars	NAl, Nairobi	Kabete, Nairobi
Glp 2	41.9a	46.3a
Glp 24	33.6ab	45.0a
Glp 1004	32.9ab	40.4a
Glp x-92	30.3b	39.0a
Glp x-1127(a)	30.6b	40.3a
Mexican 142	28.9b	31.0b
Glp 585	31.7b	43.0a
Statistical analysis		
F value	1.653	3.499*
C V (%)	20.3	13.3
S E	3.3	2.7
LSD: 5%		8.0

Statistical analysis is on transformed values Arcsin $\sqrt{X}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

* $p < 0.5$

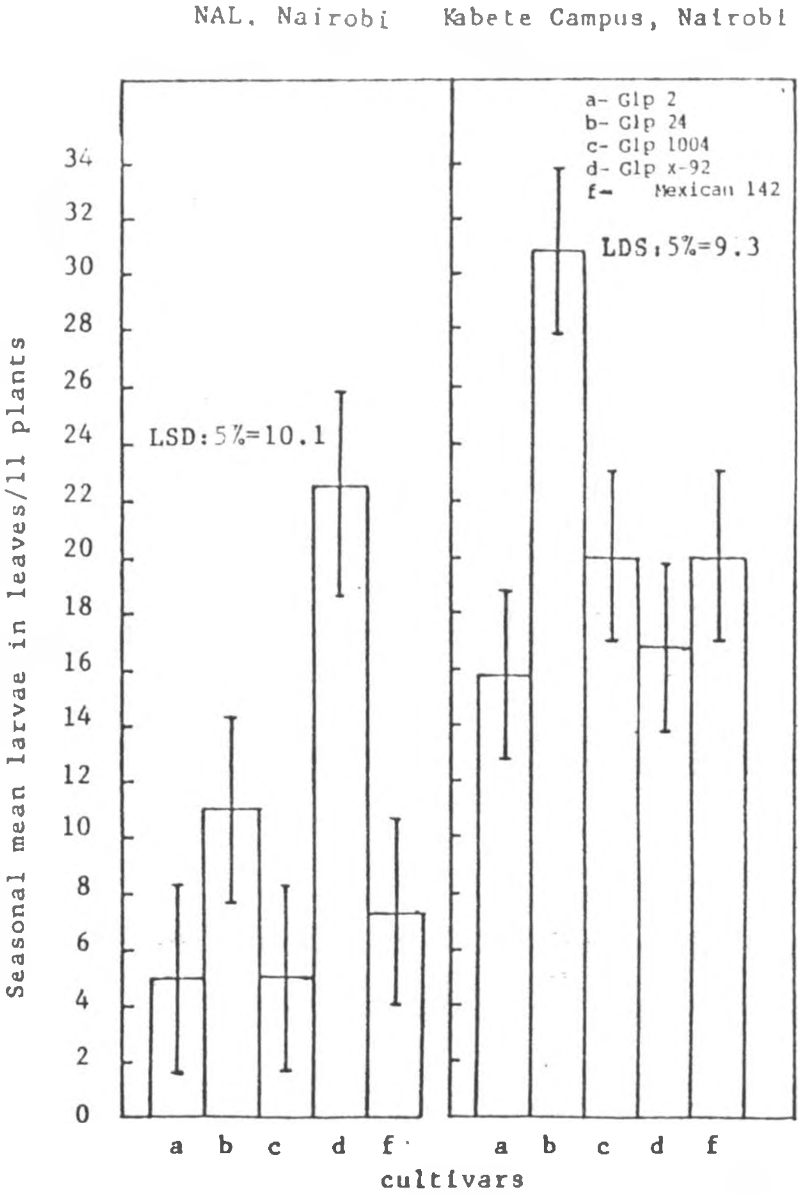

Figure 33. Beanfly larvae in leaves of bean cultivars grown during short rains of 1984 at two sites.

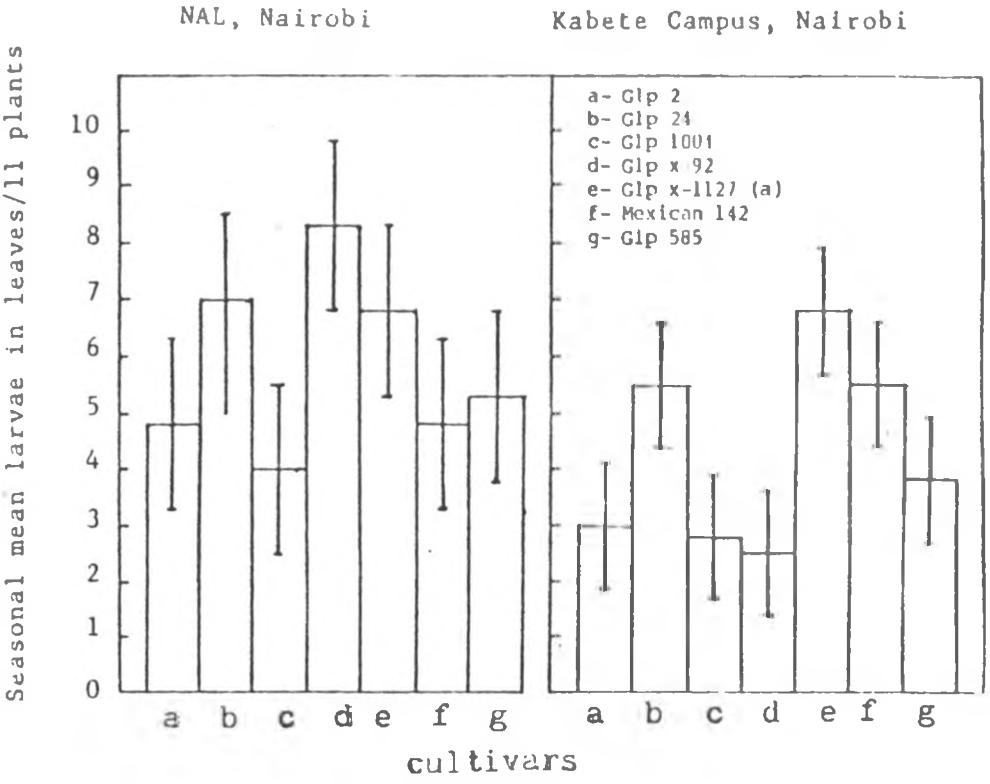

Figure 34. Beanfly larvae in leaves of bean cultivars grown during the long rains of 1985 at two sites.

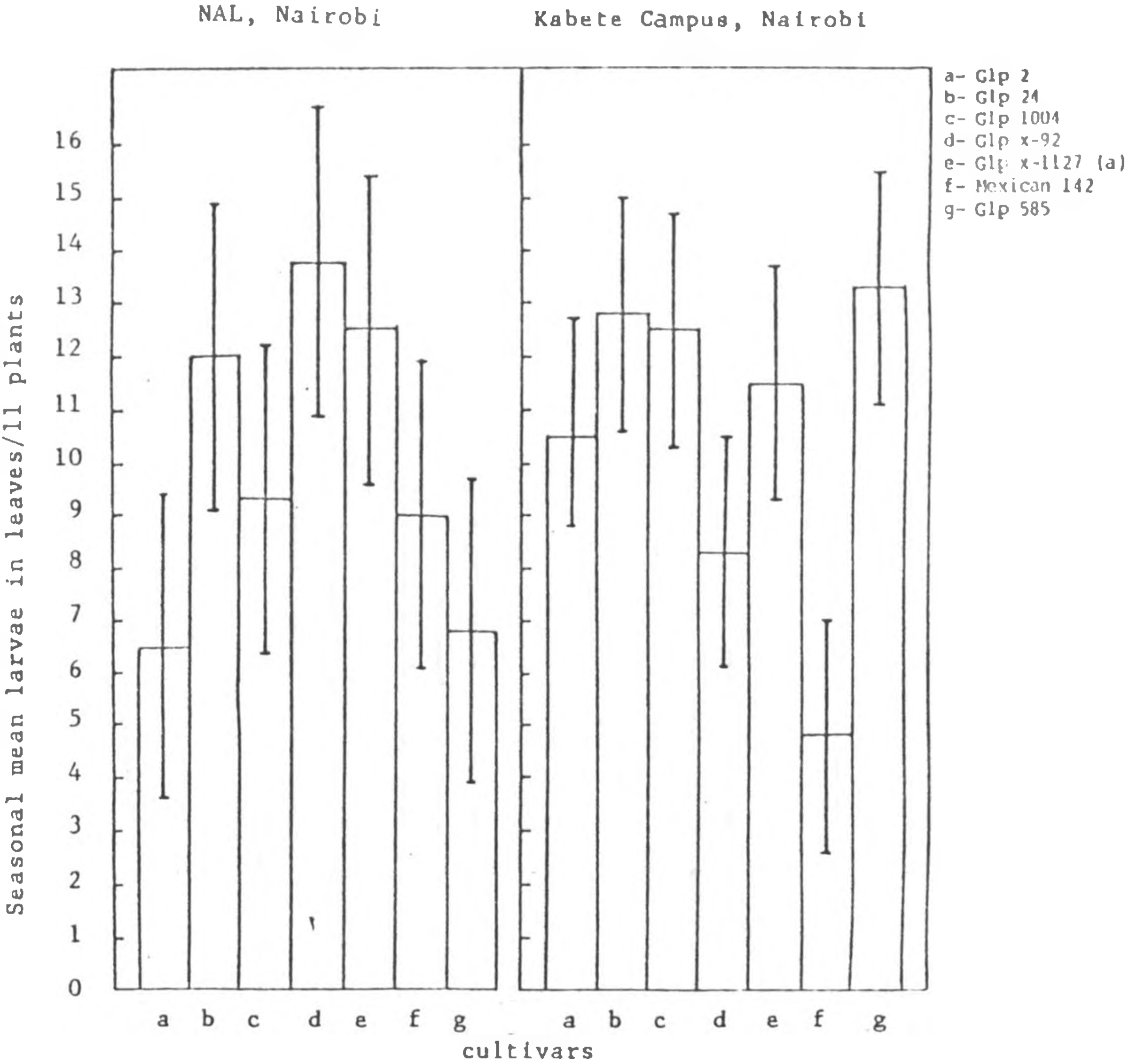

Figure 35. Beanfly larvae in leaves of bean cultivars grown during off-season of 1985 at two sites.

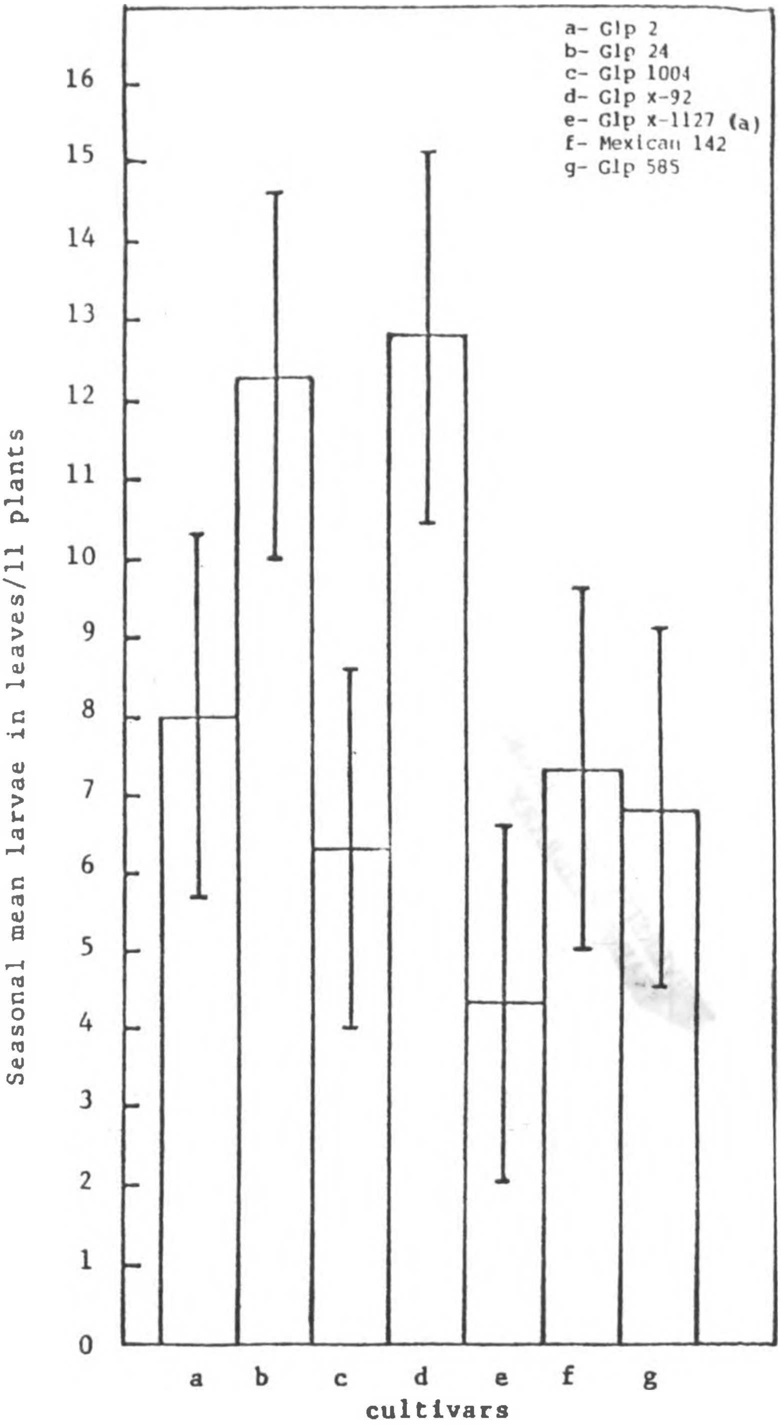

Figure 36. Beanfly larvae in leaves of bean cultivars grown during short rains of 1985 at NAL, Nairobi.

Table 7. Percentage bean plants with beanfly larvae in the leaves during the long rains, off-season and short rains of 1985 at two sites

	long rains of 1985		off-season of 1985		short rains of 1985
Cultivars	NAl	Kabete	NAl	Kabete	NAl
Glp 2	11.4b	8.0ab	19.7b	21.5ab	18.1ab
Glp 24	11.4a	10.7ab	23.5a	23.1a	20.1a
Glp 1004	10.1a	7.9ab	23.6a	21.6ab	14.6ab
Glp x-92	13.9a	6.4b	25.2a	18.2ab	17.8ab
Glp x-1127(a)	10.7a	13.8a	25.7a	21.1ab	13.3b
Mexican 142	9.4a	11.4ab	18.9a	15.8b	15.7ab
Glp 585	11.7a	10.0ab	19.2a	19.1ab	16.3ab
Statistical analysis					
F value	0.934	1.713	1.589	1.504	1.399
C V (%)	26.4	39.1	20.9	20.4	23.5
S E	1.5	1.9	2.3	2.0	1.9

Statistical anslysis is on transformed values Arcsin $\sqrt{X}$

Means in each column followed by the same letter are not significantly differen at 5% based on Duncan's multiple range test.

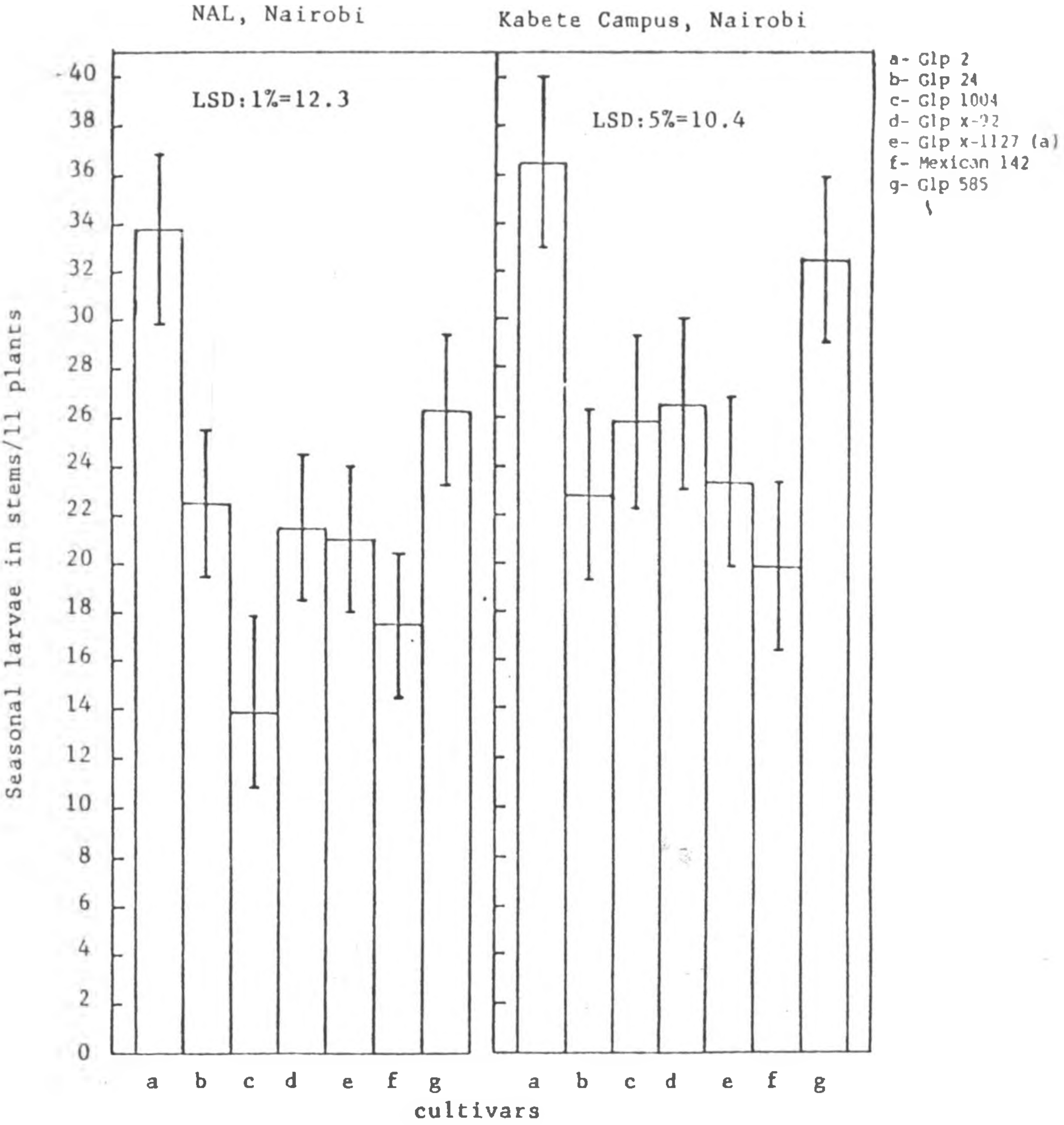

Figure 37. Beanfly larvae in stems of bean cultivars grown during long rains of 1985 at two sites.

