THE BEANFLY PEST COMPLEX OF SNAP BEAN IN THE TROPICS

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Abstract

Beanfly, Ophiomyia phaseoli (Tyron) and two other agromyzids, O. centrosematis (de Meijere) and O. spencerella (Greathead) are the most destructive pests of snap bean (Phaseolus vulgaris L.) during the seedling stage. The formers two are found in tropical to subtropical regions of Africa, Asia, Australia and the Pacific. The latter species is confined to Africa. Insect larvae feed inside the plant stem which results in severe weakening of and, at times, mortality of the snap bean plant. Insects are more serious during the dry season. The critical period of damage is within four weeks after germination. Certain cultural practices, like ridging seedlings, reduce insect damage. A large number of hymenterous parasites attack all three beanfly species, but these parasites alone cannot control the pests. The present use of broad-spectrum insecticides on commerical farms is not sustainable due to their toxicity to parasites and the development of insecticide resistance in the beanfly species. Newer chemicals with insect growth regulatory (IGR) activity, which are toxic to the pest but safer to parasites, are being developed. Two CIAT accessions, G35023 and G35075, show high levels of resistance to beanfly. An integrated pest control approach, based on the use of a resistant cultivar, seed treatment with insecticides, and occasional use of selective insecticides, will allow full exploitation of natural enemies and has a potential for sustainable control of beanflies.

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Introduction

Among all the insect pests that infest snap bean (Phaseolus vulgaris L.) in the tropics, tiny flies belonging to the dipteran family Agromyzidae, commonly called "beanflies", are the most destructive. Six species: Ophiomyia phaseoli (Tryon), Ophiomyia spencerella (Greathead), Ophiomyia centrosematis (de Meijere), Melanagromyza sojae (Zehntner), Melanagromyza phaseolivora Spencer, and a Japanagromyza sp. attack snap bean. The first three species are the most destructive, whereas the latter three are either minor or only occasional pests of snap bean in isolated areas. As such very little published information exists on the biology, damage and control of the latter three species.

Among the three Ophiomyia species, O. phaseoli and to some extent O. centrosematis, are by far the most destructive and widespread in Africa, Asia, Australia and the Pacific. Damage due to O. spencerella is confined to Africa only. These agromyzids do not occur in Europe, North and South America or the Caribbean islands. In addition to snap bean, they also feed on such economically important legumes as soybean (Glycine max (L.) Merrill), cowpea (Vigna unguiculata (L.) Wasp.) mungbean (Vigna radiata (L.) Wilczek) and pea (Pisum sativum L.) and several wild legumes. In all cases, the larvae of Ophiomyia feed inside the stem and kill or seriously weaken the plant. This results in considerable yield loss.

In Indonesia, Australia, Vietnam and East Africa, these insects are major limiting factors to successful cultivation of snap bean. Although these insects occur in the tropics and subtropics, their damage is generally greater at latitudes closer to the equator.

Identification

Adults of all three Ophiomyia species are tiny black flies which look alike. They are agile and difficult to observe in the field. Their larvae and pupae have characteristic morphological features which, coupled with their oviposition and feeding sites within snap bean, can be used to

identify these pests on the spot in the field. The morphological features of O. phaseoli and O. centrosematis larvae and pupae are depicted in Figure 1. The easily distinguishable morphological features of larvae and pupae of O. spencerella are practically identical to those of O. phaseoli. In full grown larva and pupa of O. phaseoli, the posterior spiracles closely adjoin on conical projections, usually with 10 minute bulbs. Oviposition takes place in unifoliate and early trifoliate leaves. The morphological features of posterior spiracles of O. spencerella are identical with those of O. phaseoli. The only external characteristic that distinguishes O.spencerella from O. phaseolli is the shiny black pupae of the former as against the pale yellow to brown pupae of the latter. The shiny black feature of the pupae of O. spencerella can be seen even underneath the stem epidermis where the larvae feed and pupate. In addition, O. spencerella lays eggs in the hypocotyl whereas O. phaseoli lays them in the foliage. The full grown larvae and pupae of O. centrosematis can be distinguished from the two other Ophiomyia species by the presence of three conical structures on the distal end of the posterior spiracle with one opening on each (Figure 1).

The pupal color of O. centrosematis and O. phaseoli is practically identical. Like O. spencerella, O. centrosematis lays eggs in the hypocotyl. At times, and only in East Africa, all three Ophiomyia species can attack a single snap bean plant. Under such circumstances the above described morphological and oviposition characteristics can be exploited in identifying these pests easily. Publications by Kato (1961), Greathead (1968) and Spencer (1973) describe the morphology of most economically important agromyzids and can be utilized for the identification of adults.

Geographic Distribution and Seasonality

All three Ophiomyia species are pan-tropical and their damage increases as one goes closer to the equator. The names of countries/states which have reported infestation of these species on various legumes are listed in Table 1. Among the three, O. phaseoli is the most widespread and occurs practically in every country or territory in tropical to subtropical Asia,

Africa, Australia and the Pacific. In contrast, O. spencerella is confined to Africa, mainly East Africa. O. centrosematis occurs both in Africa and Asia.