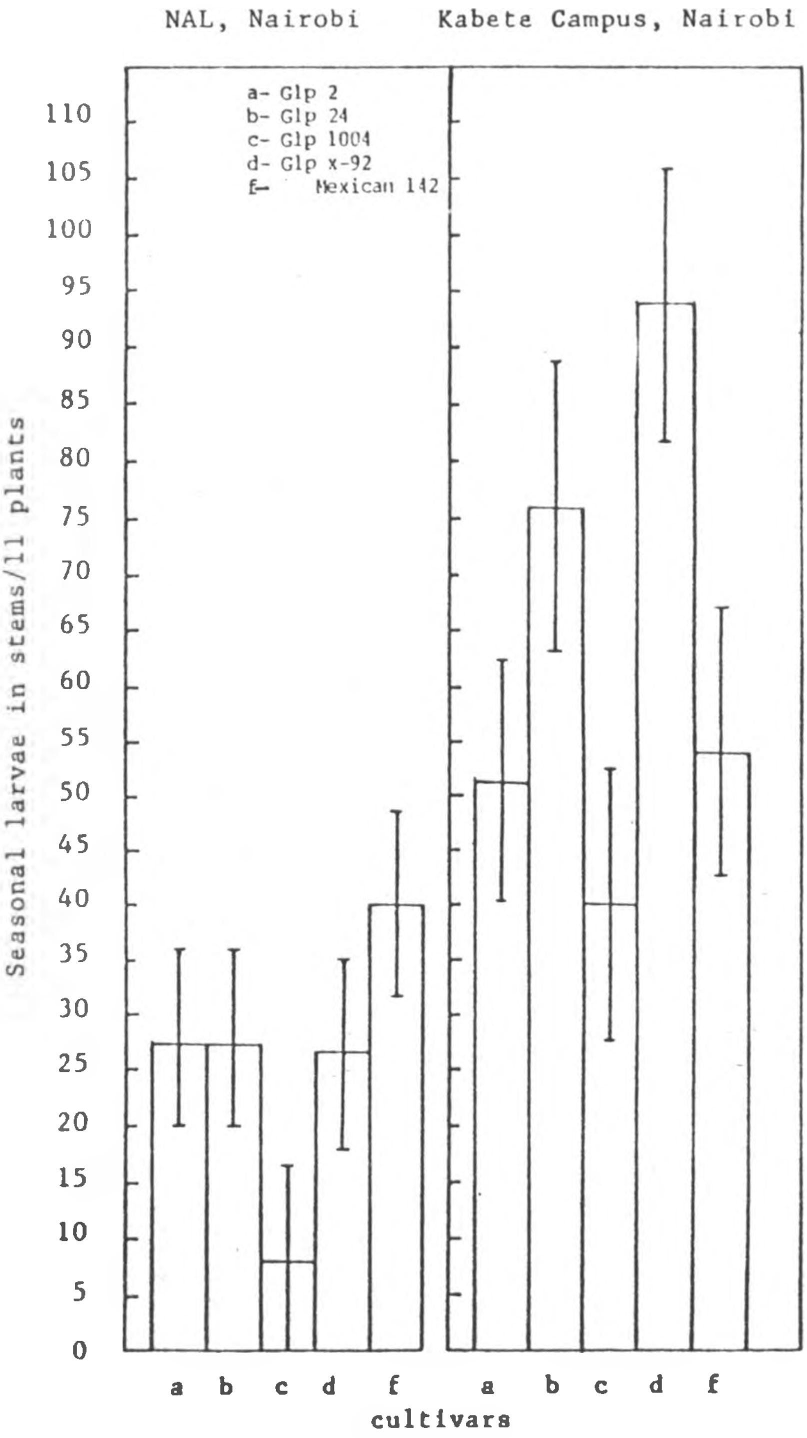

Figure 38. Beanfly larvae in stems of bean cultivars grown during short rains of 1984 at two sites.

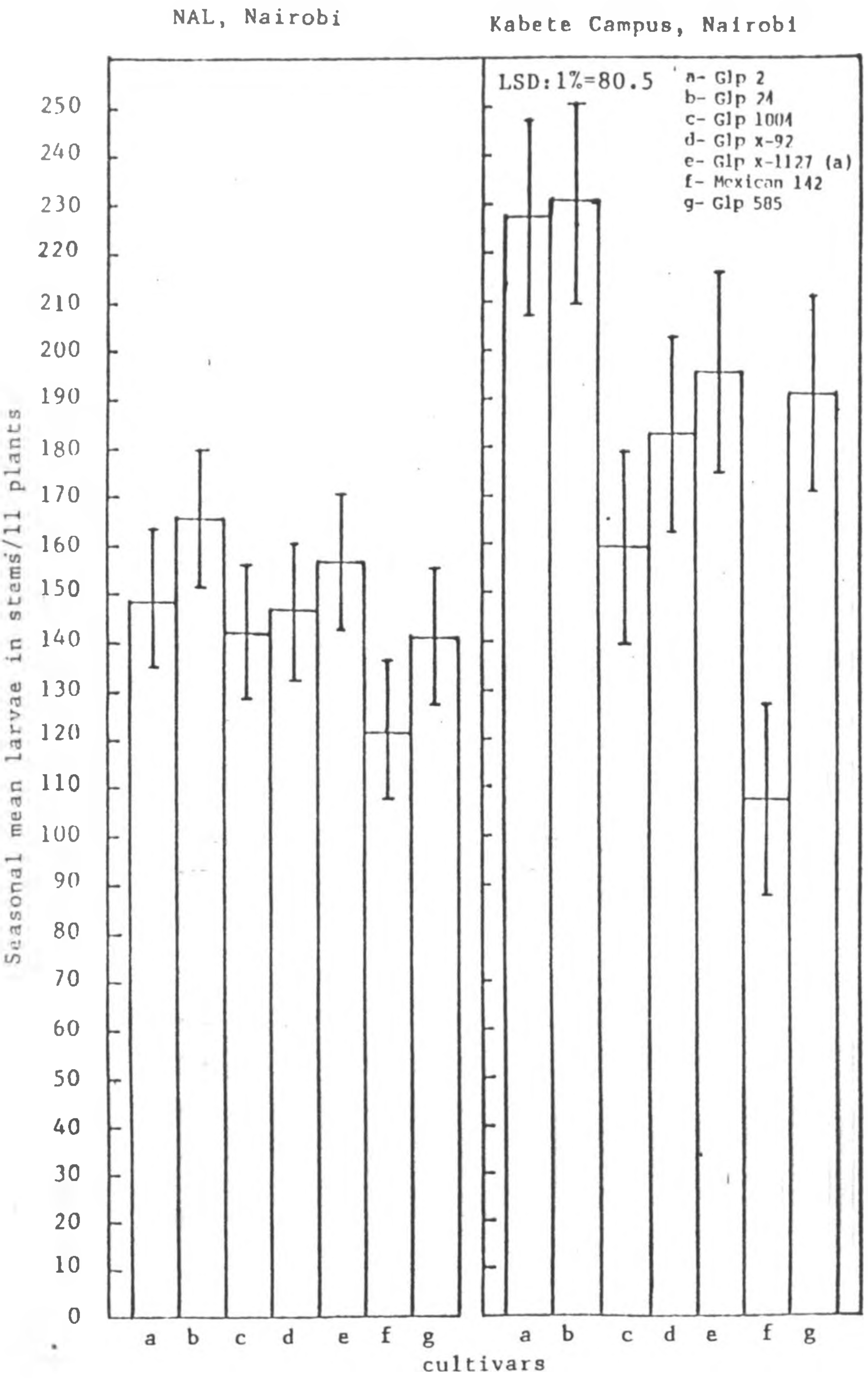

Figure 39. Beanfly larvae in stems of bean cultivars grown during off-season of 1985 at two sites.

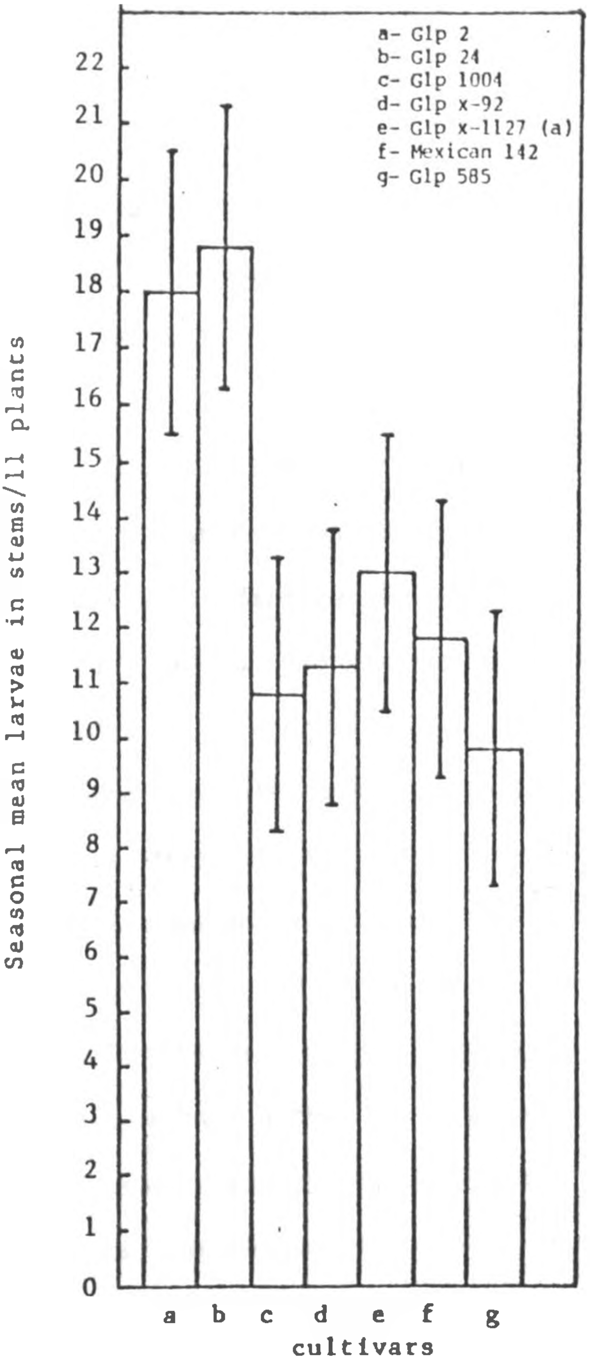

Figure 40. Beanfly larvae in stems of bean cultivars grown during short rains of 1985 at NAL, Nairobi.

bean plants infested with larvae in stems during off-season, 1985 at Kabete campus, Nairobi and during the long rains season, 1985 and short rains season, 1985 at NAL, Nairobi (Table 8). Glp 2 was among the bean cultivars with the highest while Mexican 142 was the bean cultivars with the lowest percentage bean plants with larvae in the stems.

There were significant differences among the bean cultivars in the number of _O_. _spencerella_ puparia during the short rains of 1984; long rains of 1985 and off-season of 1985 at both sites (Figs. 41, 42, 43, 44, 45, and 46). The mean seasonal number of _O_. _spencerella_ puparia in the bean cultivars were statistically similar during the short rains of 1985 at NAL, Nairobi (Fig. 47). In the seasons when there were significant differences among the bean cultivars, numerically Glp 2 had the highest while Glp x-92 and Mexican 142 had the lowest number of _O_. _spencerella_ puparia. There were statistical differences among the cultivars in the percent plants with _O_. _spencerella_ puparia during the long rains of 1985 at Kabete Campus and during off-season and short rains of 1985 at both sites (Table 9). Numerically, Glp 2 had the highest while Mexican 142 had the lowest percent plants with _O_. _spencerella_ puparia.

The mean seasonal number of _O_. _phaseoli_ puparia in the bean cultivars were statistically similar during the short rains of 1984 at Kabete Campus, Nairobi and during the long rains, off-season and short rains of 1985 at both sites (Figs. 42, 43, 44, 45, 46, and 47). They were statistcally different during the short rains of

Table 8 Percentage bean plants with beanfly larvae in the stems during the long rains, off-season and short rains of 1985 at two sites.

	long rains of 1985		off-season of 1985		short rains of1985
Cultivars	NA1	Kabete	NA1	Kabete	NA1
Glp 2	24.5a	27.6a	50.7a	63.7a	30.0a
Glp 24	21.9abc	21.6a	53.7a	60.9a	31.5a
Glp 1004	18.2c	22.8a	50.4a	61.1a	25.9abc
Glp x-92	22.1abc	24.0a	50.8a	59.2a	20.5c
Glp x-1127(a)	22.4abc	22.1a	52.0a	61.1a	27.4ab
Mexican 142	18.3c	21.5a	51.4a	50.5b	21.6bc
Glp 585	23.7ab	26.2a	50.5a	59.2a	20.6c
Statistical analysis					
F value	3.011*	1.285	0.552	3.191*	5.103**
C V (%)	13.1	17.7	6.6	7.9	15.9
S E	1.4	2.1	1.7	2.3	2.0
LSD: 5%	4.2			7.0	6.0
1%					6.0
0.1%					8.2

Statistical analysis is on transformed values Arcsin $\sqrt{X}$.

Means in each column followed by the same letter are not significantly differen
at 5% based on Duncan's multiple range test.

* $P < 0.5$; ** $p < 0.01$.

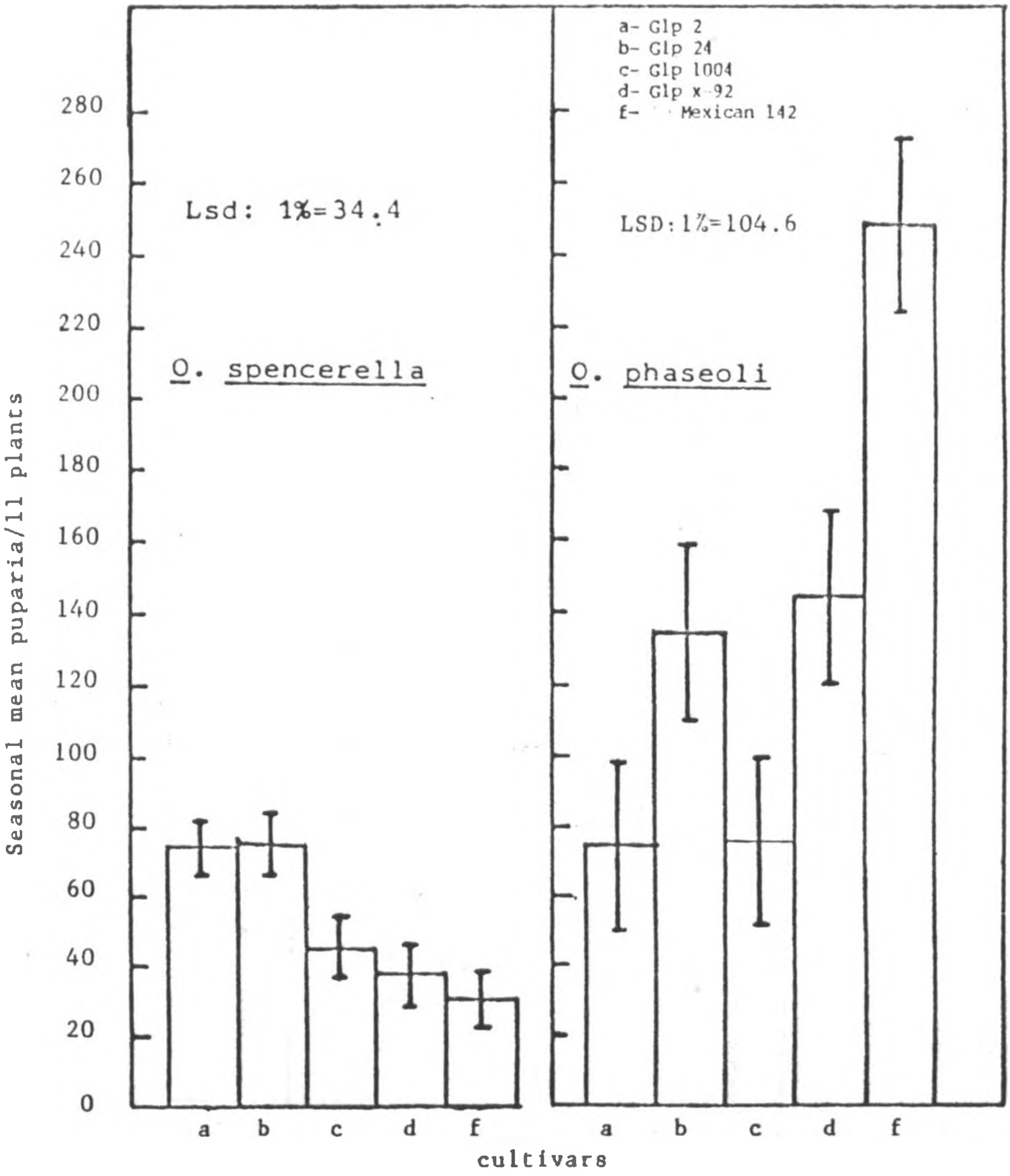

Figure 41. Beanfly puparia in bean cultivars grown during the short rains of 1984 at NAL, Nairobi.

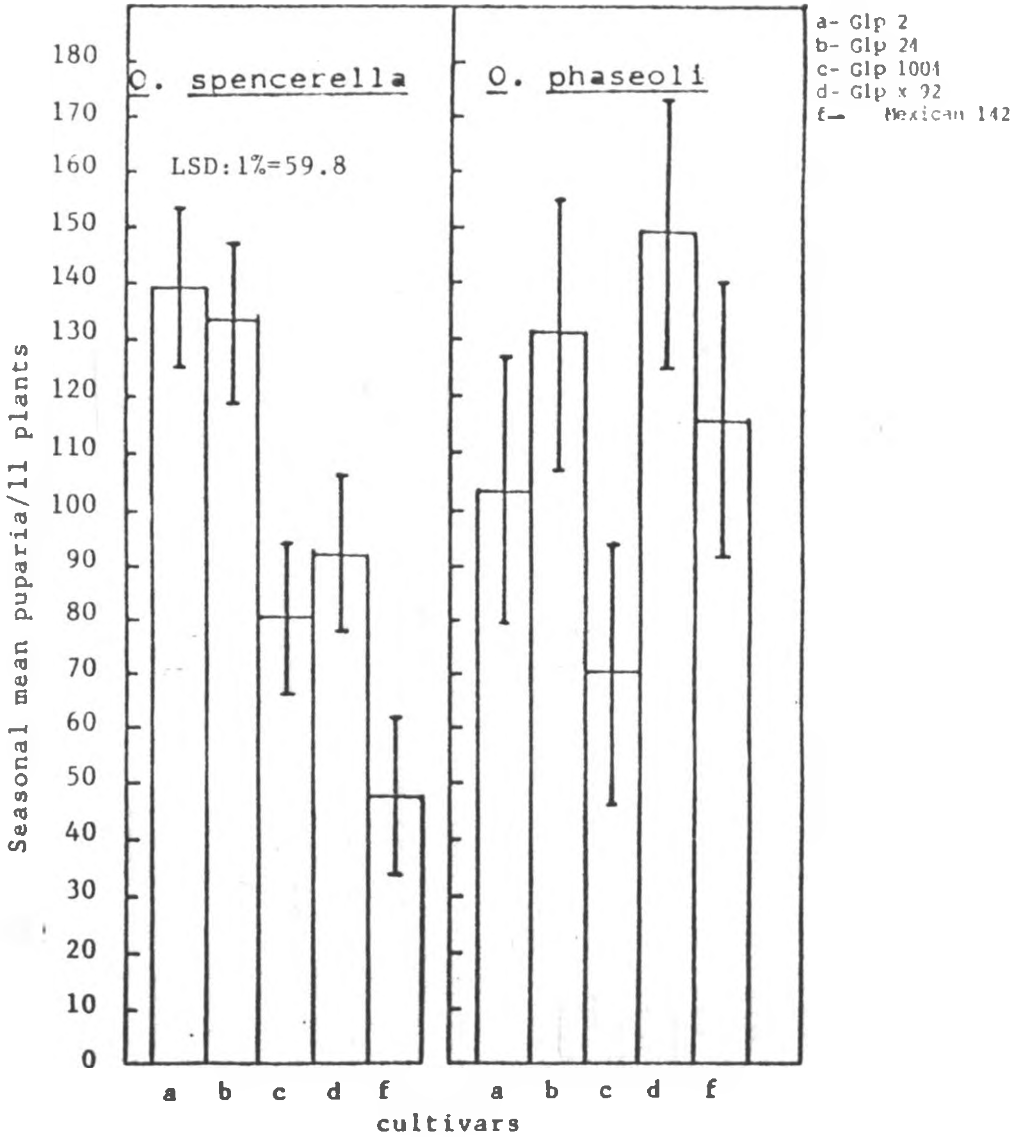

Figure 42. Beanfly puparia in bean cultivars grown during the short rains of 1984 at Kabete Campus, Nairobi.

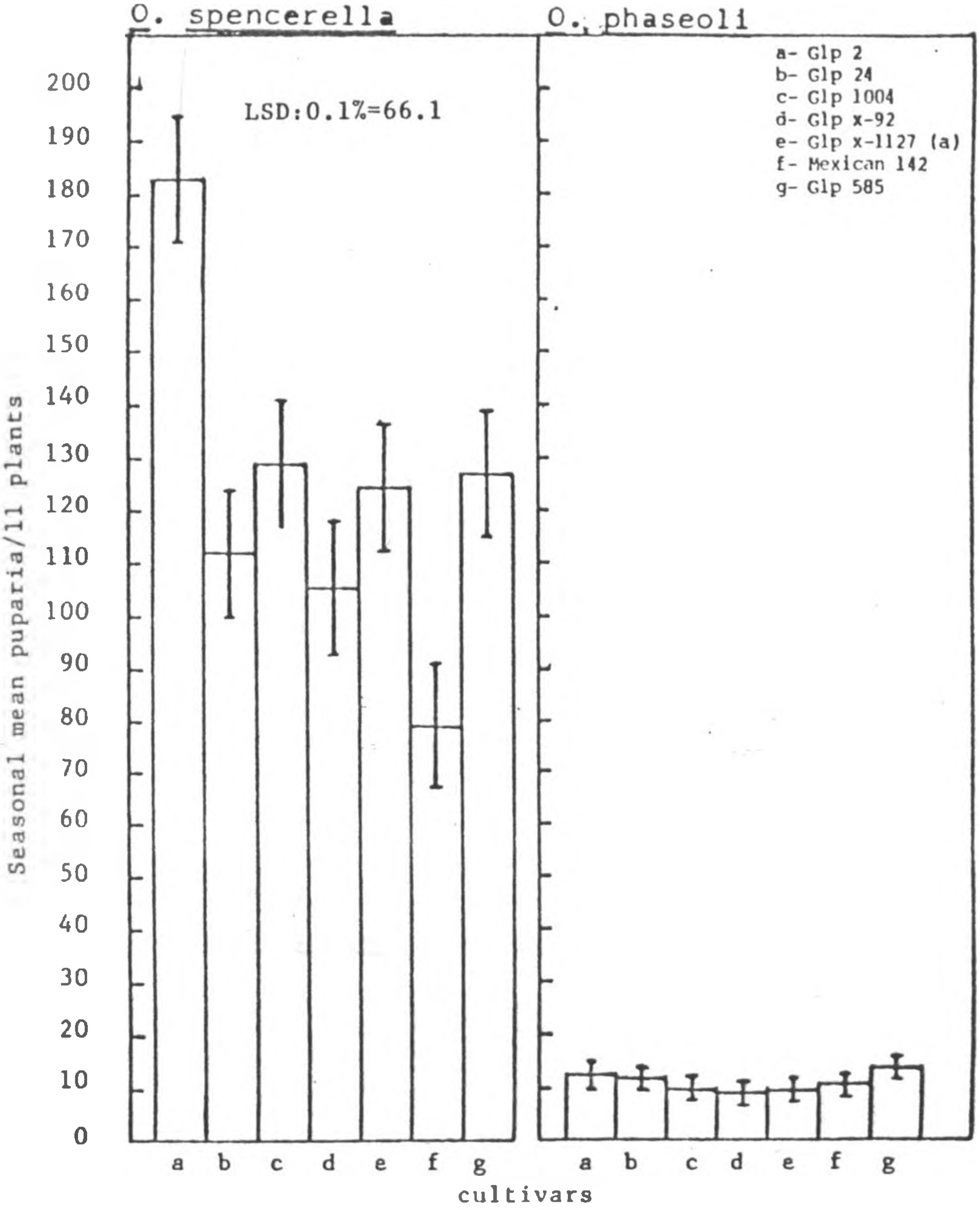

Figure 43. Beanfly puparia in bean cultivars grown during the long rains of 1985 at NAL, Nairobi.

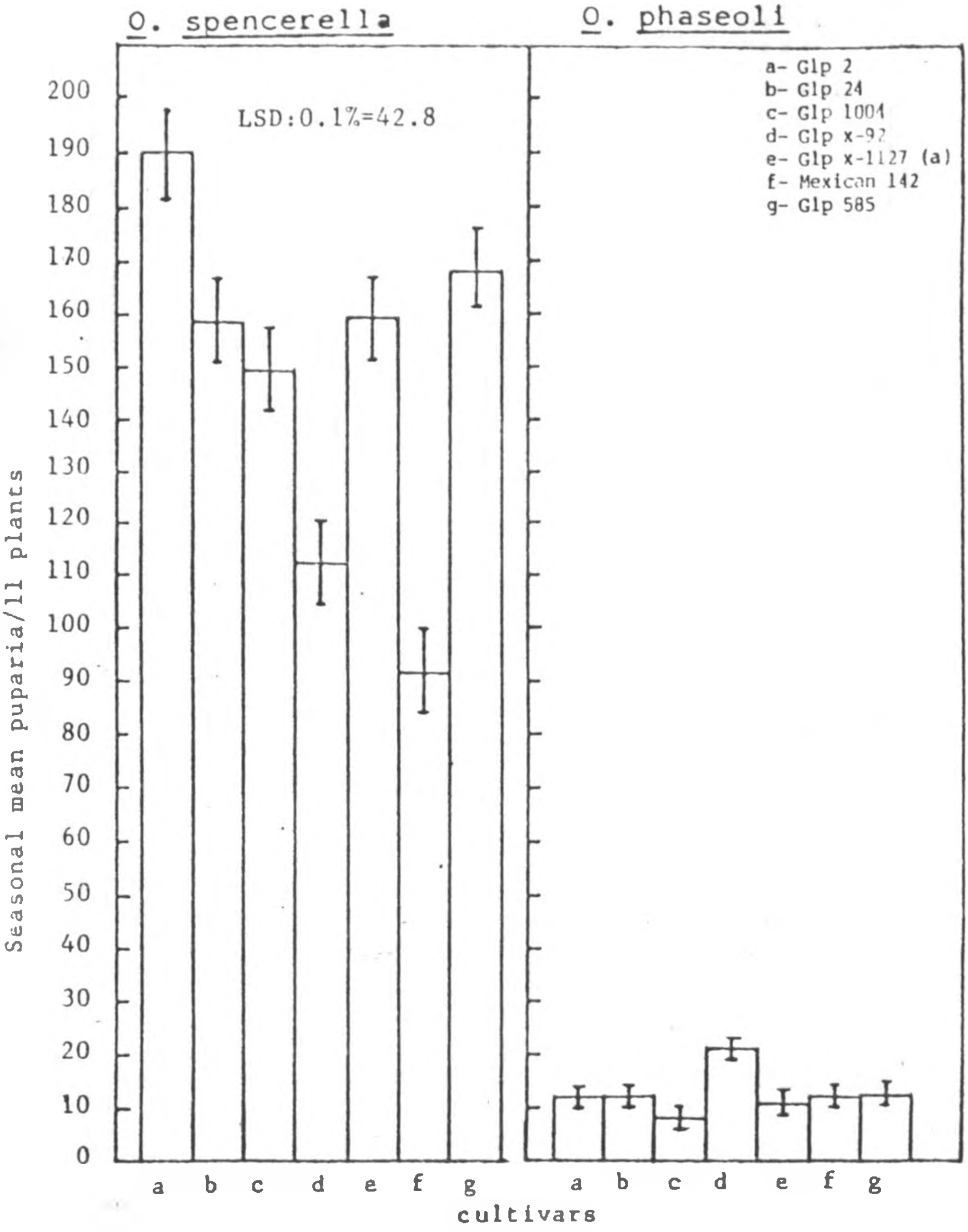

Figure 44. Beanfly puparia in bean cultivars grown during the long rains of 1985 at Kabete Campus, Nairobi

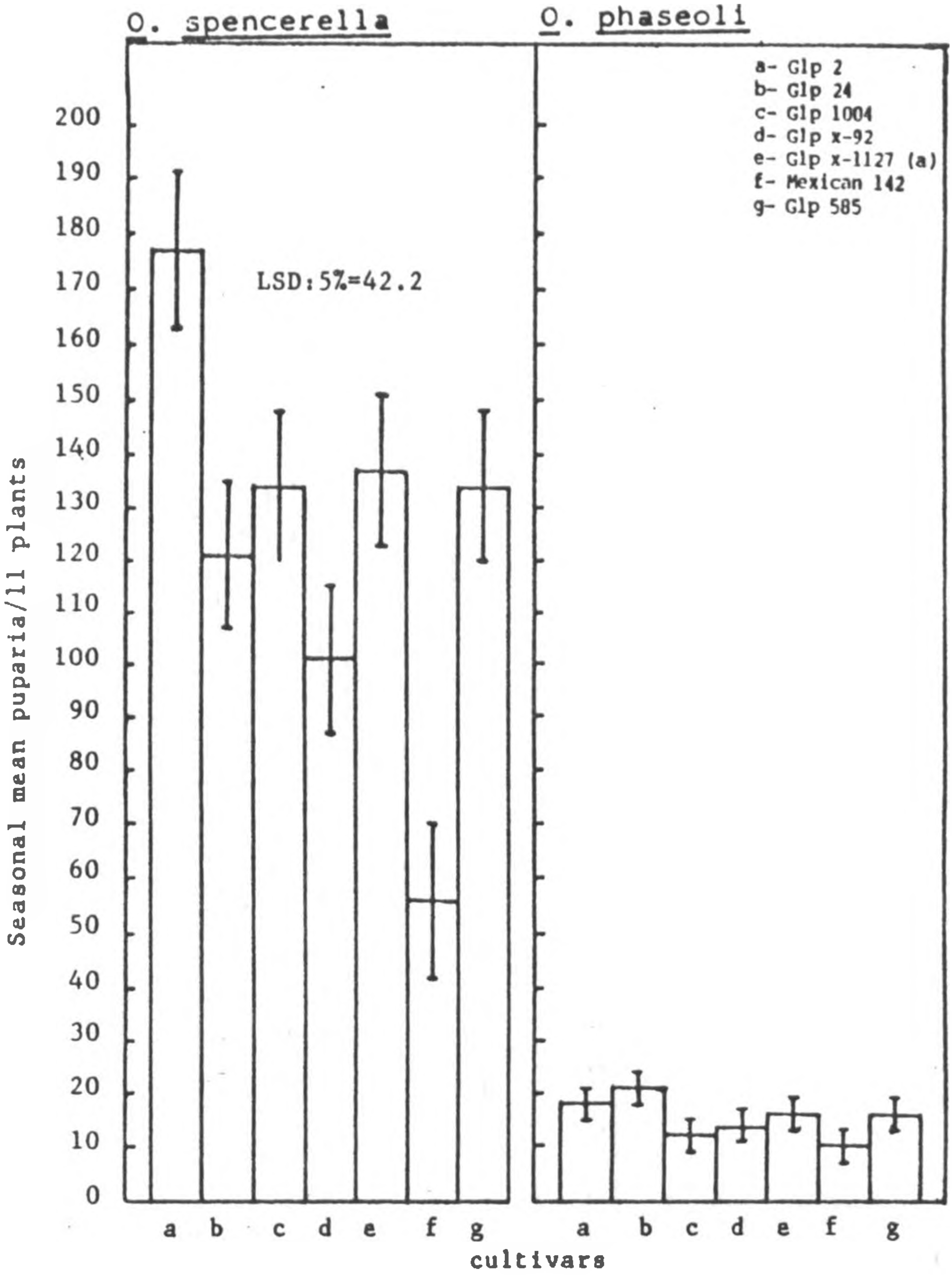

Figure 45. Beanfly puparia in bean cultivars grown during off-season of 1985 at NAL, Nairobi.

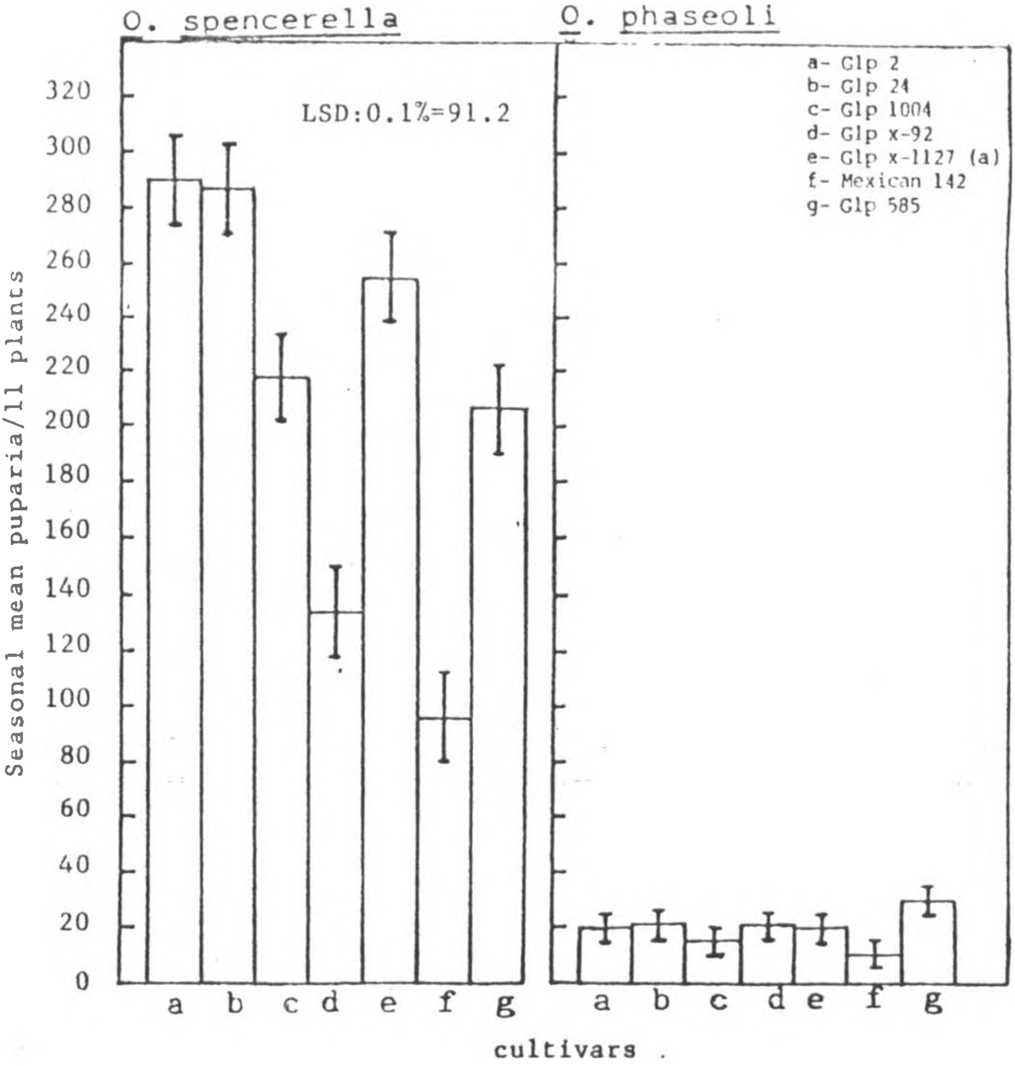

Figure 46. Beanfly puparia in bean cultivars grown during off-season of 1985 at Kabete Campus, Nairobi.

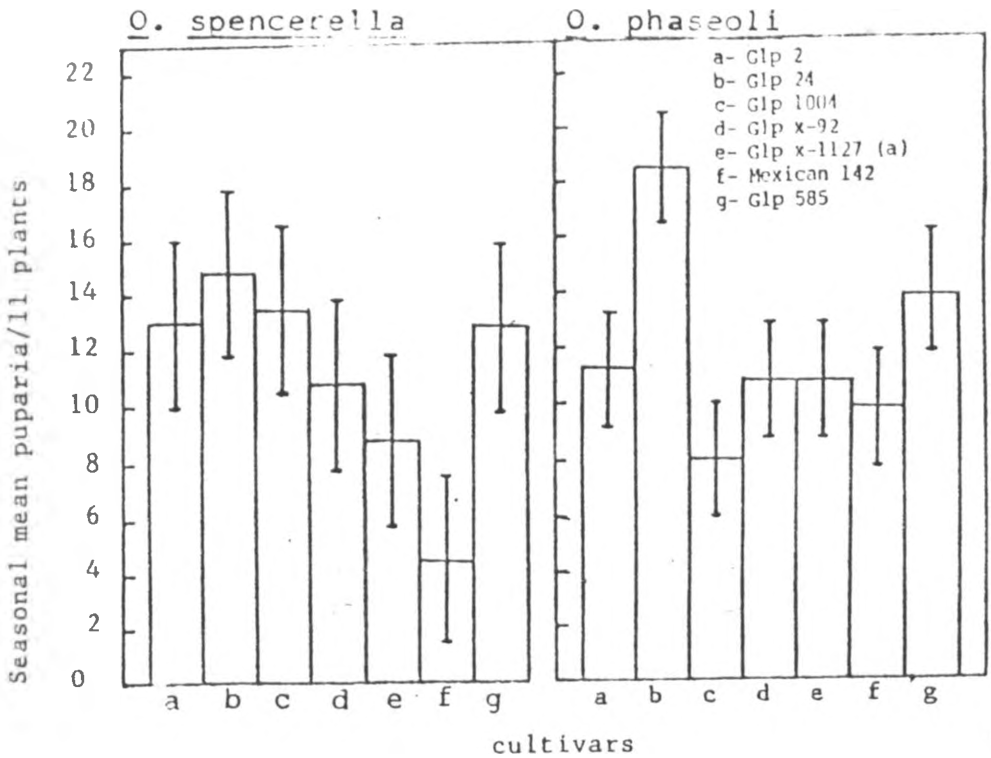

Figure 47. Beanfly puparia in bean cultivars grown during the short rains of 1985 at NAL, Nairobi.

Table 9. Percentage bean plants with *O spencerella* puparia during the long rains off-season and short rains of 1985 at two sites.

	long rains of 1985		off-season of 1985		short rains of 1985
Cultivars	NAl	Kabete	NAl	Kabete	NAl
Glp 2	51.0a	53.1a	57.5a	64.9abc	21.1a
Glp 24	44.0b	46.9b	53.1a	69.7a	14.9a
Glp 1004	47.2ab	49.9ab	52.4a	62.6bcd	14.7a
Glp x-92	45.0ab	50.2b	49.4ab	60.9cd	15.0a
Glp x-1127(a)	45.1ab	41.0ab	55.3a	67.6ab	12.8a
Mexican 142	41.6b	41.0c	42.6b	58.4d	0b
Glp 585	46.3ab	53.6a	53.4a	69.2a	15.2a
Statistical analysis					
F value	2.387	7.724***	3.349*	4.663**	5.727**
C V (%)	8.2	6.5	10.1	6.2	40.2
S E	1.9	1.6	2.6	2.0	2.7
LSD:5%		4.7	7.8	6.0	8.0
1%		6.4		8.2	11.0
0.1%		8.7			

Statistical analysis is on transformed values Arcsin $\sqrt{X}$.

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

*p <0.5; **p <0.01; ***p< 0.001.

1984 at NAL, Nairobi (Fig. 41). There was no cultivar which had consistently higher or lower numbers of O. phaseoli puparia in all the three seasons. There were also no statistical differences among the cultivars in percent plants infested with O. phaseoli puparia during off-season of 1985 at NAL, Nairobi and during the short rains of 1984 and 1985 at both sites (Table 10). They were significantly different during off-season of 1985 at Kabete Campus, Nairobi.

The population pressure of larvae and pupae in the bean cultivars were not high enough to kill seedlings or older bean plants during the short rains of 1984 and short rains of 1985 at both sites. But during these two seasons, O. phaseoli caused stunting and yellowing of leaves of plants. There were very few dead plants in each bean cultivar during the long rains of 1985 at both sites (Table 11). However,the number of dead plants due to beanflies in each cultivar was very high during the off-season of 1985 at both sites. There were statistical differences among the bean cultivars on mean percent dead plants during this season. Glp x-92 and Glp 1004 had the lowest mean percent dead plants. There were significant differences among the bean cultivars in the number of larvae, and puparia of O. phaseoli and O. spencerella per dead plant (Tables 12 and 13). In each cultivar the number of O. spencerella puparia per dead plant was greater than the number of O. phaseoli puparia. The population of larvae of O. spencerella at the seedling stage killed bean plants. Glp 2 had the highest while Glp x-92 and Mexican 142 had the lowest number of larvae+puparia per dead plant. Whilst Mexican 142 had low numbers of larvae+puparia

Table 10. Percentage bean plants with *O. phaseoli* puparia during the long rains, off-season and short rains of 1985 at two sites.

	long rains of 1985		off-season of 1985		short rains of 1985
Cultivars	NAL	Kabete	NAL	Kabete	NAL
Glp 2	16.6a	18.1ab	28.0a	26.1b	26.4a
Glp 24	18.0a	17.9ab	29.2a	28.5ab	30.9a
Glp 1004	15.8a	14.8b	22.6a	22.5c	23.8a
Glp x-92	16.1a	22.0a	26.1a	27.8ab	25.5a
Glp x-1127(a)	16.1a	16.8b	25.1a	27.6ab	25.5a
Mexican 142	16.8a	17.6ab	21.0a	16.4d	23.4a
Glp 585	19.8a	18.2ab	22.5a	31.9a	29.1a
Statistical analysis					
F value	1.070	2.276	1.120	10.34***	0.895
C V (%)	16.2	15.9	23.2	12.1	21.9
S E	1.4	1.4	2.0	1.6	2.9
LSD:5%				4.6	
1%				6.3	
0.1%				8.6	

Statistical analysis is on transformed values Arcsin $\sqrt{X}$.