The seasonality of Ophiomyia species varies from location to location depending upon climate and presence of host plant. Although these pests can occur throughout the year, their damage is more serious during the dry season. Since the occurrence of the dry season varies from location to location in a calendar year, so does the occurrence of the pest. For example: in Indonesia it is between June and September (van der Goot, 1930); in the Philippines, from January to April (Otanes, 1918); in Taiwan between September and February (Talekar and Chen, 1983); in Australia, from March to May (Morgan, 1940); in Egypt from July to October (Abul-Nasr and Aseem, 1966b); in Tanzania, from November to February (Swaine, 1968); in Kenya, between October and December (Okinda 1979); and in India, during October and November and March and April (Pandey, 1962; Singh, 1982). If snap bean planted in these seasons is not protected the loss can be total.

Biology of Ophiomyia Species

Ophiomyia phaseoli

Mated females are active fliers and seek tender foliage for oviposition. They lay oval, milky white, opaque or translucent eggs, often near the midrib close to the petiole, on both sides, only during the day time. Eggs are inserted between the epidermis and spongy parenchyma. Eggs are found in 10% to 15% of the leaf punctures made with the ovipositor by O. phaseoli female. The remaining holes are empty feeding holes. The numbers of eggs laid vary from as low as 16 (van der Goot, 1930) to as high as 1,106 (Raros, 1975). The egg incubation period varies from 2 to 4 days depending upon temperature; shorter duration at high temperature and vice versa.

The newly hatched, pale yellowish white, first instar larva mines through the lamina to the midrib and constructs a tunnel along the midrib where it completes the first instar. It continues to mine through the petiole and eventually reaches the stem, feeding in the cortex underneath the midrib. The larval period lasts from 10 to 22 days depending upon the ambient temperature. During this period the larva undergoes three instars. The first instar larvae generally suffer more natural mortality than other instars, egg or pupa.

Pupation takes place in the feeding tunnels from the root-shoot junction in the seedling stage to up to the junction of the leaf lamina and petiole or even in the midrib (Raros, 1975) in older plants. The pupa is barrel shaped, 2.25 - 2.30 mm long and 0.95 - 1.05 mm wide. The color changes from yellowish brown initially to a much darker color just before adult emergence. In the tropical lowlands the pulpal period lasts 7 - 13 days and in the highlands 13 - 20 days (van der Goot, 1930).

Soon after emergence, adults fly off in search of food sources such as water droplets on the leaves, natural secretions of plants, or sap exuding from feeding and oviposition holes made by females. Adults generally mate two days after emergence, usually in the morning hours. In the tropical lowlands there are between 9 and 14 generations a year.

Ophiomyia centrosematis

Adult females, three days after emergence from the pupae, lay an average of 63 eggs in the hypocotyl just underneath the epidermis (Talekar and Lee, 1988) in young plants. Newly hatched larvae feed on the cortex just underneath the epidermis. In the 11 days of the larval period the larva undergoes three instars (at 28 ^{o}C). Pupation takes places in the feeding channels. The 2.30 mm long and 0.89 mm wide golden yellow pupae emerge into tiny black adults in 11 days. After 2-3 days, adults mate and start laying eggs in 3 - 4 days. The oviposition continues for up to 18 days. Adults make oviposition and feeding holes in the hypocotyl and feed on sap

oozing from such holes. There are usually 3 - 4 generations in one cropping season lasting 3 - 4 months.

Ophiomyia spencerella

Females make punctures in the leaf tissue but rarely oviposit in them. Oviposition occurs in the hypocotyl at ground level in the first 2 - 3 days after the plants emerge above ground. A few eggs are also laid in stems just above the cotyledons. Larvae mine in the cortex downwards feeding in the hypocotyl and tap root and return to the ground level or above for pupation. In a laboratory study at 21 ^{o}C, Greathead (1968) found that eggs take 28 - 37 days to develop into adults followed by a pre-oviposition period of about 2 days.

Nature and Extent of Damage

The major damage comes from the feeding of Ophiomyia larvae inside the stems; adult feeding damage, although visible, is insignificant. Although infestation can occur throughout the plant growth, in general, the plants are more heavily damaged in their seedling rather than more mature stage. The consequences of insect attack in the seedling stage, if the plant survives, are manifested even in older plants. Whether the plant is young or old, the Ophiomyia species are cortex feeders and feed in only that part of the plant in either the stem or the petiole.

Ophiomyia phaseoli

In general, adult beanfly damage is negligible. The most serious damage by adults, if it occurs, takes place when snap bean plants are at the unifoliate leaf stage. The unifoliate leaves show a large number of feeding and oviposition punctures (Figure 2) on the upper side with corresponding light yellow spots, especially on the basal portion of the leaf. Sometimes the feeding holes progressively enlarge and the damaged unifoliate leaves become prematurally yellow and usually drop off (van der

Goot, 1930). This type of damage, however, does not affect the physiology of the plant or the seed yield.