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

***p< 0.001).

Table 11. Damage caused by Ophiomyia spp on bean cultivars grown during the long rains, and off-season of 1985 at two sites.

	Cumulative mean per cent dead plants			
	long rains of 1985		off-season of 1985	
Cultivars	NAl	Kabete	NAl	Kabete
Glp 2	0	0.5a	42.6a	53.2a
Glp 24	0	0.7a	26.8b	59.4a
Glp 1004	0	0.8a	11.1c	10.3b
Glp x-92	0	1.9a	12.6c	7.9b
Glp x-1127(a)	0.2	1.5a	43.3a	44.6a
Mexican 142	0.3	0.8a	54.7a	51.7a
Glp 585	0.8	2.7a	45.2a	52.0a
Statistical analysis				
F value			19.234***	19.324***
C V(%)			15.1	24.5
S E			2.6	4.9
LSD:5%			7.8	14.6
1%			10.7	20.0
0.1%			14.6	27.2

Statistical analysis is on transformed values Arcsin $\sqrt{X}$.

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

***$p < 0.001$.

Table 12. Mean number of larvae and puparia per dead bean plant from a crop grown during off-season of 1985 at NAL, Nairobi.

Cultivars	larvae	O. spencerella puparia	O. phaseoli puparia	larvae+pupae
Glp 2	2.0a	4.8a	0.7ab	7.4a
Glp 24	1.2b	4.5a	0.7ab	6.4ab
Glp 1004	1.2b	3.7ab	0.3bc	4.8bcd
Glp x-92	0.9bc	2.6b	0.8a	4.3cd
Glp x-1127(a)	1.4b	3.9ab	0.7ab	5.9bcd
Mexican 142	0.6c	2.7b	0.2c	3.3d
Glp 585	1.0c	3.9ab	0.5abc	5.4bcd
Statistical analysis:				
F value	9.33***	3.024*	3.090*	5.443***
C V (%)	24.4	25.9	50.0	21.6
S E	0.1	0.5	0.1	0.6
LSD:5%	0.4	1.4	0.4	1.7
1%	0.6			2.4
0.1%	0.8			

Statistical analysis is on transformed values Arcsin $\sqrt{X}$.

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

*$P < 0.5$; ***$p < 0.001$.

Table 13. Mean number of larvae and pupae per dead bean plant from a crop grown during off-season of 1985 at Kabete Campus, Nairobi.

Cultivars	larvae	O. spencerella puparia	O. phaseoli puparia	larvae+pupae
Glp 2	1.2a	8.2a	0.6ab	10.1a
Glp 24	1.0ab	6.8b	0.8a	8.4bc
Glp 1004	1.4a	6.9b	0.4b	8.9ab
Glp x-92	0.9ab	5.5c	0.7ab	7.2c
Glp x-127(a)	0.7bc	7.7a	0.7ab	8.9ab
Mexican 142	0.3c	3.2d	0.5ab	4.3d
Glp 585	0.7bc	6.9b	0.8a	8.8bc
Statistical analysis				
F value	6.47***	25.53***	2.0753	26.334***
C V (%)	32.2	10.2	33.3	9.0
S E	0.1	0.3	0.1	0.4
LSD:5%	0.4	1.0		1.1
1%	0.6	1.3		1.5
0.1%	0.8	1.8		2.0

Statistical analysis is on transformed values Arcsin $\sqrt{X}$.

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

$***p < 0.001$.

per dead plant it had a large percentage of dead plants. Glp x-92 had few larvae+puparia per dead plant and a low percentage of dead plants. Glp 1004 had high numbers of larvae+puparia per dead plant but few plants died. In each bean cultivar there were significant positive correlations between the dead plants and the number of larvae+puparia in the dead plants (Table 14). There were significant positive correlations between the dead plants and the larvae, and puparia of O. phaseoli and O. spencerella in those plants (Table 15).

There were significant differences in the number of pods per plant in all the four seasons at both sites (Table 16). There were significant differences among the bean cultivars in seed weight /plant during the short rains of 1984 at NAL, Nairobi. There were no significant differences among the bean cultivars in seed weight/plant during the other seasons at the two sites. Although more bean plants died due to beanflies during the off-season of 1985 than during the other seasons the seed weight/plant was higher during this season than during the other seasons.

Table 14. Correlation coeffecients between the numbers of beanfly larvae+pupae in dead plants and dead plants per cultivar grown during off-season of 1985 at two sites.

	Correlation coefficients	
Cultivars	NAl	Kabete
Glp 2	0.77***	0.54***
Glp 24	0.88***	0.93***
Glp 1004	0.75***	0.95***
Glp x-92	0.84***	0.93***
Glp x-1127(a)	0.67**	0.92***
Mexican 142	0.70***	0.87***
Glp 585	0.81***	0.92***

***p< 0.001.

Table 15. Correlation coefficents between the number of dead bean plants and larvae, O. <u>phaseoli</u> and <u>O</u>. <u>spencerella</u> puparia in dead plants.

	correlation coeffients	
	NAL	Kabete
	dead plants	dead plants
larvae	0.64***	0.41***
<u>O</u>. <u>phaseoli</u> puparia	0.64**	0.71***
<u>O</u>. <u>spencerella</u> puparia	0.78***	0.82***
larvae+pupae	0.84***	0.84***

***p< 0.001.

Table 16. Yield parameters of bean cultivars grown during the short rains of 1984; long rains, off-season and short rains of 1985 at two sites.

	Short rains season, 1984						Long rains season, 1985				Off-season of 1985				short rains of 1985	
	NAL			Kabete Campus			NAL		Kabete Campus		NAL			Kabete	NAL	
Cultivars	pods/ plant	seeds/ pod	gms/ plant	pods/ plant	seeds/ plant	gms/ plant	pods/ plant	gms/ plant	pods/ plant	gms/ plant	pods/ plant	gms/ plant	pods/ plant	gms/ plant	pods/ plant	seeds/ pods
Glp 2	11.5b	3.5a	14.8a	6.1bc	3.4b	9.5b	7.3b	9.5ab	7.6bc	14.0ab	6.7c	10.3a	8.5b	19.8ab	7.1bcd	3.2ab
Glp 24	13.4b	4.1a	18.5a	5.7c	3.5b	9.5b	10.1b	13.5a	13.2ab	16.3a	14.0ab	17.9a	16.2a	29.0a	5.7d	3.1ab
Glp 1004	14.3ab	3.6a	22.0a	6.6bc	3.3b	9.3b	6.8b	8.9ab	8.9bc	14.3ab	7.4c	12.7a	11.9ab	23.8ab	9.5abc	2.9ab
Glp x-92	17.0a	3.4a	19.7a	8.8b	2.8c	9.7ab	9.2b	7.6b	11.2bc	11.4ab	12.6b	13.6a	15.5a	18.7ab	10.5ab	2.4b
Glp x-1127 (a)							8.4b	8.9ab	7.9bc	12.9ab	5.6c	9.7a	10.3ab	18.7ab	6.5cb	3.1ab
Mexican 142	12.0b	3.8a	6.2b	18.2a	4.1a	14.7a	21.7a	10.5ab	18.0a	11.8ab	18.6a	15.5a	15.9a	13.4b	12.4a	3.5a
Glp 585							12.6b	10.4ab	9.6bc	8.9b	13.1b	11.9a	16.0a	24.5a	9.5ab	3.4a
Statistical analysis																
F value	5.443***	1.627	6.083***	37.13***	20.19***	2.37	3.857*	1.849	5.129**	2.066	11.6***	1.431	2.363	2.411	4.963*	1.866
S E	0.9	0.21	2.5	0.9	0.1	1.51	2.6	1.4	1.6	1.7	1.4	2.4	2.1	3.2	1.1	0.3
C V	13.7	11.3	31.0	18.9	5.8	28.6	48.5	28.1	29.8	25.9	25.0	36.9	30.8	30.9	24.6	17.1
Lsd: 5%	2.9			3.8			7.8		4.8		4.1				3.2	
1%	4.0			3.7					6.6		5.7				4.4	
0.1%				5.3							7.7					

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

*p< 0.5; **p<0.01; ***p< 0.001.

5:4. DISCUSSION

In the work being reported here the criteria used to measure resistance have included the number of beanfly punctures, eggs, puparia, percentage infestation and percentage plant mortality which are based on the assumptions that they are accurate indices of the level of population density of the pest and therefore can be related to damage being caused to the plant. As Davis (1985) points out the criteria for measuring resistance are generally on the effect that the insect has on the plant and/or the effect that the plant has on the behaviour and biology of the insect. The bean cultivars were separated into different resistant categories using the most appropriate parameters which in most cases were the number of puparia and percent plant mortality.

The seven bean cultivars evaluated had not been breed for resistance to beanflies and as a group they encompassed a very small segment of the genetic variability known to occur in common beans. Each bean cultivar was not consistently ranked into any resistant category, using the leaf puncture counts or percentage plants with punctures, in different seasons and in different sites. These results are supported by those of Msangi and Karel (1984) and Karel (1984) who showed no significant varietal differences in leaf puncture counts. In the field the categorization of bean cultivars, using leaf punctures, may be masked if _O. phaseoli_ and _O. spencerella_ show puncturing preference for different cultivars.

Saxena (1985) mentioned that some insects show ovipositional nonpreference by laying fewer eggs in resistant than in susceptible cultivars. All the bean cultivars were equally preferred for oviposition in the leaves by the beanflies. Counting the number of eggs oviposited in the leaves by the two species together may have obscured the oviposition preference for any bean cultivar by *O. spencerella* or *O. phaseoli*. Despite no significant differences between the bean cultivars, Glp 2 had numerically high while Mexican 142 had low number of eggs in the stems. Therefore, Glp 2 appeared to be the most preferred while Mexican 142 the least preferred for oviposition in the stems by *O. spencerella*.

There was no bean cultivar which had consistently high or low numbers of larvae in the leaves in different seasons at both sites. In seasons when there were statistical differences among the bean cultivars in the number of larvae in the stems, Glp 2 had the highest while Mexican 142 had the lowest number of larvae in the stems. Under East African conditions the larvae found in the stems of growing beans are mixture of at least two species of beanflies and are not easily identified. These tend to complicate the interpretation of results of any experiment designed to evaluate the resistance of a given bean cultivar using larvae as parameter for resistance. Nevertheless, it would seem from the work reported in this thesis and other work done in East Africa (Maerere and Karel, 1984; Rwamugira and Karel, 1984; Mushebezy and Karel, 1985 and Mueke, 1979b) that there are varietal differences in number of larvae in the stems.

The bean cultivars showed differences in *O. spencerella* puparia infestation. Glp x- 92 and Mexican 142 were identified as the least infested and Glp 2 as the most infested by *O. spencerella* puparia. In contrast *O. phaseoli* puparia were very low to the extent that there were no stricking differences between the bean cultivars in infestation. It was noted that in seasons when beanfly population was low as indicated by low counts of puparia the differences between the cultivars disappeared. Chiang and Talekar (1980) used combined larvae+pupae of agromyzid flies as a criteria for resistance. In the field the pupae/puparia of *O. spencerella* and *O. phaseoli* are accurately identified and therefore could be used to screen bean cultivars to the two species separately. Redy *et. al*. (1983) used plant mortality as an indicator of susceptibility/resistace of bean cultivars to *O. phaseoli*. Under high population of *O. spencerella* which occurred in some seasons the percentage mortality of plants were used to separate the bean cultivars into resistant categories. Glp 1004 had large numbers of *O. spencerella* puparia but low plant mortality while Mexican 142 was vice versa. In contrast Glp x- 92 had low plant mortality and low numbers of *O. spencerella* puparia. The other four bean cultivars namely, Glp 2, Glp 24, Glp 585 and Glp x- 1127(a) had large numbers of *O. spencerella* puparia and high mortality. Therefore, Glp 1004 can be assumed to be reasonably tolerant while Glp x- 92 appear to have some resistance. The remaining cultivars namely, Glp 2, Glp 24, Glp 585, Glp x- 1127(a) and Mexican 142 show some degree of susceptibility to *O. spencerella*. With regard to *O. phaseoli* the results obtained were at best inconclusive as there were no statistical differences in response of the bean cultivars due to low numbers of O. phaseoli during the seasons when the experiments were done.

The criteria used to identify resistance characteristics of bean cultivars in this study can be used for rapid screening and breeding work involving large numbers of bean cultivars in the field. In this study determining number of beanfly leaf punctures, larvae and puparia in stems were simpler, more efficient and accurate than the number of eggs or larvae in leaves. Even plant mortality which occurs when the beanfly population is high can be useful to identify those cultivars which have little ability to recover from severe attack. In such cases percentage plant mortality is correlated to the larvae and puparia of beanflies and it may be the best parameter for resistance/susceptibility.

CHAPTER 6

EVALUATION OF COMMON BEAN (PHASEOLUS VULGARIS L.) CULTIVARS IN SUCCESSIVE PLANTINGS FOR RESISTANCE/SUSCEPTIBILITY TO BEANFLIES (DIPTERA: AGROMYZIDAE).

6:1.INTRODUCTION.

Although beanflies are present throughout the year in bean fields in Kenya and other parts of East Africa, infestation varies from season to season. Swaine (1969) working in Northern Tanzania and Okinda (1979) working in Highlands of Kenya reported that populations of beanflies in bean crops remain high when there is little rainfall and decline sharply as the rain intensity increases. Accordingly beans planted during the short rains often suffer more severe damage if there is an intervening drought. Beanfly infestation increased with delay in planting dates in a season (Okinda, 1979; Kwon et. al., 1981; Talekar and Chen, 1983). Other workers (Kooner et. al., 1980; Sing et al., 1981) showed that beanfly infestation increased with early planting dates. Although beanflies attack the bean plants throughout the growing period the most vulnerable period is the seedling stage. A uniform and high level of beanfly infestation in the seedling stage of bean cultivars must be timed for screening purposes.

In the present studies the relationship between time of planting and levels of beanfly infestation were assessed and degree of damage was estimated. The bean cultivars were planted at different planting dates within cropping and noncropping seasons to determine the time when there are uniform and sufficiently high beanfly populations at the seedling stage for screening purposes. These studies have implications for mass screening of bean cultivars to beanflies, where staggered sowings are normally unavoidable because of the large number of cultivars to be evaluated.

6:2. MATERIALS AND METHODS.

6:2.1. Beanfly infestation on bean cultivars planted at different dates in a season.

The seven bean cultivars viz Glp 2, Glp 24, Glp x-92, Glp x-1127(a), Glp 585, Glp 1004 and Mexican 142 were used in the experiments for evaluation for resistance/susceptibility to beanflies. They were grown in a split-plot design, with sowing dates in the main plots and cultivars in the subplots. The sizes of subplots were 4m.x3m. each, with an inter-row spacing of 50cm and within-row spacing of 10cm. The paths left between the main plots were one metre and between subplots were 0.5m. Each bean cultivar was replicated four times. For each of the cultivars there were four successive plantings (Table 3). The first sowing was done immediately after the onset of the rains. Then subsequent three sowings were at weekly intervals.

After germination the bean seedlings were liable to attack by the residual natural beanfly population generally present in the field. Sampling started 7 days after emergence of the seedlings of each sowing time and continued at weekly intervals during the growing period of the crop. From the five middle rows in each subplot, one plant was sampled per row and the five sampled plants per subplot were placed in polythene bags and taken to the laboratory for examination. In the laboratory a number of records were taken for each sample:-

1. The number of beanfly punctures in the leaves.
2. The number of eggs and 1st instar larvae obtained by dissecting leaf punctures.
3. The number of eggs obtained by dissecting the beanfly punctures in the stems.
4. The number of larvae and puparia obtained by dissecting the stems.
5. The number of dead bean plants due to beanflies per each subplot.
6. The stem damage of the bean plants rated on a score of 1-5 where, 1 = no damage, 2 = slight damage- small stem callous, 3 = Moderate damage- large stem callous, slight stunting of bean plants, 4 = severe damage- large cracked stem callous, stunted leaves which become yellow and brown, 5 = complete damage- wilted plants or dead plants due to beanflies.

In addition to the above parameters the plants that remained in the field after completion of the sampling were harvested at the end of the season and plant characteristics related to yield were recorded.

The data obtained were analyzed statistically using ANOVA and the results obtained were presented in tables form for ease of reference.

The experiments were done during the short rains of 1985; long rains of 1986; off-season of 1986 and short rains of 1986.

6:2:2. Evaluation of bean cultivars at different stages of growth for resistance to beanflies

Seven bean cultivars viz Glp 2, Glp 24, Glp 1004, Glp x-92, Glp x- 1127(a), Glp 585 and Mexican 142 were used in the experiments. For each cultivar there were three groups of 24 potted plants. Group 1 comprised of one day, Group 2 ten days and Group 3 twenty days old seedlings. The three groups of potted plants were removed to the field and placed in the vicinity of growing beans where natural beanfly populations were known to be present. After five days all the potted plants were brought back to the greenhouse before any eggs laid on them hatched.

Sampling of bean plants was done on 1st, 15th, and 28th day after transferring the seedlings to the greenhouse. In each sampling period eight potted bean plants per cultivar were sampled in each planting. The sampled plants were placed in polythene bags and taken to the laboratory.

The leaves of bean plants sampled one day after transferring them to the greenhouse were held against light to enable counting the leaf punctures. The leaf punctures were dissected under the binocular microscope and the number of eggs counted. The punctures in the stems were dissected under the microscope and the eggs counted.

The stems of bean plants sampled 15 days after transferring them to the greenhouse were dissected and the number of larvae counted.

The number of puparia in the bean plants sampled 28 days after transferring them to the greenhouse were recorded.

6:3. RESULTS.

6:3:1. Beanfly infestation on bean cultivars planted at different dates in a season.

The mean number of leaf punctures in the seven bean cultivars were significantly different during the short rains of 1985; long and short rains of 1986 (Table 17). Glp x-92, Mexican 142 and Glp 585 had higher numbers of leaf punctures than other bean cultivars during these seasons. The mean number of leaf punctures in the four planting dates were statistically different in all the seasons. There were more leaf punctures in the late planted than in the early planted bean cultivars during the short rains of 1985; long and short rains of 1986. The percentage plants with leaf punctures among the bean cultivars were significantly different during the long and short rains of 1986 (Table 18). There were more bean plants with leaf punctures in the early planted than in the late planted bean crop.

The mean number of eggs in the leaves of bean cultivars were significantly different during the long rains of 1986 (Table 19).

Table 17. Seasonal mean number of beanfly leaf punctures on bean cultivars in four planting dates during the short rains of 1985: long rains, off-season and short rains of 1986 at NAL, Nairobi.

	Short rains of 1985					Long rains of 1986					Off-season of 1986					Short rains of 1986				
Cultivars	1st planting	2nd planting	3rd planting	4th planting	cultivar means	1st planting	2nd planting	3rd planting	4th planting	cultivar means	1st planting	2nd planting	3rd planting	4th planting	cultivar means	1st planting	2nd planting	3rd planting	4th planting	cultivar means
Glp 2	17.3	33.9	35.3	50.5	34.2bcd	20.4	39.7	46.4	49.4	39.1c	72.5	66.6	53.2	52.0	61.1a	15.8	29.3	37.0	52.4	33.6c
Glp 24	20.0	37.0	37.7	55.9	37.6bc	21.1	35.2	50.7	40.0	36.8c	69.3	66.1	53.6	50.0	59.8ab	14.6	28.2	36.6	51.5	32.7c
Glp 1004	16.2	27.1	35.9	52.6	32.9cd	20.3	38.6	53.5	50.9	40.8c	72.7	61.8	53.7	51.5	60.0ab	15.4	26.5	37.7	51.3	32.7c
Glp X-92	23.4	44.5	46.6	66.6	45.3a	23.8	54.0	74.4	56.4	52.2b	84.2	62.8	47.9	48.3	60.8a	20.4	33.2	46.8	59.7	40.1b
Glp X-1127(a)	19.7	26.3	32.4	46.9	31.3d	21.2	37.9	48.8	50.5	39.6c	74.5	62.1	52.5	48.1	59.3ab	16.5	27.6	38.1	51.3	33.4c
Mexican 142	22.1	35.5	39.0	58.3	38.7b	23.2	63.6	89.6	77.3	63.4a	61.2	58.8	50.6	48.2	54.7b	24.6	39.6	52.6	58.6	43.8a
Glp 585	21.2	47.2	37.3	72.9	44.7a	26.5	50.7	80.6	68.0	56.5b	68.8	59.5	53.5	52.1	58.5ab	21.9	40.3	49.6	60.6	43.1a
Time of planting means	20.0c	35.9b	37.7b	57.7a		22.4d	45.7c	63.5a	56.1b		71.9a	62.5b	52.1c	50.0c		18.5d	32.1c	42.6b	55.1a	
Statistical analysis																				
Cultivars :																				
F value	9.681***					41.11***					1.287					23.22***				
C V(%)	18.8					13.8					12.8					11.4				
S E	1.8					1.6					1.9					1.1				
LSD:5%	5.1					4.5										3.1				
1%	6.7					6.0										4.1				
0.1%	8.8					7.8										5.4				
Time of planting																				
F value	133.88***					138.08***					21.48***					245.55***				
C V (%)	18.6					17.2					19.5					14.2				
S E	1.3					1.5					2.2					1.0				
LSD: 5%	4.2					4.8					7.0					0.3				
1%	6.0					6.9					10.1					0.5				
0.1%	8.4					10.2					15.0					0.7				

Statistical analysis is on transformed values $\sqrt{x+0.5}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

***$p < 0.001$.

Table 18. Infestation of bean cultivars with beanfly punctures in four plantings dates in two seasons at NAL, Nairobi.

	Long rains of 1986					Short rains of 1986				
Cultivars	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	74.0	97.1	97.2	98.6	91.7	93.6	97.2	99.3	100	97.5a
Glp 24	62.1	95.7	95.7	100	88.4	87.9	98.6	100	94.3	95.2ab
Glp 1004	70.7	94.3	97.1	100	90.5	94.4	95.0	97.1	100.0	96.6ab
Glp x-92	74.3	96.3	94.3	100	91.2	87.9	93.6	99.3	97.2	94.5ab
Glp x-1127(a)	72.2	94.3	97.9	99.3	90.9	95.7	97.2	94.3	94.3	95.4ab
Mexican 142	70.0	88.6	99.3	98.6	89.1	94.3	93.7	98.6	97.9	96.1ab
Glp 585	76.4	99.3	98.6	99.3	93.4	87.8	99.4	96.4	92.9	94.1b
Time of planting means	71.4a	95.1a	97.1a	99.4b		91.6b	96.4a	97.9a	96.6a	
Statistical analysis:										
cultivar:										
F value		2.48*					1.35			
C V(%)		4.6					4.3			
S E		1.1					1.0			
LSD :5%		3.0					2.9			
1%		3.9					3.8			
0.1%		5.1					5.0			
Time of planting means		227.***					5.42*			
C V(%)		5.1					6.4			
S E		0.9					1.2			
LSD :5%		2.78					3.8			
1%		4.0					5.4			
0.1%		5.9					7.9			

Statistical analysis is on transformed values Arcsin $\sqrt{X}$.

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

Table 19. Seasonal mean number of beanfly eggs in leaves of bean cultivars grown on four planting dates during the short rains of 1985; long rains, off-season and short rains of 1986 at NAL, Nairobi

Cultivars	Short rains of 1985					Long rains of 1986					Off-season of 1986					Short rains of 1986				
	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3th planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	3.0	5.2	3.5	6.1	4.5ab	4.5	7.8	7.0	7.5	6.7cd	12.7	13.7	12.8	8.9	12.0a	2.7	4.7	4.6	6.5	4.6ab
Glp 24	4.0	5.9	4.8	5.7	5.1a	4.2	7.2	9.1	7.9	7.1bc	12.6	11.5	12.4	9.2	11.4ab	1.9	4.6	4.3	6.6	4.4b
Glp 1004	2.7	4.1	4.0	6.0	4.2ab	4.0	7.2	7.6	7.4	6.5d	13.2	12.5	11.0	9.0	11.4ab	2.5	4.2	4.8	6.8	4.6ab
Glp x-92	3.3	5.2	5.3	6.4	5.0a	4.6	8.8	9.5	8.0	7.7a	13.6	11.3	11.5	8.3	11.2ab	2.5	5.6	4.6	6.7	4.9ab
Glp x-1127 (a)	3.3	4.1	3.6	5.3	4.1b	5.2	7.2	8.2	7.7	7.1bc	14.2	12.3	11.9	8.3	11.7a	2.7	4.6	5.4	6.7	4.9ab
Mexican 142	3.7	4.6	4.3	5.6	4.5ab	4.0	9.2	9.2	9.2	7.9a	12.0	11.1	12.3	8.1	10.6b	2.4	5.7	5.5	5.9	4.9ab
Glp 585	4.0	5.4	3.6	5.5	4.6ab	4.6	8.4	9.3	7.4	7.4ab	12.7	12.1	9.9	9.2	11.0ab	2.0	5.4	5.7	7.1	5.0a
Time of planting means	3.4c	4.9ab	4.2bc	5.8a		4.4b	8.0a	8.6a	7.9a		13.0a	12.1ab	11.5b	8.7c		2.4c	5.0b	5.0b	6.6a	
Statistical analysis																				
Cultivars:																				
F value	1.788					8.911^{***}					2.080					1.996				
C V (%)	25.7					9.2					11.2					14.3				
S E	0.3					0.2					0.3					0.2				
LSD: 5%						0.6														
1%						0.7														
0.1%						1.0														
Time of planting																				
F value	11.514^{**}					32.069^{***}					32.402^{***}					109.477^{***}				
C V (%)	34.9					24.2					15.1					18.7				
S E	1.0					0.3					0.3					0.2				
LSD: 5%	0.3					1.0					1.0					0.6				
1%	0.5					1.4					1.4					0.9				
0.1%						1.5					15.0					1.4				

Statistical analysis is on tranformed values $\sqrt{x+0.5}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

$^{**}p < 0.01$; $^{***}p < 0.001$.

Glp x-92 and Mexican 142 had higher numbers of beanfly eggs in the leaves than the other bean cultivars during this season. No significant differences were observed for the other seasons. The mean number of eggs in the leaves were significantly different between the four planting dates in all the seasons. There were more eggs in the leaves in the late planted than in the early planted bean plants during the short rains of 1985, long and short rains of 1986. During the off-season of 1986 the late planted beans were less oviposited upon than the early planted beans. The percentage plants with eggs in the leaves among the bean cultivars were statistically significant during the long rains of 1986 (Table 20). Glp x-92 , Mexican 142 and Glp 585 had higher percentage infested bean plants with eggs than other bean cultivars during this season. There were fewer plants with eggs in the early planted than in the late planted bean plants.

There was no oviposition in the stems of bean cultivars during the short rains of 1985, long and short rains of 1986. There was oviposition in the stems of bean cultivars during off-season of 1986 (Table 21). The mean number of eggs in the stems were statistically similar among the bean cultivars. However, Glp 2, Glp 24 and Glp 1004 had higher mumbers of beanfly eggs in the stems than other bean cultivars during the season. The mean number of eggs in the stems were significantly different between the four planting dates during the off-season of 1986. The late planted beans were less oviposited upon than the early planted beans.

Table 20. Beanfly eggs infestation in leaves of bean cultivars grown in four planting dates in two seasons at NAL,Nairobi.

	Long rains of 1986				Short rains of 1986					
Cultivars	1st planting	2rd planting	3rd planting	4th planting	Cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	44.2	69.2	60.8	70.8	61.2bc	21.0	44.0	29.0	64.0	39.5b
Glp 24	35.8	60.0	74.2	69.2	59.8c	32,0	54.0	49.0	60.0	48.8a
Glp 1004	40.0	69.2	70.9	70.8	62.7abc	19.0	34.0	44.0	73.0	42.5ab
Glp x-92	41.7	69.2	75.8	77.5	66.0a	26.0	44.0	56.0	61.0	46.8ab
Glp x-1127(a)	40.0	62.5	72.5	72.5	61.9bc	21.0	45.0	37.0	61.0	41.0ab
Mexican 142	35.0	70.0	75.0	78.4	64.6a	35.0	37.0	44.0	52.0	43.5ab
Glp 585	42.5	73.4	77.5	73.3	66.7a	28.0	58.0	40.0	48.	
Time of planting means	39.9b	67.6a	72.4a	73.2a		26.oc	45.1b	42.7b	59.9a	
Statistical analysis cultivar:										
F value	3.92**					1.67				
C V (%)	8.2					23.2				
S E	1.3					2.5				
LSD : 5%	3.6					7.1				
1%	4.8					9.4				
0.1%	6.2					12.1				
Time of planting means										
F value	54.270***					24.1***				
C E(%)	17.9					34.5				
S E	2.1					2.8				
LSD 5%:	6.9					9.1				
1%	9.8					13.0				
0.1%	14.3					19.1				

Statistical analysis is on transformed values Arcsin$\sqrt{x}$

Means in each column followed by the same letter aae not significantly different at 5% based on Duncan's multiple range test.

**$P < 0.01$; ***$p < 0.001$.

Table 21. Seasonal mean number of beanfly eggs in stems of bean cultivars grown in four planting dates during off-season of 1986 at NAL, Nairobi.

Cultivars	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	3.8	3.8	4.8	3.0	3.8a
Glp 24	4.1	3.9	3.8	3.0	3.7a
Glp 1004	4.7	4.1	4.3	3.1	4.0a
Glp x-92	4.4	3.5	3.6	2.4	3.5a
Glp x-1127(a)	4.1	3.7	3.9	2.4	3.5a
Mexican 142	3.7	3.4	3.8	2.3	3.3a
Glp 585	3.8	4.1	3.7	2.1	3.4a
Time of Planting means	4.1a	3.8a	4.0a	2.6b	

Statistical analysis:

Cultivars:

F value:	0.450
C V (%):	25.2
S E :	0.2

Time of planting means:

F value:	14.782***
C V (%):	25.8
S E :	0.2
LSD :	5% : 0.6, 1%: 0.9; 0.1%: 1.4

Statistical analysis is on transformed values $\sqrt{x+0.5}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

$*P < 0.5$; $**P < 0.01$; $***p < 0.001$.

The mean number of larvae in the leaves were significantly different among the seven bean cultivars during the short rains of 1985 and the long rains of 1986 (Table 22). The mean number of larvae in the bean cultivars were statistically similar during the off-season of 1986 and short rains of 1986. There was no bean cultivar which had consistently high or low numbers of larvae in the four seasons. The mean number of larvae in the leaves were significantly different between the four planting dates in all the seasons. The late planted bean plants were more infested than the early planted bean plants during the short rains of 1985; long and short rains of 1986. The late planted bean plants were less infested than the early planted bean plants during the off-season of 1985. The percent plants infested with larvae in the leaves were significantly different among the bean cultivars during the short and long rains of 1986 (Table 23). There were more plants with larvae in the leaves in the late planted than in the early planted bean crop. The mean number of larvae in the stems differed significantly among the bean cultivars during the short rains of 1985, off-season and short rains of 1986 (Table 24) . The mean number of larvae in the stems of bean cultivars were statistically similar during the long rains of 1986. Mexican 142 had consistently low numbers of larvae in the stems. The mean numbers of larvae in the stems were significantly different between the four planting dates in the four seasons. The late planted beans had more larvae in the stems than the early planted beans during the short rains of 1985, long and short rains of 1986. The late planted beans had less

Table 22. Seasonal mean number of beanfly larvae in leaves of bean cultivars grown in four planting dates during the short rains of 1985; long rains, off-season and short rains of 1986 at NAL, Nairobi.

	Short rains of 1985					Long rains of 1986					Off-season of 1986					Short rains of 1986				
Cultivars	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	1.6	3.9	2.9	3.6	3.0b	1.5	4.5	4.5	4.7	3.8c	7.4	8.7	5.9	5.8	6.9a	2.1	3.5	4.4	5.5	3.9a
Glp 24	2.2	5.2	3.9	4.1	3.9a	2.4	3.7	5.3	4.7	4.0abc	6.2	7.0	5.3	5.7	6.1b	1.5	3.5	4.4	5.2	3.7a
Glp 1004	1.4	2.7	3.5	4.3	3.0b	1.6	4.4	4.7	4.3	3.8c	7.1	7.8	6.5	6.0	6.9ab	2.3	3.3	4.3	5.0	3.7a
Glp x-92	2.6	4.0	5.2	4.3	4.0a	2.3	4.7	6.1	4.3	4.4ab	7.0	6.4	6.4	5.7	6.4ab	1.7	3.4	4.5	5.3	3.7a
Glp x-1127 (a)	2.1	3.1	3.2	3.4	2.9b	2.3	4.0	5.2	4.6	4.0bc	7.1	6.5	5.7	5.8	6.3ab	1.3	3.6	4.6	5.7	3.8a
Mexican 142	2.2	3.9	3.8	3.2	3.3ab	1.3	4.7	6.1	5.9	4.4a	6.4	6.5	5.7	6.0	6.1ab	2.1	3.4	4.7	4.5	3.6a
Glp 585	2.7	4.1	3.2	3.9	3.5ab	2.6	4.9	5.6	4.7	4.4a	6.2	7.8	5.9	5.5	6.3ab	2.1	3.4	4.7	4.5	3.6a
Time of planting means	2.1b	3.8a	3.6a	3.8a		2.0c	4.4b	5.4a	4.7b		6.8ab	7.2a	5.9b	5.8b		1.9d	3.5c	4.5b	5.3a	
Statistical analysis																				
Cultivars:																				
F value	3.179**					4.742***					1.693					1.292				
C V (%)	30.2					13.0					16.4					16.4				
S E	0.3					0.1					0.3					0.2				
LSD: 5%	0.8					0.3														
1%	1.1					0.4														
0.1%	1.5					0.5														
Time of planting																				
F value	9.367**					52.511***					4.217*					214.310***				
C V (%)	42.5					26.1					28.1					14.2				
S E	0.3					0.2					0.3					0.1				
LSD: 5%	1.0					0.6					1.0					0.3				
1%	1.4					0.9											0.5			
0.1%						1.4										0.7				

Statistical analysis is on tranformed values $\sqrt{x+0.5}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

$^{*}p < 0.5$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Table 22. Seasonal mean number of beanfly larvae in leaves of bean cultivars grown in four planting dates during the short rains of 1985; long rains, off-season and short rains of 1986 at NAL, Nairobi.

Cultivars	Short rains of 1985					Long rains of 1986					Off-season of 1986					Short rains of 1986				
	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	1.6	3.9	2.9	3.6	3.0b	1.5	4.5	4.5	4.7	3.8c	7.4	8.7	5.9	5.8	6.9a	2.1	3.5	4.4	5.5	3.9a
Glp 24	2.2	5.2	3.9	4.1	3.9a	2.4	3.7	5.3	4.7	4.0abc	6.2	7.0	5.3	5.7	6.1b	1.5	3.5	4.4	5.2	3.7a
Glp 1004	1.4	2.7	3.5	4.3	3.0b	1.6	4.4	4.7	4.3	3.8c	7.1	7.8	6.5	6.0	6.9ab	2.3	3.3	4.3	5.0	3.7a
Glp x-92	2.6	4.0	5.2	4.3	4.0a	2.3	4.7	6.1	4.3	4.4ab	7.0	6.4	6.4	5.7	6.4ab	1.7	3.4	4.5	5.3	3.7a
Glp x-1127 (a)	2.1	3.1	3.2	3.4	2.9b	2.3	4.0	5.2	4.6	4.0bc	7.1	6.5	5.7	5.8	6.3ab	1.3	3.6	4.6	5.7	3.8a
Mexican 142	2.2	3.9	3.8	3.2	3.3ab	1.3	4.7	6.1	5.9	4.4a	6.4	6.5	5.7	6.0	6.1ab	2.1	3.4	4.7	4.5	3.6a
Glp 585	2.7	4.1	3.2	3.9	3.5ab	2.6	4.9	5.6	4.7	4.4a	6.2	7.8	5.9	5.5	6.3ab	2.1	3.4	4.7	4.5	3.6a
Time of planting means	2.1b	3.8a	3.6a	3.8a		2.0c	4.4b	5.4a	4.7b		6.8ab	7.2a	5.9b	5.8b		1.9d	3.5c	4.5b	5.3a	
Statistical analysis																				
Cultivars:																				
F value	3.179**					4.742***					1.693					1.292				
C V (%)	30.2					13.0					16.4					16.4				
S E	0.3					0.1					0.3					0.2				
LSD: 5%	0.8					0.3														
1%	1.1					0.4														
0.1%	1.5					0.5														
Time of planting																				
F value	9.367**					52.511***					4.217*					214.310***				
C V (%)	42.5					26.1					28.1					14.2				
S E	0.3					0.2					0.3					0.1				
LSD: 5%	1.0					0.6					1.0					0.3				
1%	1.4					0.9										0.5				
0.1%						1.4										0.7				

Statistical analysis is on tranformed values $\sqrt{x+0.5}$

Means in each column followed by the same letter are not significantlydifferent at 5% based on Duncan's multiple range test.

$^{*}p \leq 0.5$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$.

Table 23. Beanfly larvae infestation in leaves of bean cultivars grown in four planting dates in two season at Nal, Nairobi.

	Long rains of 1986					Short rains of 1986				
Cultivars	1st planting	2rd planting	3rd planting	4th planting	Cultivars means	1st planting	2rd planting	3rd planting	4th planting	Cultivars means
Glp 2	5.0	46.0	50.0	52.0	38.3bc	9.0	28.0	22.0	21.0	20.0c
Glp 24	14.0	29.0	61.0	31.0	33.8c	13.0	42.0	26.0	28.0	27.3abc
Glp 1004	7.0	41.0	54.0	45.0	36.8bc	6.0	25.0	19.0	41.0	22.8bc
Glp x-92	13.0	39.0	64.0	46.0	40.5ab	16.0	34.0	40.0	38.0	32.0a
Glp x-1127(a)	15.0	42.0	57.0	50.0	41.0ab	13.0	28.0	19.0	32.0	23.0bc
Mexican 142	6.0	50.0	62.0	58.0	44.0a	19.0	34.0	24.0	28.0	26.3abc
Glp 585	19.0	42.0	54.0	50.0	41.3ab	15.0	32.0	31.0	38.0	29.0ab
Time of planting means	11.3c	41.3b	57.4a	47.4b		13.0b	31.9a	25.9a	32.3a	

Statistical analysis		
cultivars:		
F value	3.90*	2.41*
C V (%)	17.4	41.2
S E	1.7	2.7
LSD 5 %	4.8	7.5
1%	6.4	10.0
0.1%	8.2	13.0
Time of planting means		
F value	81.560***	14.570***
C V (%)	29.5	48.3
S E	2.2	2.4
LSD: 5%	7.0	7.5
1%	10.1	10.7
0.1%	14.8	15.8

Statistical analysis is on transformed values $\arcsin\sqrt{X}$.

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

*$P < 0.5$; **$P < 0.ol$; ***$p < 0.001$.