The larval feeding starts in the leaf lamina where newly hatched larva, from the point where the adult laid eggs, mines through the lamina into the midrib and eventually in the petiole and stem. The numerous mines are most visible on the underside of the leaves just beneath the epidermis and appear as silvery, curved stripes. Larval mines in the stems can be easily seen under the epidermis as wide, straight, white stripes (Figure 3).

The larva spends most of the first instar feeding in the leaf lamina. By the time it reaches the petiole, it molts to the second instar. The second instar larva mines downwards into the stem, where the third molt occurs. The larva in the third instar feeds voraciously, mining in the cortex just underneath the stem epidermis. In some cases when the population is very high, it even feeds on the woody portion of the stem. Initially, the presence of the insect in the field can be noticed by the stunting of the plants. This symptom, however, usually goes unnoticed since in snap bean the infestation is usually total and all plants are stunted. The third instar larva continues feeding downwards into the tap root, and returns to pupate close to the soil surface. As several larvae feed in a localized area the cortex tissue is often devoured around the root collar. This, at times, results in a swollen and brown collar with raised and cracked skin, and in the formation of a gall with a rather cankerous surface (Figure 4). The cortex tissue is totally destroyed which weakens the stems and such plants are easily lodged during moderate winds. Lodged plants do not recover and this results in a considerable yield loss. In many cases this damage results in plant mortality within 3 to 4 weeks after germination. If part of the cortex tissue remains intact, the plant continues growing and develops a new root system above the point of injury by forming adventitious roots (Figure 5). In wet weather the lowest adventitious roots can reach considerable lengths and can compensate for the loss of a large part of the root system (van der Goot, 1930).

The extent of damage and the yield loss fluctuates with season, time of planting within a season and weather factors, such as rainfall. In general the yield loss during the rainy season is much less than in the dry season (van der Goot, 1930; Okinda, 1979). This is because the rain interferes with the movement of adult flies, which affects oviposition, and also because adequate soil moisture promotes vigorous growth, which can compensate for insect damage. In Indonesia in the dry season, van der Goot (1930) found high plant mortality in fields showing up to 100% of plants affected. In Tanzania, Wallace (1939) reported a 50% yield loss. In later studies, Swaine (1968) found plant damage ranging from 10% to 92% and yield loss up to 35%. In the Gosford district of New South Wales in Australia, Morgan (1940) found it impossible to grow snap bean, indicating that 100% of the plants were damaged and the yield loss was total. In Kenya, except for April plantings, Okinda (1979) found significant yield loss due to O. phaseoli (and possibly O. spencerella) due to fewer pods per plant and fewer seeds per pod. At AVRDC in Taiwan, a yield loss of about 35% was observed in one experiment (Talekar, 1989).

The nature of damage by O. centrosematis and O. spencerella is similar to O. phaseoli. However, the extent of damage by these two agromyzids is not as high and widespread as that by O. phaseoli. O. centrosematis is a distinctly minor pest, both in Asia and Africa. O. spencerella, which occurs only in Africa, can at times be as serious as O. phaseoli and may even surpass damage by the latter. The identical seasonality and nature of damage in snap bean makes it impossible to judge the contribution of O. spencerella and O. centrosematis independent of O. phaseoli.

Control of Beanflies

Host-plant resistance

Attempts have been made in the past to screen snap bean germplasm to find a cultivar resistant to O. phaseoli (Otanes) 1918; Hutson et al., 1929; van der Goot,1930; Raros, 1975; Rogers, 1979; Reddy et al., 1983). However, these attempts involved only a few cultivars with a narrow

genetic base, and other than noting differences in beanfly infestation of various cultivars included in such tests, no serious efforts were made to breed beanfly resistant cultivars.

At AVRDC, a large collection of CIAT's Phaseolus germplasm was screened to identify O. phaseoli-resistant cultivars. Among 588 accessions of Phaseolus spp. screened between 1977 and 1983, three accessions, G05478, G35023 and G35075, were significantly less damaged in tests at AVRDC. A multilocation screening within Taiwan of these three accessions and a local susceptible check revealed that only G35023 and G35075 are consistently less damaged (Table 2). Both accessions belong to P. coccineus. Further screening of additional P. coccineus accessions showed that only G35023 and G35075 are consistently resistant. These accessions are now actively used in CIAT's snap bean breeding program. Crosses between G35023 and susceptible agronomic cultivars of P. vulgaris are made at CIAT and the progeny are screened and selected for beanfly resistance at AVRDC. With the establishment of CIAT's regional program in southern Africa, the breeding for resistance to O. spencerella and O. phaseoli is expected to be expedited.

Biological control

Despite the hidden mode of existence of eggs, larvae and pupae, several species of parasites have been reared from each of the three Ophiomyia species. In most cases, parasitic insects lay eggs in the late larval instars and the parasite adults emerge from the pupae. Table 3 lists all recorded parasites from each of the three Ophiomyia species from various locations. Information on the biology of these parasites is adequately covered elsewhere (Talekar, 1989).