Table 24. Seasonal mean number of beanfly larvae in stems of bean cultivars grown in four planting dates during the short rains of 1985; long rains, off-season and short rains of 1986 at NAL, Nairobi

	Short rains of 1985					Long rains of 1986					Off-season of 1986					Short rains of 1986				
Cultivars	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd plantng	4rd planting	Cultivar means	1st planting	2rd planting	3rd planting	4rd planting	cultivar means
Glp 2	2.9	4.4	4.8	7.0	4.6ab	2.1	2.9	4.3	3.6	3.2a	11.0	10.8	7.5	8.4	9.4a	2.2	2.9	5.0	5.8	4.0a
Glp 24	2.9	4.8	5.9	6.2	4.9ab	2.0	2.6	4.1	4.3	3.3a	6.0	9.5	7.0	8.8	8.3b	2.1	2.3	3.9	4.7	3.3bc
Glp 1004	1.9	4.0	5.0	7.1	4.5b	2.2	2.8	4.0	4.0	3.2a	9.1	9.2	8.0	8.1	8.6b	1.3	3.1	4.5	5.9	3.7ab
Glp x-92	2.6	5.4	5.6	7.4	5.2a	1.8	2.8	4.2	3.3	3.1a	10.6	10.1	8.0	8.0	9.4a	2.3	2.9	4.4	5.6	3.6a
Glp x-1127 (a)	2.6	4.0	5.4	6.5	4.6ab	2.0	2.8	4.2	3.3	3.1a	9.3	9.5	7.6	9.1	8.9ab	1.7	2.4	3.5	5.2	3.2bc
Mexican 142	2.4	4.4	4.3	5.9	4.3b	1.7	3.6	3.9	3.1	3.1a	8.0	9.1	7.5	8.8	8.3b	1.6	2.9	3.7	4.3	3.1c
Glp 585	2.6	4.1	4.3	6.7	4.4b	2.3	3.2	4.7	3.7	3.5a	9.1	9.3	8.0	10.0	9.1ab	2.3	2.5	4.7	4.5	3.5abc
Time of planting means	2.5c	4.5b	5.0b	6.7a		2.0c	3.0b	4.2a	3.7a		9.3a	9.6a	7.6b	8.9b		1.9d	2.7c	4.3b	5.1a	
Statistical analysis																				
Cultivar:																				
F value	2.270*					0.900					3.218**					3.522**				
C V (%)	18.9					17.9					11.8					20.2				
S E	0.2					0.1					0.3					0.2				
LSD: 5%	0.6										0.8					0.6				
											1.1					0.7				
Time of planting																				
F value	59.182***					22.614***					5.427*					131.880***				
C V (%)	25.2					32.6					22.3					19.0				
S E	0.2					0.2					0.4					0.1				
LSD: 5%	0.6					0.6					1.3					0.3				
1%	0.9					1.4										0.5				
0.1%	1.4					1.4										0.7				

Statistical analysis is on tranformed values $\sqrt{x+0.5}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

*P< 0.5; **P < 0.01; ***p<0.001.

larvae in the stems than the early planted beans during off-season of 1986. The percentage infested plants with larvae in the stems were statistically similar among the bean cultivars (Table 25). There were significant differences in percent bean plants with larvae in the stems in the four planting dates. There were more bean plants infested with larvae in stems in late planted than in early planted bean crop during the short and long rains of 1986. There were significant differences in percent bean plants with larvae in stems in the four planting dates . There were more plants infested with larvae in stems in late planted than in early planted beans during the short rains of 1986.

The mean number of *O. phaseoli* puparia in the seven bean cultivars differed significantly during the long rains and off-season of 1986 (Table 26). They were statistically similar during the short rains of 1985 and the short rains of 1986. Mexican 142 had lower numbers of *O. phaseoli* puparia than other bean cultivars during the four seasons. The differences in *O. phaseoli* puparia in other bean cultivars was small and not consistent. The mean number of *O. phaseoli* puparia in the bean cultivars were significantly different in the four planting dates. The late planted beans had more *O. phaseoli* puparia than the early planted beans during the short rains of 1985; long and short rains of 1986. There were significant differences among the bean cultivars in percent plants with *O. phaseoli* puparia during the short rains of 1986 (Table 27). Mexican 142 had the least number of plants with *O. phaseoli* puparia. There were significant differences in percent

Table 25. **Beanfly larvae infestation in stems of bean cultivars grown in four planting dates in two seasons at NAL, Nairobi.**

	Long rains of 1986					Short rains of 1986				
Cultivars	1st planting	2rd planting	3rd planting	4th planting	cultivars means	1st planting	2rd planting	3rd planting	4th planting	cultivars means
Glp 2	11.0	30.0	44.0	32.0	29.3a	31.3	53.8	48.8	14.0	36.9b
Glp 24	15.0	27.0	41.0	39.0	30.5a	26.3	50.0	56.3	68.8	50.3a
Glp 1004	12.0	25.0	42.0	42.0	30.3a	13.8	48.8	57.5	65.0	46.3a
Glp x-92	11.0	31.0	44.0	41.0	31.8a	20.0	57.5	45.0	68.8	47.8a
Glp x-1127(a)	12.0	19.0	44.0	35.0	27.5a	27.5	46.3	51.3	70.0	48.8a
Mexican 142	10.0	21.0	42.0	32.0	26.3a	20.0	51.3	50.0	57.5	44.7ab
Glp 585	15.0	22.0	43.0	39.0	29.8a	26.3	47.5	37.5	65.0	44.1ab
Time of planting means	12.3c	25.0b	42.9a	37.1a		23.6c	50.7ab	49.5b	58.4a	
Stistical analysis										
Cultivars:										
F value	0.78					2.12				
C V	29.0					26.5				
S E	2.1					3.0				
LSD: 5%	6.0					8.5				
1%	7.9					11.1				
0.1%	10.3					14.4				
Time of planting										
F value	24.250***					35.340***				
C V	49.8					29.7				
S E	2.8					2.6				
LSD: 5%	8.8					8.2				
1%	12.7					11.7				
0.1%	18.6					17.2				

Statistical analysis is on transformed values Arcsin $\sqrt{x}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

***$p < 0.001$.

Table 26. Seasonal mean number of O. phaseoli puparia in bean cultivars grown in four-planting dates during the short rains of 1985; long rains, off-season and short rains of 1986 at NAL, Nairobi

	Short rains of 1985					Long rains of 1986					Off-season of 1986					Short rains of 1986				
Cultivars	1st planting	2rd planting	3rd planting	4rd planting	Cultivar means	1st planting	2rd planting	3rd planting	4th planting	Cultivar means	1st planting	2rd planting	3rd planting	4th planting	Cultivar means	1st planting	2rd planting	3rd planting	4th planting	Cultivar means
Glp 2	2.4	3.9	4.9	9.7	5.2ab	1.3	2.6	3.8	2.9	2.7ab	3.7	2.4	1.3	3.2	2.7a	1.3	2.7	4.1	7.4	3.9a
Glp 24	2.4	4.6	5.5	9.8	5.6a	1.4	2.9	4.4	3.6	3.1a	2.4	2.2	1.5	3.6	2.4a	1.4	3.3	3.8	7.7	4.1a
Glp 1004	1.7	3.1	4.6	9.0	4.6b	1.5	1.6	3.0	3.4	2.6b	2.4	1.4	1.3	3.5	2.1ab	1.7	3.6	4.7	8.1	4.0a
Glp x-92	2.1	4.0	4.1	11.4	5.4ab	1.2	2.2	3.1	2.8	2.3b	2.2	1.5	1.9	3.5	2.3a	1.8	3.1	4.1	7.7	4.2a
Glp x-1127 (a)	2.2	4.0	4.6	8.4	4.8ab	1.4	2.9	3.1	3.2	2.7b	2.6	1.8	1.4	3.5	2.3a	1.7	2.5	4.2	6.5	3.7a
Mexican 142	1.9	3.4	3.2	9.3	4.4b	1.1	1.8	2.7	2.0	1.9c	1.6	1.5	1.3	2.0	1.6a	2.0	3.1	3.6	5.6	3.6a
Glp 585	2.5	4.1	4.7	9.7	5.2ab	1.1	2.5	3.6	2.5	2.4d	3.7	1.8	1.7	2.8	2.5a	1.6	2.9	4.3	7.6	4.1a
Time of planting means	2.2c	3.9b	4.5b	9.6a		1.3b	2.4a	3.4a	2.9a		2.6ab	1.8bc	1.5c	3.2a		1.6d	3.0c	4.1b	6.9a	
Statistical analysis																				
Cultivars:																				
F value	2.114					6.301***					3.428**					1.127				
C.V (%)	23.8					23.6					32.6					20.4				
S.e	0.3					0.1					0.2					0.2				
Lsd: 5%						0.3					0.6									
1%						0.4					0.7									
0.1%						0.5														
Time of planting:																				
F value	56.915***					16.741***					5.307*					127.530***				
C.V (%)	44.5					46.5					78.1					26.9				
S.e	0.4					0.2					0.3					0.2				
Lsd: 5%	1.3					0.6					1.0					0.6				
1%	1.8					0.9										0.9				
0.1%	2.7					1.4										1.4				

Statistical analysis is on transformed values $\sqrt{x+0.5}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

*p< 0.5; **p< 0.01; ***p< 0.001.

Table 27. Infestation of bean cultivars with O. phaseoli puparia in four planting dates in two seasons at NAL, Nairobi.

	Long rains of 1986					Short of season,1986				
Cultivars	1st planting	2rd planting	3rd planting	4th planting	cultivars means	1st planting	2rd planting	3rd planting	4th planting	cultivars means
Glp 2	25.0	30.0	42.0	24.0	30.3a	23.4	53.4	58.3	73.3	52.1a
Glp 24	20.0	27.0	48.0	31.0	31.5a	25.0	55.0	60.0	73.3	53.3a
Glp 1004	21.0	14.0	31.0	32.0	24.5ab	16.7	40.0	65.0	68.3	47.5ab
Glp x-92	25.0	27.0	29.0	23.0	26.0ab	30.0	55.0	46.7	78.2	52.5a
Glp x-1127 (a)	17.0	35.0	28.0	29.0	27.3ab	25.0	60.0	55.0	78.3	54.6a
Mexican 142	15.0	25.0	26.0	15.0	20.3b	21.7	45.0	43.4	60.0	42.5b
Glp 585	18.0	40.0	35.0	16.0	27.3ab	31.7	53.3	55.0	70.0	52.5a
Time of planting means	20.1b	28.3ab	34.1a	24.3ab		24.8c	51.7b	54.8b	71.6a	
Statistical analysis										
Cultivars:										
F value	2.03					2.34*				
C V (%)	39.1					21.8				
S E	2.6					2.8				
LSD: 5%	7.3					7.8				
1%	9.8					10.3				
0.1%	12.6					13.3				
Time of planting means										
F value	2.74					69.190***				
C V(%)	71.4					24.3				
S E	3.6					2.3				
LSD: 5%	11.5					7.5				
1%	16.6					10.7				
0.1%	24.4					15.8				

Statistical analysis is on transformed values Arcsin $\sqrt{X}$.

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple test.

$^{*}P < 0.5$; $^{***}P < 0.001$.

plants with O. phaseoli puparia between the four planting dates during the short rains of 1986. There were more plants with O. phaseoli in late than in the early planted bean crop.

There were significant differences in the mean number of O. spencerella puparia in the bean cultivars in the four seasons (Table 28). Mexican 142 had consistently low while Glp 2 had consistently high numbers of O. spencerella puparia. The differences between O. spencerella puparia in other bean cultivars were small and inconsistent. There were significant differences between the four planting dates in O. spencerella puparia in the four seasons. The late planted bean crop had more puparia than the early planted bean crop during the short rains of 1985; long and short rains of 1986 . During the off-season of 1986 there was inconsistent increase in O. spencerella puparia with late planting. There were significant differences in percent plants with O spencerella puparia among the bean cultivars (Table 29). Mexican 142 had consistently low numbers of plants with O. spencerella puparia. The late planted bean crop had higher percent plants with O. spencerella puparia than the early planted bean crop.

There were significant differences among the bean cultivars in beanfly stem damage (Table 30). Glp 1004 and Glp x-92 showed the highest while Mexican 142, Glp x-1127(a) and Glp 24 showed the least stem damage. There were significant differences between the four planting dates in beanfly stem damage. The late planted beans had higher stem damage than the early planted ones. The beanfly infestation in the bean crop during the off-season of 1986 was too

Table 28. Seasonal mean number of *O. spencerella* puparia in bean cultivars grown in four planting dates during short rains of 1985; long rains, off-season and short rains of 1986 at NAL, Nairobi.

	Short rains of 1985					Long rains of 1986					Off-season Of 1986					Short rains of 1986				
Cultivar	1st planting	2rd planting	3rd planting	4rd planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	1.6	3.4	4.1	6.0	3.6a	1.1	2.7	3.3	3.5	2.6a	7.1	4.6	4.7	5.9	5.7a	3.5	5.3	7.5	9.0	6.3a
Glp 24	1.2	2.5	3.1	4.8	2.9b	1.1	2.2	3.8	3.6	2.7a	5.0	4.0	3.7	5.8	4.6b	2.5	3.4	5.4	7.6	4.7b
Glp 1004	0.9	2.4	3.3	5.7	3.1b	1.4	2.3	2.5	3.7	2.5a	5.0	3.5	4.3	5.9	4.7b	3.1	4.0	6.4	7.4	5.2b
Glp x-92	1.3	3.0	3.1	5.5	3.2ab	1.3	2.0	2.7	3.2	2.3a	4.4	3.6	3.7	6.8	4.6b	2.3	4.0	5.8	7.9	5.0b
Glp x-1127 (a)	1.6	2.5	3.6	5.1	3.2ab	0.7	2.5	3.3	3.8	2.6a	5.5	3.7	4.7	6.3	5.0ab	3.2	3.5	5.8	8.4	5.2b
Mexican 142	1.2	1.7	2.7	3.6	2.3c	1.3	1.1	2.4	2.5	1.8b	4.4	3.1	3.3	4.1	3.7c	2.7	3.6	4.1	5.8	4.0c
Glp 585	1.4	2.1	2.7	4.7	2.7bc	0.8	2.6	3.6	3.2	2.6a	6.4	3.8	3.6	4.9	4.7b	2.3	4.7	5.2	6.6	4.7b
Time of planting means	1.3c	2.5b	3.2b	5.1a		1.1c	2.2b	3.1a	3.3a		5.4a	3.8b	4.0b	5.7a		2.8d	4.1c	5.7b	7.5a	
Statistical analysis																				
Cultivar																				
F value	5.624***					4.583***					5.014***					16.887***				
C V (%)	25.7					23.4					21.1					13.3				
S E	0.2					0.1					0.2					0.2				
LSD: 5%	0.6					0.3					0.6					0.6				
1%	0.7					0.4					0.7					0.7				
0.1%	1.0					0.5					1.0					1.0				
Time of planting																				
F value	43.802***					23.939***					6.581*					121.285***				
C V (%)	41.3					44.9					42.5					19.5				
S E	0.2					0.2					0.4					0.2				
LSD: 5%	0.6					0.6					1.3					0.6				
1%	0.9					0.9										0.9				
0.1%	1.4					1.4										1.4				

Statistical analysis is on tranformed values $\sqrt{x+0.5}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

$^{*}p < 0.5$; $^{***}p < 0.001$.

Table 29. Infestation of bean cultivars with *O. spencerella* puparia in four planting dates in two seasons at NAL, Nairobi.

	Long rains of 1986					Short rains of 1986				
Cultivars	1st plantings	2rd planting	3rd planting	4th planting	cultivars means	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	17.0	31.0	31.0	32.0	27.8a	13.3	47.9	54.6	68.4	46.0a
Glp 24	11.0	22.0	39.0	33.0	26.3a	10.0	28.3	40.0	61.7	35.7b
Glp 1004	15.0	25.0	20.0	41.0	25.3a	3.4	31.7	40.0	68.3	35.8b
Glp x-92	20.0	23.0	23.0	25.0	22.8ab	8.3	36.7	35.0	68.3	37.1ab
Glp x_1127 (a)	15.0	28.0	30.0	38.0	27.8a	20.0	31.7	46.7	61.7	40.0ab
Mexican 142	14.0	6.0	28.0	17.0	16.3b	10.0	13.4	26.7	41.7	22.9c
Glp 585	21.0	33.0	25.0	29.0	27.0a	10.0	25.0	35.0	55.0	31.3bc
Time of planting means	16.1b	24.0ab	28.0a	30.7a		10.7d	30.7c	39.7b	60.7a	
Statistical analysis										
Cultivars										
F value	2.56*					4.78**				
C V (%)	41.7					37.1				
S E	2.6					3.3				
LSD: 5%	7.3					9.3				
1%	9.5					12.4				
0.1%	12.3					16.1				
Time of planting										
F value	5.63*					64.090***				
C V (%)	57.3					38.7				
S E	2.7					2.5				
LSD: 5%	8.6					8.3				
1%	12.4					12.0				
0.1%	18.2					17.7				

Statistical analysis is on transformed values Arcsin $\sqrt{x}$

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

$*p < 0.5$; $**P < 0.01$; $***p<0.001$.

Table 30. Mean damage scores of bean cultivars grown in four planting dates during short rains of 1986 at NAL, Nairobi.

	Short rains of 1986				
Cultivars	1st planting	2nd planting	3rd planting	4th planting	Cultivar means
Glp 2	2.2	2.1	3.2	3.0	2.6c
Glp 24	1.7	2.2	2.6	3.0	2.4d
Glp 1004	2.3	2.2	3.2	2.9	2.7b
Glp x-92	2.2	2.0	3.5	3.3	2.8a
Glp x-1127 (a)	2.0	2.0	2.7	2.8	2.4b
Mexican 142	2.0	1.9	2.7	2.8	2.4d
Glp 585	2.1	2.1	3.1	3.0	2.6c
Time of planting means	2.1b	2.1b	3.0a	3.0a	

Stastistical analysis:	
Cultivars:	
F value	40.682***
C V (%)	3.5
S E	0.02
LSD: 5%	0.07
1%	0.09
0.1%	0.1
Time of planting	
F value	31.019***
C V (%)	25.5
S E	0.1
LSD: 5%	0.3
1%	0.5
0.1%	0.7

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

***$p < 0.001$.

high to cause the death of the bean plants. Beanfly larvae, O. phaseoli puparia and O. spencerella puparia were found in the dead plants. O. spencerella puparia per plant were more than O. phaseoli puparia per plant in all the bean cultivars (Table 31). Mexican 142 and Glp 585 had less larvae and pupae per dead plant than other bean cultivars . There were no consistent differences in the early planted and late planted beans in the number of larvae and puparia in the dead bean plants.

There were significant differences among the bean cultivars in yield (Table 32). There was reduction in pods/plant, seed/pod and yield/plant when the bean cultivars were planted late in a season. The level of beanfly infestation reduced the yield of the late planted bean crop.

6:3:2. Evaluation of bean cultivars at different stages of growth for resistance to beanflies.

All the stages of the bean plants were punctured and oviposited upon but leaf puncturing and ovipostion were much greater in seedling than in older plants (Table 33). Consequently, the larvae and pupae in stems were more in Group 1 than Group 2 plants. The number of beanfly punctures, eggs, larvae and puparia were statistically similar among the bean cultivars. There were more eggs in leaves than in stems of bean cultivars. O. phaseoli were more than O. spencerella in the stems of the bean cultivars.

Table 31 Mean number of larvae and puparia per dead plant in bean cultivars grown in four planting dates during Off-season of 1986 at NAL, Nairobi.

	O. phaseoli puparia					O. spencerella puparia					larvae+puparia				larvae+
Cultivars	1st planting	2rd planting	3rd planting	4th planting	puparia means	1st planting	2rd planting	3rd planting	4th planting	puparia means	1st planting	2rd planting	3rd planting	4th planting	puparia means
Glp 2	6.9	1.0	2.3	2.2	3.1a	3.1	2.8	4.6	5.1	3.9bc	4.9	4.0	11.4	11.0	7.8ab
Glp 24	4.0	2.7	2.0	3.1	2.9a	4.0	3.0	3.9	5.6	4.1ab	8.4	6.6	10.0	11.6	9.0a
Glp 1004	2.4	2.5	2.4	2.2	2.4ab	3.5	5.2	4.6	6.1	4.8a	5.7	9.2	9.5	12.0	9.1a
Glp x-92	2.8	1.6	3.4	3.3	2.8a	4.3	3.7	4.6	4.9	4.4ab	7.1	6.1	11.3	10.8	8.8a
Glp x-1127 (a)	2.4	1.7	2.5	2.6	2.3ab	2.9	4.4	5.6	5.6	4.6ab	6.4	6.6	12.6	10.3	9.0a
Mexican 142	1.2	0.3	1.4	1.1	1.0a	2.4	1.2	2.4	1.8	1.9d	3.7	1.5	5.9	4.9	4.0a
Glp 585	2.8	0.9	2.1	3.1	2.2ab	2.8	2.0	3.7	4.7	3.3c	5.8	3.2	8.7	9.8	6.9b
Time of planting means	3.2a	1.5a	2.3a	2.5a		3.3b	3.1ab	4.2ab	4.6a		6.0b	5.3b	9.6a	10.0a	
Statistical analysis															
Cultivar:															
F value	1.712					14.554***					13.891***				
S E.	0.5					0.3					0.5				
LSD: 5%						0.7					1.4				
1%						1.0					1.9				
0.1%						1.3					2.4				
Time of planting															
F value	1.759					4.929*					14.774***				
S E	0.5					0.4					0.7				
LSD: 5%						1.1					2.1				
1%						1.5					3.0				
0.1%						1.9					4.4				

Statistical analysis is on transformed values $\sqrt{x+0.5}$
Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.
$*P < 0.5$; $***P < 0.001$.

Table 32. Yield parameters of bean cultivars grown in four planting dates during the long and short rains of 1986 at NAL, Nairobi.

	Long rains of 1986										Short rains of 1986														
	poded/plant					seed wt (Gms/ plant)					pods/ plant					seeds/pod					seeds wt (Gms/ plant)				
Cultivars	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means	1st planting	2rd planting	3rd planting	4th planting	cultivar means
Glp 2	13.8	8.8	5.8	5.7	8.5cd	25.8	18.8	9.5	8.7	15.7ab	6.1	5.8	9.1	5.4	6.6c	3.1	3.4	3.4	2.0	3.0b	9.7	9.1	13.5	4.8	9.3bc
Glp 24	10.6	12.5	6.2	6.9	9.0bcd	15.2	21	8.5	8.4	13.3abc	8.1	9.4	6.0	7.5	7.7c	3.8	3.6	3.2	2.5	3.3b	10.4	9.5	6.1	5.9	8.0cd
Glp 1004	8.1	9.6	5.4	5.8	7.2d	12.3	17.0	8.4	8.8	11.6bc	5.0	7.6	6.9	6.7	6.5c	3.3	3.1	3.6	2.6	3.2b	7.9	10.3	9.1	7.3	8.6bcd
Glp x-92	13.3	11.1	9.0	7.8	10.3bc	26.6	16.6	11.2	10.0	16.0abc	9.7	8.3	11.0	7.9	9.2b	3.3	3.4	3.6	2.4	3.2b	12.9	11.4	14.2	6.9	11.3a
Glp x-1127(X)	6.2	12.7	5.8	5.7	7.6d	9.0	25.3	8.9	9.4	13.1ab	6.1	8.7	8.8	5.4	7.2c	3.3	3.7	3.7	2.7	3.3ab	8.4	13.9	12.5	5.4	10.0ab
Mexican 142	22.3	14.5	15.9	15.6	17.1a	24.5	12.8	11.2	11.5	15.0ab	13.3	13.4	12.5	9.2	12.1a	4.4	3.8	3.9	2.9	3.7a	9.8	q7.2	7.5	3.9	7.1d
Glp 585	14.5	12.0	8.4	9.2	11.0b	16.7	11.0	8.3	7.0	10.7c	11.0	8.3	11.9	10.8	10.5b	3.0	3.4	4.0	3.0	3.3ab	7.8	6.8	11.7	7.5	8.5bcd
Time of planting means	12.7a	11.6a	8.1b	8.1b		18.6a	17.4a	9.4b	9.1b		8.4ab	8.8ab	9.4a	7.5b		3.4a	3.5a	3.6a	2.6b		9.5a	9.7a	10.7a	5.9b	
Statistical analysis																									
Cultivars											18.745***					2.701*					6.006***				
F value	16.401***					2.904*					22.9					17.9					25.5				
C V (%)	31.0					34.9					0.5					0.1					0.6				
S E	1.0					1.2					1.4					0.4					1.6				
LSD: 5%	2.2					3.4					1.8										2.1				
1%	2.9										2.4										2.8				
0.1%	3.8																								
Time of planting																									
F value	22.584***					50.581***					4.251*					11.262**					10.992**				
C V (%)	26.1					27.6					23.5					23.1					36.9				
S E	1.0					1.0					0.4					0.1					0.6				
Lsd: 5%	1.6					2.3					1.2					0.5					2.0				
1%	2.3					3.3										0.7					2.9				
0.1%	2.9					4.8																			

Means in each column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

*P< 0.5; **p< 0.01; ***p< 0.001.

Table 33. Mean number of beanfly leaf punctures, eggs, larvae and puparia on bean cultivars grown in three planting dates.

Cultivars	Punctures				Eggs in leaves				Eggs in stems				Larvae in stems				O. spencerella				O. phaseoli			
	1st planting	2nd planting	3rd planting	cultivar means	1st planting	2nd planting	3rd planting	cultivar means	1st means	2nd planting	3rd planting	cultivar mean	1st planting	2nd planting	3rd planting	cultivar means	1st planting	2nd planting	3rd planting	cultivar means	1st planting	2nd planting	3rd planting	cultivar means
Glp 2	11.0	13.2	18.4	14.2a	2.3	2.4	3.4	2.7a	1.2	1.0	1.8	1.3a	1.6	2.1	1.3	1.7b	1.3	1.1	1.8	1.4a	1.7	1.2	3.3	2.1ab
Glp 24	8.9	12.2	16.6	12.6ab	2.0	2.2	2.6	2.3a	0.9	1.5	1.3	1.2a	1.4	2.1	1.5	1.7b	1.0	1.0	1.5	1.2a	2.1	1.3	3.3	2.2ab
Glp 1004	10.0	9.9	19.4	13.1ab	2.4	1.8	2.9	2.4a	0.9	1.3	1.9	1.4a	1.7	2.1	0.9	1.6b	0.8	1.0	1.7	1.2a	2.0	1.5	3.0	2.2ab
Glp x-92	5.6	13.6	19.2	12.8c	1.3	2.4	3.8	2.5a	0.8	1.0	2.5	1.4a	2.2	2.7	1.7	2.2a	1.3	0.9	1.7	1.2a	2.0	2.0	3.5	2.5a
Glp x-1127 (a)	8.5	10.6	20.2	13.1ab	2.8	2.3	3.2	2.7a	0.9	1.1	1.8	1.3a	1.3	2.0	1.2	1.6b	1.2	1.1	2.1	1.5a	1.6	1.4	3.1	2.0ab
Mexican 142	6.5	10.6	18.1	11.7b	2.1	2.1	3.5	2.6a	1.2	1.1	1.8	1.4a	1.2	2.0	1.4	1.5b	0.8	1.0	1.6	1.1a	1.8	1.3	2.3	1.8b
Glp 585	9.9	11.6	18.2	13.2ab	2.0	2.3	2.9	2.4a	1.1	1.1	2.0	1.4a	1.4	1.6	1.5	1.5b	1.7	0.9	1.6	1.4a	1.7	1.6	2.5	1.9b
Time of planting means	8.6b	11.7b	18.4a		2.1b	2.2b	3.2a		1.0c	1.2b	1.9a		1.5b	2.1a	1.4b		1.2b	1.0b	1.8a		1.8b	1.5b	3.0a	
Statistical analysis																								
Cultivar:																								
F value	1.278				0.708				0.379				2.481				0.816				1.796			
C V (%)	15.0				21.9				25.4				30.3				38.3				27.7			
S E	0.9				0.3				0.1				0.02				0.2				0.2			
Time of planting means																								
F value	14.297*				19.884**				142.942***				6.937*				12.052*				7.138*			
C V (%)	47.6				28.3				12.8				43.3				45.4				74.5			
S E	1.9				0.2				0.05				0.3				0.2				0.4			
LSD: 5%	1.6				0.4				0.3				0.4				0.4				0.5			
1%					0.5				0.4															
0.1%					0.7				0.5															

Means in the same column followed by the same letter are not significantly different at 5% based on Duncan's multiple range test.

*P< 0.5; **p< 0.01; ***p<0.001.

6:4. DISCUSSION.

A close scrutiny of the results indicate that the parameters that have been used to evaluate bean cultivars do not show seasonal or varietal consistency. Thus although there were no significant differences for leaf punctures for the seven bean cultivars during the off-season of 1985 growing period, the differences in punctures and oviposition obtained during the previous long rains of 1985 when the natural population were apparently low was significant. Similarly the results obtained for larvae in leaves and stems for each of the seasons were also inconsistent. For example, while larvae in leaves were significant during the long rains of 1986, larvae in stems were not significant. Similar differences and inconsistences were found with O. phaseoli and O. spencerella puparia. Guthrie (1975) and Davis (1985) attributed such inconsistences partly to lack of adequate number of insects for uniform level of infestation. Hence, the need to develop methods to regulate the infestation to give maximum differences between susceptible and resistant cultivars as advocated by Dahms (1972). The apparent low beanfly population as indicated by low beanfly punctures and immature stages in early planted cultivars during cropping seasons obviously mitigates against these field screening techniques. The natural field population of beanfly may have to be manipulated to increase the chance of having a uniformly high population at the appropriate growth stage of the bean plants.

It is for this reason that Chiang and Telekar (1980) planted a susceptible soybean/mungbean cultivar every two weeks as a source of a uniform and high natural field population of beanfly for selection for resistance.

Successive planting of bean cultivars in cropping seasons increased the level of beanfly punctures, eggs, larvae, puparia, damage and percent infested bean plants in the late planted beans. Such a high level of beanfly population in beans planted in the middle or late part of the cropping seasons could give maximum differences between resistant and susceptible bean cultivars. High levels of beanfly infestation produced in successive planting during the off-season of 1986 were undesirable because cultivars with moderate degrees of resistance were also eliminated. There may not be need to have successive planting in off-seasons to increase the level of beanfly population because it is already at a damaging level at single planting during this season. However, it would be advisable to do sequential screening of bean cultivars during the off-seasons when there is no appreciable increase of beanfly infestation from one planting date to the other. The above findings are in agreement with those of Kwon *et. al*. (1980, 1981) who showed an increase in beanfly infestation rate, damage and significant varietal differences among soybean cultivars with delay in planting dates.

The results obtained indicate that older plants are less preferred for oviposition and feeding than the young seedlings. Consequently the damage caused on older plants tend to be less severe. These findings support work by Taylor (1958) who observed that mature plants have less severe damage than the seedlings. It is therefore suggested that future work on screening for resistance should use bean seedlings which should coincide with a high natural field population of the beanfly.

There is a need to develop evaluation methods for a particular species of beanfly. Evaluation of bean cultivars for resistance to *O. spencerella* should mainly be in the seedling stage. Heavy *O. spencerella* attack at this stage kills the bean plants and a dead plant score or percent dead plants could be taken at 4-5 weeks after emergence. *O. phaseoli* attack is rarely severe enough to kill young bean seedlings; those attacked would normally survive and reach maturity in debilitated conditions. Evaluation for resistance to *O. phaseoli* should be done on more mature plants on which damage scores could give a reliable resistance index. As shown in the results some cultivars had high numbers of leaf punctures, larvae and puparia but less severe damage. This apparent anomally might be due to the differential responses of the bean cultivars to the two species of beanflies. For this reason the damage scores or percent dead plants could be a more reliable method of field screening of bean cultivars against the beanflies than the number of beanfly punctures, eggs, larvae or puparia in the bean plants.

that mature plants have less severe damage than the seedlings. It is therefore suggested that future work on screening for resistance should use bean seedlings which should coincide with a high natural field population of the beanfly.

There is a need to develop evaluation methods for a particular species of beanfly. Evaluation of bean cultivars for resistance to *O. spencerella* should mainly be in the seedling stage. Heavy *O. spencerella* attack at this stage kills the bean plants and a dead plant score or percent dead plants could be taken at 4-5 weeks after emergence. *O. phaseoli* attack is rarely severe enough to kill young bean seedlings; those attacked would normally survive and reach maturity in debilitated conditions. Evaluation for resistance to *O. phaseoli* should be done on more mature plants on which damage scores could give a reliable resistance index. As shown in the results some cultivars had high numbers of leaf punctures, larvae and puparia but less severe damage. This apparent anomally might be due to the differential responses of the bean cultivars to the two species of beanflies. For this reason the damage scores or percent dead plants could be a more reliable method of field screening of bean cultivars against the beanflies than the number of beanfly punctures, eggs, larvae or puparia in the bean plants.

CHAPTER7

7. GENERAL DISCUSSION AND CONCLUSIONS.

The criteria used for determining relative population density of beanflies as pointed out in the thesis included leaf punctures, eggs, larvae and pupae (see pp 34-90). These parameters have also been found to be useful for evaluating resistance/susceptible bean cultivars. In this regard puncturing in the leaves of beans continued throughtout the season on all cultivars. The time and rate of leaf puncturing varied from season to season, depending on the time and level of adult beanfly infestation in the field. Leaf punctures counted within three to four weeks after they were made could be used as a relative index of the level of adult beanfly infestation. However, with regard to _O. phaseoli_ they overestimated the degree of infestation because not all leaf punctures were used for oviposition. In contrast they underestimated the degree of infestation as _O. spencerella_ also oviposits in the stems.

Both _O. spencerella_ and _O. phaseoli_ oviposited in the leaves of bean plants. Eggs were found in the leaf punctures in all the seasons and throughout the season. During the short rains season the eggs in the leaves built up in the late part of the seasons. _O. spencerella_ normally oviposited in the leaves, but also oviposited in the stems of bean seedlings when its oviposition pressure was very high. The beans planted at the end of the cropping seasons had high numbers of eggs and were always oviposited on in the leaves and stems. In some cases during the noncropping season, there were more eggs in the stems than in the leaves. When there was oviposition in the stems, O. spencerella often laid more eggs than O. phaseoli. Consequently, the immature stages of O. spencerella were in such cases more than those of O. phaseoli.

Throughout this study it has not been possible to distinguish the two species on the basis of leaf punctures, eggs or larvae found in the bean plants. Nevertheless, it was observed that first instar larvae of both species which are usually found in the leaves migrate down into the stems and can be found there within seven days after hatching. The numbers of second and third instar larvae in the stems would give an accurate estimate of the level of beanfly infestation.

The diffulties of distinguishing the two species on the basis of leaf punctures, eggs and larvae has been pointed out. In contrast puparia of both O. phaseoli and O. spencerella were easily differentiated on the basis of their colour. Consequently the differences in level of infestation between the two species on each of the cultivars could be assessed for each season. Thus during the long rains of 1985, the numbers of O. phaseoli puparia were lower than O. spencerella puparia in the bean plants while during the short rains of 1984 and 1985 the numbers of puparia of both species build up much later in the season reaching similarly high levels. The numbers of O. phaseoli puparia were more in the bean plants in the short rains of 1984 and 1985 than in the long rains of 1985. However, no such seasonal patterns of O. spencerella puparia in the bean plants was observed. O. spencerella infestation was generally high in all seasons when there was prolonged wet conditions. This dominance of one species over the other as indicated by puparia count might be an indication of competition, a subject not investigated during the study, but well worthwhile for future studies on the biology of these two closely related species.

The preferences of ovipositing females to lay their eggs in younger plants reflects their behavioural adaptation to ensure that their offsprings have the best chance of completing their developmental stages while the host plant is in its most nutritive stage. The implication of this preference is that beanflies cause more severe damage in young bean seedlings.

As with other insect pests on short term annual crops, populations tend to build up rapidly following the initial invasion by egg-laying females (Southwood and Way, 1970). Any crop planted late in the season is likely to be severely damaged due to the generally higher population levels which have been building up in the course of the season. The findings of this study supports this general principle in that there were more beanfly leaf punctures, eggs, larvae and puparia in the late planted than in the early planted bean plants during cropping seasons. At the end of the cropping seasons, successive planting of beans did not lead to high numbers of beanfly punctures, eggs, larvae and pupae in the late planted than in the early planted bean plants.

Beans planted in the noncropping seasons were more severely attacked than those planted in the long and short rains seasons. Well cared for isolated off-season bean crops, like those grown during the experiments reported in this thesis, attract more beanflies from wild hosts on an account of their being more nutritious than the wild hosts.

The difficulties of evaluating bean cultivars for their resistance/susceptibility to beanfly attack under field conditions have been discussed at length in chapters 5 and 6. It has been pointed out that field trials designed to evaluate resistance/susceptibility lack the precision in determining the level of beanfly infestation to which cultivars are subjected during the growing period. The results reported in this thesis based on the number of beanfly leaf punctures, larvae, pupae/puparia, and percent plant mortality, percent infested plants and damage scores give a fair indication of the potential that exists in some of the cultivars for resistance. Thus Glp 1004 and Glp x-92 showed some resistance on the basis of their least plant mortalities and low puparia surviving on them. Although there were seasonal differences in the response of the cultivars to beanfly attack these two cultivars generally performed reasonably well Thus the results obtained in this work only indicate the possibility of the existence of resistance/susceptibility traits which could be exploited in future breeding or screening of bean cultivars suitable for Kenya.

Under normal circumstances the study would have been confined to one species of beanfly but in most bean growing areas throughout East Africa the two species studied here invariably occur together in the same field (Greathead, 1968; Okinda, 1979). However, it was difficult to identify the leaf punctures, eggs and larvae of each species of beanfly using the morphological characters. Therefore, the differentiation of the seven bean cultivars into different resistant categories was probably masked by analyzing the mixtures of leaf punctures, eggs, and larvae of O. phaseoli and O. spencerella together. In contrast pupae/puparia of the two species were easily distinguished by their colour and were often found in the same bean plant. Therefore, determination of the number of pupae/puparia could be very useful for field screening studies for specific species of beanfly since they were easily identified by their colour and accurately counted.

Percent plant mortality or damage scores would be perfectly adequate for resistance studies in the field since the plants having low damage or surviving a heavy beanfly infestation probably have some resistance qualities. Under moderate population pressure of O. spencerella, percent plant mortality or stem damage scores could be used to evaluate bean cultivars seedlings for resistance. The bean plants attacked by moderate population of O. phaseoli survived seedling stage and reached maturity in debilitated conditions and therefore in such cases evaluation for resistance should be in mature stages where whole plant damage scores or stem damage scores would be a reliable resistance index.

There were seasonal variations of each species of beanfly in the field. Therefore, sampling and identifying the adult beanfly prior to planting could indicate which species is likely to be more in a bean crop. It is more likely to get a high O. spencerella population at the end of a long rains season and a high O. phaseoli population at the end of a short rains season. Thus evaluation for a particular species of beanfly could be manipulated by planting the bean cultivars when a known adult beanfly population for infestation is highest in the field.

Close examination of the results for each of the season indicated lack of consistency in the response of the cultivars to attack by the two species of beanfly. This is to be expected in field trials in which enviromental conditions are not controlled. For this reason previous workers (Guthrie, 1975; Davis, 1985) have suggested that greenhouse experiments in which conditions are more precisely controlled would be more appropriate as was done by Rogers (1979) in evaluating bean cultivars against _O_. _phaseoli_. For example, Rogers (1979) work involved screening 13 bean cultivars simultaneously in the greenhouse using a laboratory colony of _O_. _phaseoli_. In contrast, in the field studies being reported in this thesis, it was only possible to evaluate seven bean cultivars. The only drawback on greenhouse screening at the moment is that mass rearing of beanflies on artificial diets in the laboratory and infestation methods for resistance studies has not been developed.

Small isolated trial plots planted with beans at the end of the cropping seasons can attract unusually high population of beanfly from the surrounding weeds as well as previous crop field. Under such conditions damage to the crop can be severe. Thus during the off-season of 1985 and 1986, the more susceptible cultivars were eliminated and even those cultivars like Glp 1004 and Glp x-92 which showed signs of being resistant in previous seasons faired badly, most of them being actually killed off. In the work of this kind it is therefore necessary to define the level of beanfly populations above which the plants' ability to withstand damage can no longer hold.

Unlike other annual crops beans are only susceptible to or suffers damage from beanflies for a brief period i.e. during the first four weeks after emergence (Taylor, 1958). In East Africa, planting early has been the basis of the cultural recommendation to avoid severe beanfly damage later in the season (Greathead, 1968; Swaine, 1968). The present study has confirmed those earlier findings. For the purpose of screening bean cultivars under field conditions it should therefore be possible to time the planting dates such that the most susceptible stage in the phenology of the crop occurs at the time when the natural population is sufficiently high. Futhermore, where feasible, beanfly infestation could also be greatly enhanced by off-season planting when no other bean crops are being grown. Under such circumstances work being reported in this thesis has shown that beanfly population can build up to sufficient levels causing observable damage symptoms which could reliably be used as parameters for resistance.

REFERENCES

Abul-Nasr, S. 1966. The external morphology of the beanflies, Melanagromyza phaseoli Tryon. Bull Soc. Entomol. Egypte 50:61-69

Abul-Nasr, S. and M.A.H. Assem. 1966. Some ecological aspects concerning the beanflies, Melanagromyza phaseoli Tryon. Bull. Soc. Entomol. Egypte 50:163-172.

Abul-Nasr, S. and M.A.H. Assem. 1968. Studies on the biological processes of the beanfly, Melanagromyza phaseoli Tryon. Bull. Soc. Entomol. Egypte. 52:283-295.

Agrawal, N.S. and N.D. Pandey.1961. Bionomics of Melanagromyza phaseoli Coq (Diptera: Agromyzidae). Indian J. Entomol. 23:292-298.

Ali, A. M. 1957 On the bionomics and control of the beanfly, Agromyza phaseoli Coq. Bull. Soc. Entomol. Egypte. 41:511-554.