Among various parasite species, Opius phaseoli Fischer is the most effective in checking the population of O. phaseoli. It is widespread in eastern Africa, and Greathead (1968) reports a parasitism between 70% and 90%. This parasite, along with a related species Opius importatus

Fischer, was introduced from Uganda to Hawaii to control Ophiomyia phaseoli (Davis, 1971). Initial studies by Davis (1972) showed 100% parasitism of Ophiomyia phaseoli on Kaui and 25% - 83% on Maui islands. In later observations Raros (1975) found peak parasitism of only 8.3% - 23.5% by Opius phaseoli and Ophiomyia phaseoli assumed a pest status. Greathead (1975) observed a weak density dependence parasitism. Under such circumstances, sporadic outbreak of the pest is to be expected. Nonetheless the parasites were able to achieve a useful degree of control during most months.

Cultural control

As all three Ophiomyia species cause serious damage in young plants and are confined to the part of the stem closer to the ground, several attempts have been made to minimize insect damage by devising cultural methods to protect the plants soon after germination. These include ridging the plants, using mulch to cover the planted area, fertilizers to encourage vigorous growth, intercropping and adjusting the planting date. Many of these methods were actually practiced on the farms for O. phaseoli control before the introduction of synthetic organic insecticides, and some of these are still practiced, especially by Javanese farmers in Indonesia. The most common of these practices, ridging, derives its usefulness from the fact that beanfly-damaged stems of snap bean plants produce adventitious roots which hang in the air. Covering these plant parts with soil, besides giving physical support, allows them to absorb moisture and nutrients to sustain the growth of damaged plants (Otanes, 1918; van der Goot, 1930). This technique is not practical on a commercial farm but has potential in home gardens or subsistence farming.

Intercropping is a common practice on small farms in the tropics. Van der Goot (1930) was able to reduce O. phaseoli damage to snap bean by intercropping with maize. However, it is necessary to sow maize ahead of snap bean, as simultaneous planting of both crops did not reduce damage by O. phaseoli. In a trial at AVRDC, snap bean, soybean and mungbean were intercropped with 60 crop species belonging to 14 botanical families. The

intercrops were planted four weeks ahead of snap bean. None of the intercrops significantly reduced O. phaseoli or O. centrosematis infestation of snap bean compared to monocrop snap bean control (AVRDC, 1981a, 1981b).

In most locations, even in the tropics, agromyzids are not serious in the rainy season compared with the dry season. Thus the rainy season can be utilized to plant snap bean to reduce O. phaseoli damage. However, in most locations in humid tropical Asia, snap bean is a secondary crop and is always grown in the dry season; in the rainy season rice and other staples receive preference. Within a cropping season, van der Goot (1930) found that planting delayed by three weeks resulted in higher plant mortality. The delay allows the beanfly population to build up on earlier sown crops and causes serious damage to late sown snap bean.

Fertilization has an indirect effect on O. phaseoli damage. It reduces plant mortality and yield loss by promoting luxuriant plant growth (van der Goot, 1930). Fertilization should, however, be timed so that the nutrients are available for vigorous plant growth in the early stages when insect infestation can kill plants.

Chemical control

Both preventive and curative insecticide treatments show promise in the control of beanflies, however, due to the concealed nature of larval feeding, preventive measures are more likely to provide control. Since all three Ophiomyia species attack mainly young plants, an early application of a suitable chemical, in most cases simultaneously with crop sowing, acts as a good control measure.

Since the introduction of modern synthetic organic insecticides in the mid-1940s, a large number of chemicals in a variety of formulations have been tested to obtain adequate control of the beanfly. The chief modes of application of these chemicals are seed treatment, incorporation in soil at sowing, and post-planting foliar sprays.

Seed treatment: The treatment of seeds with insecticides ensures the presence of insecticide residues in the seedlings, when the plant is most vulnerable to damage by the beanfly. In addition to being relatively inexpensive, this mode of insecticide application can help protect predators and parasites. Under field conditions this treatment also does not seem to affect nitrogen-fixing organisms. In the initial stages persistent organochlorine insecticides, such as aldrin, dieldrin, lindane, endrin, etc. were recommended for the control of beanfly (Taylor, 1958, 1959; Walker, 1960; Wickramasinghe and Fernando, 1962; Jones, 1965; Swaine, 1968). Although all of these chemicals have very low water solubility and systemic activity, their physical proximity to the plant facilitates sufficient quantities of active ingredients to move within the plant and protect against invading larvae in the stem. Most of these chemicals have now been replaced with less persistent but more systemic organophosphorus and carbamates. Among these chemicals, trichlorphon, thiometon, malathion, diazinon, phorate, triazophos and carbofuran have been widely tested and recommended (Wickramasinghe and Fernando, 1962; Abul-Nasr and Aseem, 1968b; Sepswasdi and Meksongnsee, 1971; Sudarwohadi and Eveleens, 1974; Saxena et al., 1975; Babu, 1977; AVRDC, 1979; IRRI, 1981). In most cases these treatments are effective for up to three weeks after germination and one or two additional foliar sprays are usually required to provide optimum control of beanfly.

Soil application: In this method of insecticide application, organophosphorus and carbamates are applied to the soil, generally in close bands, but not touching the seeds, at the time of planting. In this type of application the insecticide is not too close to the root to cause phytotoxicity but is still close enough for the developing roots to absorb and translocate enough quantity of active ingredient to kill the invading beanfly larvae when seedlings have formed enough roots. This strategy, made possible by the 2-3 day incubation period of beanfly eggs, avoids phytotoxicity and at the same time translocates the insecticide within the plant to provide adequate control. Several insecticides such as phorate, disulfoton, dimethoate, carbofuran and aldicarb have been tested and recommended (Chang, 1969; Sepswasdi and Meksongsee, 1971; Naresh and

Thakurs, 1972; Saxena et al., 1975; Babu, 1977; AVRDC, 1981b). In all cases the chemicals are formulated in granules which are relatively easy to apply. A large portion of the chemical is complexed with the soil organic matter or clay colloidal complexes. Hence dosages far in excess of the actual amount of chemical required to kill the insect are needed. Soil property, mainly pH, has considerable influence on the persistence of these chemicals in the soil and thus their effectiveness in killing the insects over a period of time. At pH levels approaching 6.5 and above, organophosphorus and carbamates are degraded rapidly (AVRDC, 1981b). Under such circumstances, foliar application of a suitable insecticide 2-3 weeks after germination becomes necessary.

Both seed treatment and soil application of insecticides are especially valuable in the case of frequent rains, which make it difficult to enter the waterlogged field to apply foliar insecticides. Under such conditions foliar-applied chemicals are also washed off by frequent rains.

Foliar application: In this mode of application, the chemicals are dispensed as high volume sprays, ultra-low volume formulations or dusting directly on the plants. Foliar sprays of the insecticide affects the agromyzid adult population which is not affected either by seed treatment or incorporation of insecticides in the soil. In addition insecticides with a local systemic activity are absorbed in the plant tissue, where larvae, possibly pupae and even eggs could be killed. The insecticide spray application thus provides much quicker results than the seed dressing or soil treatments. The major drawback of insecticide spray in controlling beanfly is its adverse effect on predators and parasites, most of whom tend to be more susceptible than the pest to the insecticides. In all cases the chemicals are contact poisons ranging from the old organochlorines, organophosphorus, carbamates and synthetic pyrethroids to newest phenylurea-type insect growth regulators.

Among the plethora of chemicals tested and recommended, three, monocrotophos, dimethoate and omethoate, demonstrate consistently superior toxicity than most others on a wide variety of beanfly hosts (Table 4).

All three are O, O-dimethyl phosphates or phosphorothionates with a N-methyl carbamoyl group in the 'tail' part of the molecule. This means that if the beanfly becomes resistant to one it will have cross resistance to the remaining chemicals (Talekar, 1987).

In a search for alternative chemicals a fungicide, pyrazophos, was found to be as effective as any of the insecticides in controlling the beanfly (AVRDC, 1989). Earlier, cyromazine, a phenylurea-type insect growth regulator, proved to be very effective in controlling the beanfly (AVRDC, 1988). This chemical is selectively toxic to beanfly but not to its parasites. It makes an ideal candidate for integrated control of the beanfly. No matter what chemicals are used, spraying must start within the week of germination and continue for 4 - 5 weeks at once-a-week intervals. In fact, during the first week, two sprays, one at 3 days and the other at 7 days after emergence followed by four weekly sprays of any one of the above cited effective chemicals are essential to obtain complete control of the beanfly.

Integrated control

Although insecticides presently still seem to give adequate control of the beanfly, overdependence on chemical insecticides alone will lead to the insect becoming resistant as well as the negative environmental consequences so frequently documented in literature for other insects. The beanfly already shows resistance to dimethoate and even to monocrotophos, the most commonly used chemicals for beanfly and other agromyzid control in Asia. If used judiciously, insecticides can play a leading role on a sustainable basis in the control of beanfly. In order to protect parasites and predators so that their full potential in controlling the beanfly can be utilized, it is necessary to use only a seed treatment or soil application of a suitable chemical before sowing. This will protect the plant without harming the natural enemies for up to three weeks. At this juncture, if the beanfly population is still too high, the insect growth regulator cyromazine, which is relatively safe to the parasites, can be utilized. The introduction of beanfly resistant

cultivars, when they become available, will reduce, but not eliminate the need for insecticides, as it is unlikely that a highly resistant cultivar can be developed by conventional breeding. O. phaseoli already has two biotypes: one is prevalent in Indonesia where it is a deadly pest of soybean; the other is found in the rest of Asia and barely damages soybean. To keep the beanfly population low, thereby minimizing the possibility of beanfly developing further biotypes and prolonging the utility of a resistant cultivar, use of a seed treatment where feasible will be very useful. The low insect population due to the introduction of a beanfly resistant cultivar in turn will postpone the inevitable development of insecticide resistance in the beanfly and allow the presently available chemicals to realize their full potential. In the meantime, introduction of such effective parasites as Opius phaseoli, where it does not exist, will provide an additional natural enemy to combat the pest. Because of the concealed feeding habit and high population during the peak period of activity, the use of action threshold or other similar measures is of no use in beanfly control where the insect is endemic.