Anon. 1975 Production year book FAO, Rome

REFERENCES

Abul-Nasr, S. 1966. The external morphology of the beanflies, Melanagromyza phaseoli Tryon. Bull Soc. Entomol. Egypte 50:61-69

Abul-Nasr, S. and M.A.H. Assem. 1966. Some ecological aspects concerning the beanflies, Melanagromyza phaseoli Tryon. Bull. Soc. Entomol. Egypte 50:163-172.

Abul-Nasr, S. and M.A.H. Assem. 1968. Studies on the biological processes of the beanfly, Melanagromyza phaseoli Tryon. Bull. Soc. Entomol. Egypte. 52:283-295.

Agrawal, N.S. and N.D. Pandey.1961. Bionomics of Melanagromyza phaseoli Coq (Diptera: Agromyzidae). Indian J. Entomol. 23:292-298.

Ali, A. M. 1957 On the bionomics and control of the beanfly, Agromyza phaseoli Coq. Bull. Soc. Entomol. Egypte. 41:511-554.

Anon. 1975 Production year book FAO, Rome

Anon. 1978 Kenya statistical Abstracts. Ministry of Finance. Kenya Government.

Anon. 1983 Thika Hortivultural Research Station, Kenya.(Mimeograph)

Anon., 1986 Proceedings of the beanfly workshop Arusha, Tanzania, 16-20 November, 1986.(Mimeograph)

Balboa, F.C. 1972 Comparative resistance of five varieties of Mungo, *Phaseolus aureus* Roxb, to the attack of the beanfly, *Agromyza phaseoli* Cog. Araneta Res. J. 18:66-79.

Beck, S.D. 1965 Resistance of plants to insects. Ann Rev. Ent. 10:207-232.

Bhattacharjee, N.S. 1980. Incidence of stemfly, *Ophiomyia phaseoli* Tryon. on soybean. Indian J. Ent. 42 (2): 280-282.

Bohlen, E. 1973. Crop pests in Tanzania and their control pp 91. Verlag Paul Parey Berlin and Hamburg.

Burikam, I. 1978. Ecological investigation on the beanfly, Ophiomyia phaseoli Tryon (Diptera: Agromyzidae), and its natural enemies in Thailand . M.sc. Thesis, Kasetsart university, Bangkok, Thailand 71pp.

Caldwell, N.E.H. 1939. Beanfly control in Southern Queensland. Queensland agric. J. 52:393-396.

Caldwell, N.E.H. 1945. Bean pests in Queensland. Queensland Agric. J. 60: 157-160.

Chiang, S.H. and D.M. Norris 1982. Soybean resistance to beanflies. Proc.5th Int. symposium insect-plant relationship, Wageningen, 357-361.

Chiang, S.H. and D.M. Norris. 1983a. Physiological and anatomical parameters of soybean resistance anatomical to agromyzid beanflies. Entomol. Exp. Appl. 33:203-212.

Chiang, H.S. and D.M. Norris. 1983b Morphological and physiological parameters of soybean resistance to agromyzid beanflies. Environ. Entomol. 12:260-265.

Chiang, H.S. and D.M. Norris. 1983C. Phenolic and tannin contents as related to anatomical parameters of soybean resistance to agromyzid beanflies. J. Agric. Food chem. 3(4): 726-730.

Chiang, H.S. and D.M. Norris. 1984. 'Purple Stem' a new indicator of soybean stem resistance to beanflies (Diptera: agromyzidae) J. Econ. Entomol. 77(1): 121-125.

Chiang, H.S. and D.M. Norris. 1985. Expression and stability of soybean resistance to agromyzid beanflies. Insect sci. Applic. 6(3) :265-270.

Chiang, H.S. and N.S. Talekar. 1980. Identification of sources of resistance to the beanfly and two other agromyzid flies in soybean and mungbean. J. Econ. Entomol. 73(2): 197-199.

Dahms, R.G. 1972. Techniques in the evaluation and development of host-plant resistance. J. Environ. Quality. 1(3):254-259.

Davis, F.M. 1985. Entomological techniques and methodologies used in research programmes on plant resistance to insects. Insect Sci. Applic. 6(3):391-400.

Davis, J.J. 1969. Beanfly and its control. Qd agric. J. 95:101-106.

Deeming, J.C. and A.C. Njend. 1979. Ophiomyia phaseoli Tryon (Diptera : Agromyzidae) attacking bean plants, phaseolus vulgaris L. in Northern Nigeria. Nigeria J. Entomol. 3(2): 129-133.

de Lima, C.P.F. 1976. A guide to the biology and control of the pests of field and stored produce in Kenya. pp.B.1.2. Ministry of Agriculture, Kenya.

Fernando, M. 1941 The relative resistance of some cowpea varieties to Agromyza phaseoli Coq. Trop Agric. May. Ceylon. Agric. Soc. 96:221-224.

Gangrade, G.A. and M. Kogan. 1980. Sampling stem flies in soybean. 'Sampling methods in soybean Entomology' (Eds Kogan, M. and D.C. Herzog). New York, Springer - Verlag 587pp.

Greathead, D.J. 1968. A study in East Africa of the beanflies (Diptera: Agromyzidae) affecting Phaseolus vulgaris L and of their natural enemies, with the description of a new species of Melanagromyza Hend. Bull. Ent. Res. 59:541-561.

Gupta, P.K. and J. Singh 1984. Biology of bean stemfly, Ophiomyia phaseoli Tryon (Diptera: Agromyzidae). J. Adv. zoo. 5 (1): 34-41.

Guthrie, W.D. 1975 Entomological problems involved in developing host-plant resistance programs. Iowa. St.J. Res. 49(4): 519-525.

Harris, W.V. 1937 Annotated list of insects injurious to native food crops in Tanganyika. Bull Ent. Res. 28:483-488.

Hassan, A.S. 1947. The beanfly, Agromyza phaseoli Coq. in Egypt. Bull. Soc. le'r Entomol. 31: 217-224.

Heley, P.C. 1947. Control of French beanfly. Experiments with D.D.T. Agric. Gaz. N.S.W. 58:85-89.

Hill, D. 1975. Agricultural insect pests of the tropics and their control. Cambridge University Press, Cambridge. 516pp.

Ho, T.H. 1967. The beanfly, Melanagromyza phaseoli Coq. and experiments on its control. Malay. Agric. J. 46:49-157.

Hober, E. 1972. Plant resistance to insects. Agric. Sci. Rev. 10:1-11.

Hober, E. 1978. Resistance to pests of grain legumes in the U.S.A. In 'Insect pests of grain legumes: Ecology and Control'. (Eds Singh S.R., T.A. Taylor and H.F. van Emden). Academic Press, London 454pp.

Hober, E. 1980. Types and classification of resistance. In 'Breeding plants resistant to insects' (Eds Maxwell, F.G. and P.R. Jennings). pp 15-21. Wiley, New York.

Jack, R.W. 1913 The bean stem maggot. Rhodesia Agric. J. 10:545-555.

Karel, A.K. 1984. Evaluation of common bean cultivars for resistance to beanfly, Ophiomyia phaseoli Tryon. Proc. 3rd workshop on bean research in Tanzania. (Eds. Minjas, A.N. and M.P. Salema) pp 43-46.

Karel, A.K. and J.M. Mueke; 1978. Management of insect pests in mixed cropping systems in Kiambu District. University of Nairobi, Faculty of Agriculture. Plant Protection programme. First report, 1978. pp 48-61.

Kato, S. 1961 Taxonomic studies on soybean leaf and stem mining flies (Diptera: Agromyzidae) of economic importance in Japan, with description of three new species. Bull Natn. Inst. Agric. Sci. (c) 13:171-106.

Khaemba, B.M. and C.P.M. Khamala. 1978. A preliminary survey of phytophagous pests of mixed cropping system of Kikuyu Division. University of Nairobi, Faculty of Agriculture. Plant Prot. programme. First report, 1978 pp 62-71.

Khamala, C.P.M., B.M. Khaemba and J. Epira. 1979. A survey of arthropod crop pests in Murang'a District. University of Nairobi, Faculty of Agriculture. Plant protection programme. Vol. I : 15-22.

Khamala, C.P M. 1978. Pests of grain legumes in Kenya. In 'Insect pests of grain legumes : Ecology and Control' (Eds Singh S.R, T.A. Taylor and H.F. van Emden) 1978. Academic Press, London 454 pp.

Kibata, G.N. 1980. Seasonal incidence and control of beanfly, *Ophiomyia phaseoli* Coq. Kenya Entomologist Newsletter. 11: 13.

Kleinschmidt, R.P. 1970. Studies on some Agromyzidae in Queensland. Queensland J. Agri. Anim. Sci. 27:341-384.

Kogan, M. and Ortman, E.E. 1978. Antixenosis- a new term proposed to define Painters 'non preference' modality of resistance. Bull. Ent. Soc. Am. 24:175-176.

Kooner, B.S., H. Singh, and S. Kumar. 1977. Effect of dates of sowing on the incidence of stem-fly, *Melanagromyza phaseoli* Tryon in pea Crop. J. ent. Res. 1 (1) : 100-103.

Kwon, S.H., K.N. Chung, Y.I. Lee, J.R. Kim and J. Ryu. 1980. Response of soybean varieties and planting dates to the beanfly (*Melanagromyza* sp) damage. Korean J. Breed. 12:30-34.

Kwon, S.H, K.H. Chung, Y.I. Lee and J. Ryu 1981. Studies on the ecological Characteristics of beanfly (*Melanagromyza* sp) in soybeans. Korean J. plant prot. 20(2): 98-102.

Lall, B.S. 1959. On the biology and control of the beanfly, *Agromyza phaseoli* Coq. (Diptera: Agromyzidae) Science and Culture 24(1) 531-532.

Le Pelley, R.H. 1959. Agricultural insects of East Africa. East Africa High Commission, Nairobi, Kenya. 307pp.

Lee, S.Y. 1976. Notes on some agromyzid flies destructive to soybean in Taiwan. Formosan Sci. 30:54-62.

Lin, F.J., T.C. Wang, and C.Y. Hsieh. 1977. Population fluctuation of soybean miner, Ophiomyia phaseoli Tryon. Bull. Inst. Zoo., Academia Sinica. 17(1): 69-76.

Lin, C.S. and W.C. Mitchell. 1981. Host selection of the beanfly, Ophiomyia phaseoli Tyron. J. Taiwan Museum. 34(3,4):233-236,

Londono , N.R., J.W. Gathee and J.H. Sanders. 1980. Bean production trends in Africa, 1966- 1979. In 'potential for field beans in Eastern Africa'. Proceeding of Regional Workshop, Lilongwe, Malawi, March 1980 pp 19-29.

Maerere, A.P. and A.K. Karel. 1984. Evaluation of common bean cultivars for resistance to beanfly, Ophiomyia phaseoli Tryon. Proc. 3rd workshop on bean research in Tanzania. 1984. (Eds. Minjas, A. N. and M.p. Salema) pp 49-52.

Manohar, S., and M. Balasubrammanian. 1980a. Note on the oviposition behavior of agromyzid stemfly, Ophiomyia phaseoli Tryon (Diptera: Agromyzidae). Madras Agric. J. 67(7): 470-471.

Manohar, S. and M. Balasubrammanian. 1980b. Study on the seasonal incidence of agromyzid stemfly, Ophiomyia phaseoli Tryon (Diptera: Agromyzidae) in blackgram. Madras Agric. J. 67(8): 534-537.

Matee, J. J. and A. K. Karel. 1983. Investigations on chemical control of beanfly, Ophiomyia phaseoli Tryon. Proc. 2nd Workshop on bean research in Tanzania, 6-7 September,1983

Morgan, W.L. 1938 For beanfly control use white oil nicotine sulphate mixture. Agric. Gaz. N.S.W. (Australia). 49:22-24.

Msangi, R.B. and A.K. Karel 1984. Host plant resistance in common beans to beanfly, Ophiomyia phaseoli. Proc. 3rd workshop on bean research in Tanzania, 1984 (Eds. Minjas, A. N. and M.P. Salema). pp 60-63.

Mueke, J.M. 1979a. Seasonal abundance and problems of controlling beanfly in Kenya. Symposium of Grain legume improvement in East Africa; Nairobi 20-24 August, 1979.

Mueke, J.M. 1979b A preliminary screening of seventeen bean cultivars for beanfly resistance. In 'plant protection programme report, 1979.' University of Nairobi, Faculty of Agriculture (Eds. C.N. Karue and D.M. Mukunga) pp 59-72.

Mushebezy, D. M. K. and A. K. Karel. 1985. Resistance to beanfly, Ophiomyia phaseoli Tryon in common beans. Proc. 4th Workshop on bean research in Tanzania, 1985.(Eds. Minjas, A. N. and M. P. Salema). pp62-68.

Njuguna, S.K., A.M.M. Ndegwa, H.A. Van Rheenen, and D.M.Mukunya,1980.Bean production in Kenya. In 'Potential for field beans in Eastern Africa'. Proc. of Regional Workshop, LiLongwe, Malawi, March, 1980. pp 34-53.

Norris, D.M. and M. Kogan. 1980. Biochemical and morpological bases of resistance. In 'Breeding plants resistant to insects.' (Eds Maxwell, F.G. and P.R. Jennings). pp 23-61. John Wiley & Sons, New York. 683pp.

Okinda, A.F. 1979. Influence of the beanfly (Diptera: Agromyzidae) on the performance of French Beans (Phaseolus vulgaris L.) and some aspects of its chemical control in Kenya. Msc Thesis. University of Nairobi, Kenya.

Omunyin, M.E., H.A.I. Stoetzer, G.K. Kinyua and M. Pere 1984. Food beans: Pests and other field problems. Phaseolus: Beans Newsletter for East Africa. No.3: 8-9.

Painter, R.H. 1951. Insect resistance in crop plants. MacMillan, New York. 520pp

Painter, R.H. 1968. Crops that resist insects provide a way to increase world food supply. Kans Agric. exp. Sta. Bull. 520: 22.

Pandey, N.D. 1962. Studies on the morphology, bionomics and control of some Indian agromyzidae. Agr. Univ. J. Res. Sci. 11:39-43.

Pury, J.M.S. de. 1968. Crop pests of East Africa. Oxford University Press, Nairobi. 227pp.

Quesales, F.O. 1918. The beanfly. Philip Agric. 7:2-27.

Reddy, A.R, S. Venkateswarlu, K.L. Vaid and R.M. Singh 1983. Evaluation of the germplasm of Rajmash with special reference to beanfly infestation. Indian J. Ent.45:184-189.

Rogers, D.J. 1979 Host plant resistance to Ophiomyia phaseoli Tryon (Diptera: Agromyzidae) in Phaseolus vulgaris L. J. Aust. Ent. Soc. 18:245-250.

Rwamugira, W.P. and A.K. Karel 1983. Varietal evaluation of common beans for resistance to beanfly, Ophiomyia phaseoli Tryon. Proc. 2rd Workshop on bean research in Tanzania. University of Dar-es-Salaam, Morogoro, Tanzania 6-7 September, 1983(Eds. Minjas, A. N. and M. P. Salema)

Saxena, K.N. 1969. Pattern of insect-plant relationship determining susceptibility or resistance of different plants to an insect. Entomological exp. appl. 17:303-318.

Saxena, K.N. 1985 Behavioural basis of plant resistance or susceptibility to insects. Insect Sci. Applic. 6(3):303-313.

Schonherr, S. and Mbugua, E.S. 1976. Bean production in Kenya's central and Eastern provinces. Institute of Development Studies, University of Nairobi, Kenya. Occassional paper No.23. 69p.

Sharma, S.S., B. Dayiya, K. Kapoor 1983. Some aspects of stemfly infestation influencing growth and yield attributes in Urdbean. Indian J. Plant Prot. 10(1/2): 76-78.

Singh, S. and S.K. Beri 1971. Studies on the immature stages of agromyzidae (Diptera) from India. I Notes on the biology and description of immature stages of four species of Melanagromyza. Hendel J. Nat. Hist. 5: 241-250.

Singh, G. and P.N. Mishra. 1977. Note on susceptibility of certain vegetable pea varieties to Melanagromyza phaseoli Tryon and Thrips tabaci Linderman. Indian J. Agric. Sci. 47(11):587-588.

Singh, G., P.N. Mishra and B.K. Srivastava. 1981. Effect of date of sowing peas on the damage caused by Ophiomyia centrosematis. Indian J. Agric. Sci. 51:340-343.

Singh, S.R. and H.F. Van Emden. 1979. Insect pests of grain legumes. Ann. Rev. Entomol. 24: 255-278.

Sinha, S.K. 1977 FAO plant protection paper 3. FAO Rome.

Southwood, T. R. E. and M. J. Way. 1970. Ecological background to pest management. In 'Concepts of pest management' (Eds. Rabb, R.L. and F. E. Guthrie). pp 6-29. North Calorina State University Print Shop.

Spencer, K.A. 1959. A symposis of the Ethiopian agromyzidae (Diptera). Trans. R. Ent. Soc. Lond. 111:237-329.

Spencer, 1961 Notes on African agromyzidae (Diptera). 1. stuttgt. Beitr. Naturk. no. 46, 5pp

Spencer, K.A. 1973. Agromyzidae (Diptera) of economic importance. Dr. W. Junk. B.V. Publishers. The Hague, The Netherlands. 418pp.

Spencer, K.A. 1985. East African Agromyzidae (Diptera): further descriptions, revisionary notes and new records. J. Nat. Hist. 19(5): 969-1027.

Starks, K.J. 1970. Increasing infestations of the sorghum shootfly in experimental plots. J. Econ. Entomol. 63:1790-1795.

✓ Swaine, G. 1968. Studies on the biology and control of pest of seed beans (Phaseolus vulgaris L) in Northern Tanzania. Bull. Ent. Res. 59:232-338.

Talekar, N.S. 1980. Search for beanfly resistance in soybean, mungbean and snapbean. In 'Processing of legumes in the tropics' pp 293-295. Faculty of Agriculture, University of Pertanian, Malaysia, Serdang, Selangor, Malaysia.

Talekar, N.S. and B.S. Chen. 1983. Seasonality of insect pests of soybean and mungbean in Taiwan. J. Econ. Entomol. 76:34-37.

Talekar, N.S. and B.S. Chen. 1983. The beanfly pest complex of tropical soybean. In 'Soybean in tropical and subtropical cropping systems'. Proc. of a symposium, Tsukuba, Japan, 26th september - 1 October 1983. (Eds. Shanmugasundaram, S. and E.W. Sulzberger)

Taylor, C. E.1958 The bean stem maggot. Rhodesian Agric. J. 55: 634-636

Taylor, C.E. 1980. Bean stem maggot. Zimbabwe agric. J. 77(5):213.

Tees, G.L. 1980. Breeding sorghums resistant to insects. In 'Breeding plants resistant to insects'. (Eds Maxwell, F.G. and P.R. Jennings) pp 459-471. Willey, New York.

Thairu, D.M. 1979. Grain legume production in Eastern Africa with special reference to Kenya. Symposium on Grain Legume improvement in Eastern Africa, Nairobi, August, 1979.

Walker, P.T. 1960. Insecticide studies on East African agricultural pests. III - Seed dressing for control of the beanfly, *Melanagromyza phaseoli* Coq. in Tanganyika. Bull. Ent. Res. 50:781-793.

Walker, P.T. 1971. Melanagromyza phaseoli. In ' FAO manual on the evaluation and prevention of losses by pests, diseases and weeds'. pp40.

Wallace, G.B. 1939. French bean diseases and beanfly in East Africa. E. Afric. Agric. J. 5:170-175.

Wallace, G.B.1941 Yellow bean mosaic and notes on other bean diseases. E. Afric. Agric. J. 7:114-115.

Wickramasinghe, N. and H.E. Fernando 1962. Investigations on insecticidal seed dressing, soil treatments and foliar sprays for the control of Melanagromyza phaseoli Tryon in Ceylon. Bull Ent. Res. 53(2):223-240.

Wiseman, B.R. 1985. Types and mechanisms of host plant resistance to insect attack. Insects Sci. Applic. 6(3)239-245.

van Schoonhoven, A. 1980. A summary of country reports. In 'Potential for field beans in Eastern Africa'. Proc. of a Regional workshop, Lilongwe, Malawi, 9-14 Mar. 1980

Yasuda, K.K. 1981. Life history of the beanfly _Ophiomyia phaseoli_ Tryon in Okinawa, Japan. Proc. of the Association for Plant Protection of Kyushu. 25:107-109.

Yasuda, K.K. 1982. Life tables of the French bean miner, _Ophiomyia phaseoli_ Tyron (Diptera: Agromyzidae) on young Kidney bean seedlings. Proc. of the Association for Plant Protection of Kyushu 28: 145-146.