References

Abul-Nasr, S. and Assem, M.A.H. 1966a. The external morphology of the beanfly, Melanagromyza phaseoli (Tryon). Bull. Soc. Entomol. Egypt 50:61-69.

Abul-Nasr, S. and Assem, M.A.H. 1966b. Some ecological aspects concerning the beanfly, Melanagromyza phaseoli (Tryon). Bull. Soc. Entomol. Egypt 50:163-172.

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

Abul-Nasr, S. and Assem, M.A.H. 1968b. Chemical control of the bean fly, Melanagromyza phaseoli (Tryon). Bull. Soc. Entomol. Egypt, Econ. Ser. 2:151-159.

Arunin, A. 1978. Pests of soybean and their control in Thailand. pp. 43-46. In: S.R. Singh, H.F. Van Emdem, and T.A. Taylor (Eds). Pests of Grain Legumes: Ecology and control. Academic Press, London.

Avidov, Z. and Harpaz, I. 1969. Plant pests of Israel. Israel Universities Press, Jerusalem, 549 p.

AVRDC 1979. AVRDC Progress Report for 1978. Asian Vegetable Research and Development Center, Shanhua, Taiwan, Republic of China (ROC), 173 p.

AVRDC 1981a. AVRDC Progress Report 1979. Asian Vegetable Research and Development Center, Shanhua, Taiwan, ROC. 107 p.

AVRDC 1981b. AVRDC Progress Report 1980. Asian Vegetable Research and Development Center, Shanhua, Taiwan, ROC. 110 p.

AVRDC 1984. Progress Report for 1982. Asian Vegetable Research and Development Center, Shanhua, Taiwan, ROC. 337 p.

AVRDC 1988. AVRDC Progress Report Summaries 1987. Asian Vegetable Research and Development Center, Shanhua, Taiwan, ROC. 98 p.

AVRDC 1989. AVRDC Progress Report Summaries 1988. Asian Vegetable Research and Development Center, Shanhua, Taiwan, ROC. 100 p.

Babu, C. S. J. 1977. Bionomics and control of bean stemfly Ophiomyia phaseoli (Tryon) (Diptera: Agromyzidae). M.Sc. Thesis. University of Agricultural Science, Hebbal, India. 82 p.

Burikam, I. 1980. Ecological investigation on the beanfly, Ophiomyia phaseoli (Tryon) (Diptera: Agromyzidae) and its natural enemies in Thailand. M.S. Thesis, Department of Entomology, Kasetsart University, Bangkok, Thailand. 71 p.

Campbell, A. S. 1925. Agromyzid fly in beans. Lingnaam Agric. Review. 3:16-17.

Chang, L. C. 1969. Soil treatment with granular insecticide for control of asparagus bean insects. J. Taiwan Agric. Res. 18:61-68. (in Chinese).

Chen, K. H. 1953. Control of stem-miner of legumes. Part 2. Agric. Res. (Taiwan). 4:90-104. (in Chinese with English summary).

Chu, S. C. and Chou, L. Y. 1965. Survey on parasitoids of soybean miners.p 96. In: Taiwan Agricultural Research Institute Annual Report, Taipei, Taiwan (in chinese).

Davis, C. J. 1971. Recent introductions for biological control in Hawaii. XVI. Proc. Hawaiian Entomol. Soc. 21:59-62.

Davis, C. J. 1972. Recent introductions for biological control in Hawaii XVII. Proc. Hawaiian Entomol. Soc. 21:187-190

De Lima, C. P. F. 1983. Management of pests of subsistence crops. pp. 246-250. In: A. Youdeowei and M.W. Service (Eds.). Pest and Vector Management in the Tropics. Longman, London.

De Meijere, J. C. H. 1940. Uber Melanagromyza centrosematis n. sp. aus Java nebst Bemerkungen uber andere tropische Melanagromyzen (Diptera: Agrom.) Tudschr. Entomol. 83:128-131. (in German).

Dieudonne, C. 1981. Bean Production in Burundi. pp 31-34. In: Potential for Field Beans in Eastern Africa. Centro Internacional de Agricultura Tropical (CIAT) Cali, Colombia.

Edje, O. T. et al. 1981. Bean production in Malawi. pp. 56-97. In: Potential for Field Beans in Eastern Africa. Centro Internacional de Agricultura Tropical (CIAT) Cali, Colombia.

EPADP, 1986. Grain legume research. Eastern Province Agricultural Development Project, Annual Report 1985/86. Msekera Regional Research Station, Chipata, Zambia. 84 p.

Gangrade, G. A. 1974. Insects of soybean. Technical Bulletin Jawaharlal Nehru Krish Vishwa Vidyalaya, Jabalpur, M.P. No. 24. 88 p.

Ghosh, C. C. 1940. Insect pests of Burma. Superintendent Government Printing and Stationary, Rangoon, Burma. 216 p.

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

Greathead, D. J. 1975. Biological control of the beanfly, Ophiomya phaseoli (Dipt.: Agromyzidae), by Opius spp. (Hym.: Braconidae) in Hawaiian islands. Entomophaga 20:313-316.

Hammand, S. M. 1974. Additions to the insect fauna of Libya. Bull. Soc. Entomol. Egypt. 28:207-211.

Hassan, A. S. 1947. The beanfly, Agromyza phaseoli Coq. Egypt. Bull. Soc. Fouad I Entomol. 31:217-224.

Ho, T. H. 1967. The beanfly (Melanagromyza phaseoli Coq.) and experiments on its control. Malays. Agric. J. 46:149-157.

Hutson, J. C. et al. 1929. Reports on insect pests in Ceylon during 1928. Technical Report 1928. Department of Agriculture, Colombo, Ceylon. 24 p.

Huynh, N. V. 1981. University of Can Tho, Hau Giang, S.R. Vietnam. Personal communication.

IRRI. 1981. Insecticide evaluation 1980. Department of Entomology, International Rice Research Institute, Los Banos, Philippines. 19 p with 114 tables.

Jack, R. W. 1913. The bean stem maggot. Rhod. Agric. J. 10:545-553.

Jack, R. W. 1942. Report of the Division of Entomology (Southern Rhodesia) for the year 1941. Salisbury, S. Rhodesia. (Abstracted in Rev. Appl. Entomol. A. 30:160, 1942).

Jones, R. J. 1965. The use of cyclodiene insecticides as liquid seed dressings to control beanfly (Melanagromyza phaseoli) in species of Phaseolus and Vigna marina in southeastern Queensland. Aust. J. Expt. Agric. Anim. Husb. 5:458-465.

Kato, S. 1961. Taxonomic studies on soybean leaf and stem mining flies (Diptera: Agromyzidae) of economic importance in Japan, with descriptions of three new species. Bull. Natl. Inst. Agric. Sci. Ser. C. 13:171-206.

Khamala, C. P. M. 1978. Pests of grain legumes and their control in Kenya. pp 127-134. In: S.R. Singh, H.F. Van Emden And T.A. Taylor (Eds). Pests of Grain Legumes: Ecology and Control. Academic Press, London.

Khan, S. A. and Shafique, R. M. 1974. Stem mining fly, Melanagromyza phaseoli (Tryon) observed on soybean in Punjab. Agric. Pakistan. 25:19-20.

Kleinschmidt, R. P. 1970. Studies of some Agromyzidae in Queensland. Queensl. J. Agric. Anim. Sci 27:341-384.

Lever, R. J. A. 1946. Insects of Fiji. Bull. Dept. Agric. Fiji. 23:36.

Litsinger, J .A. 1987. Entomologist, International Rice Research Institute, Los Banos, Philippines. Personal communication.

Mathieu, E. 1920. Tuba-root (Derris elliptica) as an insecticide. Gardens Bull. Straits Settlements, Singapore 2:192-197.

Morgan, W. L. 1940. The beanfly, (Agromyza phaseoli). Agric. Gaz. N.S.W. 51:103-104.

Moutia, A. 1932. Entomology Division. p. 9-12. In: Annual Report 1931, Department of Agriculture, Mauritius. 1931.

Naik, W. M., Chungu, R. K. and Chibasa, O. M. 1981. Bean production in Zambia. p. 187-199. In: Potential for Field Beans in Eastern Africa. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

Naresh, J. S. and Thakur, R. P. 1972. Efficacy of systemic granular and spray insecticides for the control of insect pests of blackgram (Phaseolus mungo Roxb.). Indian J. Agric. Sci 42:732-735.

Negasi, F. 1986. Evaluation of haricot beans for their resistance to beanfly (mimeograph). Institute of Agricultural Research, Addis Ababa, Ethiopia.

Nyabyenda, P. C. et al. 1981. Bean production in Rwanda. p. 99-121. In: Potentail for Field Beans in Eastern Africa. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

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

Ooi, P. A. C. 1973. Some insect pests of green gram, Phaseolus aureus. Malays. Agric. J. 49:131-142.

Otanes, Q. F. 1918. The beanfly. Philipp. Agric. 7:2-31.

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

Peterson, G. D. Jr. 1957. Recent additions to the list of insects which attack crops and other important plants in Guam. Proc. Hawaiian Entomol. Soc. 16:203-207.

Raros, E. S. 1975. Bionomics of bean fly, Ophiomya phaseoli (Tryon) (Diptera: Agromyzidae) and its parasites in Hawaii. PhD thesis, Department of Entomology, University of Hawaii, Honolulu, Hawaii. 105 p.

Reddy, A. R. et al. 1983. Evaluation of the germplasm of rajmash with special reference to beanfly infestation. Indian J. Entomol. 45:184-189.

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

Rose, R. I. et al. 1976. Beanflies and their control. pp 169-171. In: R.M. Goodman (Ed). Expanding the Use of Soybeans. INTSOY Series No. 10, University of Illinois at Urbana-Champaign, USA.

Rutherford, A. 1914. Pests of pulse crops. Trop. Agric. 42:411-413.

Sasakawa, M. 1963b. A revision of Polynesian Agromyzidae (Diptera). Pacific Insects 5:489-506.

Sasakawa, M. 1981. Agromyzidae of Thailand (Diptera). Akitu (New Ser.) 37:1-6

Sasakawa, M. and Fan, Z.D. 1985. Preliminary list of Chinese Agromyzidae (Diptera) with descriptions of four new species. Contr. Shanghai Inst. Entomol. 5:275-294.

Saxena, H. P., Phokela, A. and Singh, Y. 1975. Effectiveness of carbofuran as seed treatment for controlling pest complex of 'moong' (Phaseolus aureus) and 'urd' (Phaseolus mungo). Entomol. Newsl. No. 5:27-28.

Sepswasdi, P. and Meksongsee, B. 1971. A study on control of the beanfly (Melanagromyza phaseoli Coq.) on mungbean. Kasikorn 44:289-293.

Singh, S. 1982. Ecology of the agromyzidae (Diptera) associated with leguminous crops in India. Memoirs of the School of Entomol. No. 8. St. John's College, Agra, India. 126 p.

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

Singh, S. and Ipe, I. M. 1973. The Agromyzidae from India. Memoirs of the School of Entomology No. 1, St. John's College. Agra, India, 286 p.

Spencer, K. A. 1959. A synopsis of the Ethiopian Agromyzidae. Trans. Royal Entomol. Soc. London. 111:237-329.

Spencer, K. A. 1961. Notes on the African Agromyzidae (Diptera)-1. Stuttgt. Beitr. Naturk. No. 46, 5 p.

Spencer, K. A. 1962. Notes on Oriental Agromyzidae (Diptera)-1. Pacific Insects 4:661-680.

Spencer, K. A. 1973. Agromyzidae (Diptera) of Economic Importance. Series Entomologia Vol. 9. Dr. W. Junk B.V., The Hague, Netherlands. 418 p.

Sudarwohadi, S. and Eveleens, K. G. 1974. The beanfly (Agromyza phaseoli) on common bean: chemical control. p 380-384. In: Agricultural Cooperation: Indonesia-the Netherlands Research Report 1968-74. Republic of Indonesia, Ministry of Agriculture, Jakarta and Kingdom of the Netherlands, Ministry of Foreign Affairs, The Hague.

Swaine, G. 1968. Studies on the biology and control of pests of seed beans (Phaseolus vulgaris) in northern Tanzania. Bull. Entomol. Res. 59:323-338.

Talekar, N. S. 1987. Insect damaging soybean in Asia, p. 25-45. In: S. R. Singh, K. O. Rachie, and K. E. Dashiell (eds). Soybeans for the Tropics: Research, Production and Utilization. John Wiley and Sons Ltd, Chichester, UK.

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

Talekar, N. S. and Lee, Y. H. 1988. Biology of Ophiomyia centrosematis (Diptera: Agromyzidae), a pest of soybean. Ann. Entomol. Soc. Amer. 81:938-942.

Talekar, N. S. 1989. Beanflies of Food Legumes in the Tropics. Wiley Eastern Publishers, New Delhi, India, 282 p.

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

Taylor, C. E. 1959. Control of the bean stem maggot by insecticidal dressings. Rhod. Agric. J. 56:195-196.

Trutmann, P. 1986. Plant pathologist, ISAR, Rwanda, personal communication.

van der Goot, P. 1930. Agromyzid flies of some native legume crops in Java. Original in Dutch, translation published by Tropical Vegetable Information Service, Asian Vegetable Research and Development Center, Shanhua, Taiwan, ROC. 98 p.

Walker, P. T. 1960. Insecticide Studies in East African agricultural pests. III. Seed dressing for the control of beanfly, Melanagromyza phaseoli (Coq.) in Tanganyika. Bull. Entomol. Res. 50:781-793.

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

Waterston, J. 1915. New species of chalcidoidea from Ceylon. Bull. Entomol. Res. 5:325-342.

Wickramasinghe, N. and Fernando, H. E. 1962. Investigations on insecticidal seed dressings soil treatments and foliar sprays for the control of Melanagromyza phaseoli (Tryon) in Ceylon. Bull. Entomol. Res. 52:223-240.

Yasuda. K. 1982. Life tables of the French bean miner, Ophiomyia phaseoli (Diptera: Agromyzidae) on young kidney seedlings. Proc. Assoc. Plant Prot. Kyushu 28:145-148 (in Japanese with English summary).

Young, G. R. 1984. A checklist of mite and insect pests of vegetable, grain and forage legumes in Papua New Guinea. Papua New Guinea J. Agric. Fores. and Fish. 33:13-38.

Figure captions

Figure 1. Morphological characters of larvae and pupae of O. phaseoli and O. centrosematis. (The above morphological characters in O. phaseoli and O. spencerella are practically identical).

Figure 2. Feeding and oviposition punctures of O. phaseoli in snap bean.

Figure 3. Larval feeding mines of O. phaseoli in the snap bean seedling stem.

Figure 4. Swelling at the root-shoot junction due to O. phaseoli larval feeding in the snap bean stem.

Figure 5. Formation of adventitious roots on stems above O. phaseoli larval feeding damage in snap bean.